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Content

In search of messianic time*

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Yesterday, while I was reading the booklet containing the abstracts of your lectures, which will be held in the upcoming days and promise to be informative and rewarding, my mind turned to a name not necessarily associated with archaeology in general, or with the Neolithic Age in particular. It is the name of that great German philosopher, that illustrious thinker on culture and its critic, Walter Benjamin. I thought of his short, perceptive and inspiring work entitled *On the Concept of History*, written in early 1940 in the dark days of World War Two, the same year in which Benjamin commited suicide, fearing capture by the Nazis.

In his short text, Benjamin reflects upon the possibility of understanding the past, and develops the idea of a fourth time besides the past, present, and future – messianic time. Three of his insights seem particularly valuable in this context. First, his view that "*the true image of the past is flits by. The past can be seized only as an image which flashes up at the instant when it can be recognized and is never seen again*". Secondly, that "*history […] is the object of a construction whose place is not in homogeneous and empty time, but in that which is fulfilled by the here-and-now* (Jetztzeit)". And thirdly, that "*to articulate the past historically does not mean to recognize it* wie ist es eigentlich gewesen, i.e. *as it really was. It means to seize hold of a memory as it flashes up in a moment of danger*". In short, we can only know the past as a memory that emerges in our lived moment, in our *Jetztzeit*.

When this happens, the extreme human condition in its ultimate moment – in the moment of danger, as Benjamin writes in his *Concept*, but also of delirious joy, as some of his other writings reveal – is covered by the condition of man in the past, and in this coverage the memory is totally released, the memory, from which knowledge arises. And when this happens, the student of the past times is able to grasp "*the constellation into which his own era has entered, along with a very specific earlier one. Thus, he establishes a conception of the present as now time shot through with splitters of messianic time.*"

The messianic time is therefore a historiographical time. It is the fourth time alongside the past, present, and future. It is the time of man's kinship with man in time, with another man in another time, it is the time of memory, of truthful, redeeming memory. Whereas homogeneous empty time is a time of strangeness, messianic time is a time of kinship. Homogeneous empty time is a time of empty meanings, while messianic time is one of full meanings. Homogeneous empty time is quantitative, messianic time is qualitative – the former is in itself meaningless, while the latter is a time of delirium of overlapping meanings. The first is a time of continuous movement, the second a time that has stopped; the former a time of running; the latter a time of rupture. While the first is a time which, with its teachings, is meant to soothe us with regard to death, the second is a time which, with its insights, calls us to life. While the first enslaves us to the ruling order of its time, the second time liberates, redeems us from all order. In messianic time, Benjamin writes, every second is "*the small gateway in time through which the Messiah might enter.*"

Messianic time is thus not seen primarily in religious terms – although it can, of course, be seen as such as well – but epistemologically, as enlightenment, as the joyful apocalyptic delirium of the knowledge of oneself, of man in time, of man in all times. Messianic time is indeed a time of the Apocalypse, a time of rupture with the conditions of the real(istic) world on the one hand, and of establishing the prospects of a new, sacred world on the other.

Who knows this time better than you archaeologists? In your research, you return again and again to the places where this time is most evident, where the human condition is manifested in its fullest and most complete form, *i.e.* to fireplaces, sanctuaries and cemeteries, to sacred, holy places. For the sake of a completely honest explanation, one must, however, add to these sacred places the dump sites, which, to be honest, also have something sacred in their own way. *Candidi omnia candida*.

In the following days you will be reflecting and discussing the Neolithic ways of living, the social and cultural patterns of change in that remote time in the past, its social dynamics, its understanding of art, its symbolic forms and much more. And when doing so, you will be talking about man in time, about our time as well – you will be talking about man in his entirety. You will speak of all of us. Your lectures will one day be followed by an excellent book, and I am confident that I along with many others will be reading it with great interest and excitement.

I wish you a successful and above all inspiring conference. I wish you the best of times, that the door of knowledge will open, and the Messiah step through it.

Reference

Benjamin W. 2003. On the Concept of History. In H. Eiland, M. W. Jennings (eds.), *Selected Writings. Volume 4 (1938-1940)*. The Belknap Press of Harvard University Press. London: 388-400.

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* The text is a slightly modified version of the opening speech held at the conference, 26th Neolithic Seminar '*Eurasian Neolithics: How Cultures and Societies Evolve and Why it Matters*' by Sašo Jerše, Vice-Dean for Scientific Research and Doctoral Studies at the Faculty of Arts of University Ljubljana.

Inspired individuals and charismatic leaders: hunter-gatherer crisis and the rise and fall of invisible decision-makers at Göbeklitepe

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ABSTRACT - *Recent fieldwork at Pre-Pottery Neolithic (PPN) Göbeklitepe has revealed a life-size limestone statue of a wild boar in Special Building D, which, alongside discoveries from nearby contemporaneous sites, broadens our understanding of late hunter-forager communities, including the presence of (archaeologically speaking) invisible decision-makers. Evidence points to three groups from which these charismatic leaders could have emerged: storytellers, hunters and ritual experts. An important function of these leaders was to uphold traditional values in the face of changing lifeways in the Early Holocene, a period referred to here as the 'hunter-gatherer crisis'. This paper also includes a summary of recent excavation results from Göbeklitepe.*

KEY WORDS – *Göbeklitepe; Pre-Pottery Neolithic (PPN); social hierarchisation; adaptive cycles; hunter-gatherer crisis*

Navdahnjeni posamezniki in karizmatični voditelji: kriza lovcev in nabiralcev ter vzpon in padec nevidnih odločevalcev v Göbeklitepeju

IZVLEČEK – *Nedavno terensko delo je na najdišču predkeramičnega neolitika (PPN) Göbeklitepe v posebni stavbi D razkrilo apnenčast kip divjega prašiča v naravni velikosti. Skupaj z odkritji z bližnjih sočasnih najdišč širi naše razumevanje poznih skupnosti lovcev in nabiralcev, vključno s prisotnostjo (arheološko gledano) nevidnih odločevalcev. Dokazi kažejo na tri skupine, iz katerih bi lahko izšli karizmatični voditelji: pripovedovalci zgodb, lovci in vodje obredov. Pomembna naloga vodij je bila podpora tradicionalnim vrednotam ob soočanju s spreminjajočimi se načini življenja v zgodnjem holocenu, obdobju, ki ga tukaj imenujemo 'kriza lovcev in nabiralcev'. Članek vključuje tudi povzetek nedavnih rezultatov izkopavanj v Göbeklitepeju.*

KLJUČNE BESEDE – *Göbeklitepe; predkeramični neolitik (PPN); družbeno razslojevanje; prilagoditveni cikli; kriza lovcev in nabiralcev*

Introduction

Göbeklitepe is located in one of the primary zones of Neolithisation in Southwest Asia that covered the upper Euphrates and Tigris basins in southeastern Türkiye and northern parts of Syria and Iraq (most recently, *Özdoğan 2022; 2024*). Recent years have witnessed an increase in research in this region, with new results from Turkish sites such as Gusir Höyük (*Karul 2020*), Çemka Höyük (*Kodaş* et al. *2020*), Gre Fılla (*Ökse 2022*), and Boncuklu Tarla (*Kodaş 2023*) along the Tigris River in the east, and in the frame of the Şanlıurfa

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Neolithic Research Project (*Taş Tepeler*) in the hills around the modern city of Şanlıurfa, to the east of the Euphrates (*Karul 2022a; Karul 2023a*). Meanwhile, the Taş Tepeler project encompasses continued work at Göbeklitepe (this paper), Karahantepe (*Karul 2021; 2022b; 2023b*), Harbetsuvan Tepesi (*Matsui* et al. *2022*) and Gürcütepe (*Erdalkıran 2023*), as well as initial excavations at the sites of Sayburç (*Özdoğan E. 2022; Özdoğan, Uludağ 2022; Özdoğan 2023*), Sefertepe (*Güldoğan 2021; 2023; Güldoğan, Uludağ 2022*) and Çakmaktepe (*Şahin 2023; Şahin, Uludağ 2023*) (Fig. 1).

Settled hunter-foragers

Sites with a clear continuity of occupation from the Younger Dryas to the Early Holocene have so far been discovered along the Tigris (Körtiktepe, Boncuklu Tarla, Çemka Höyük), though with emerging evidence now appearing in Şanlıurfa, where several find-spots featuring mixed Epipalaeolithic and Pre-Pottery Neolithic (PPN) assemblages are known from recent field surveys around the southwestern outskirts of the modern city (*Şahin* et al. *2023*). Additionally, renewed field investigations at Söğüt Tarlası and Biris Mezarlığı in the Bozova basin could reveal further evidence from this period (*Özdoğan 2020.424–425; Ekinci, İlci 2023*).

An increase in settled hunter-forager communities in the Early Holocene (from around the mid-tenth millennium cal BC) in the upper Tigris and Euphrates basins also witnessed earliest (PPNA) occupations at Göbeklitepe. Despite the increase in sedentary lifeways at this time, subsistence practices remained faithful to the Palaeolithic roots of these communities, and at the central site of Göbeklitepe there is still no evidence of morphologically domesticated plant or animal species in the subsequent EPPNB (*Neef 2003; Peters* et al. *2019.6*). Only at the EPPNB site of Nevali Çori is there evidence for human control over small numbers of sheep, goats and possibly pigs (*Peters* et al. *2017*). As for the other Taş Tepeler settlements now under excavation, the results from archaeobotanical and archaeozoological investigations are still pending.

Based on these observations, the emergence of food-producing strategies, at least in the Şanlıurfa region, appears to have occurred asymmetrically in space and time, suggesting that conscious choices were made at the community, group and even household levels, leading to a mosaic of different subsistence forms. Equally, it could be argued that such decisions were made by more privileged parts of society. Discussions around social hierarchisation during the transition to food-producing economies in Southwest Asia have been un-

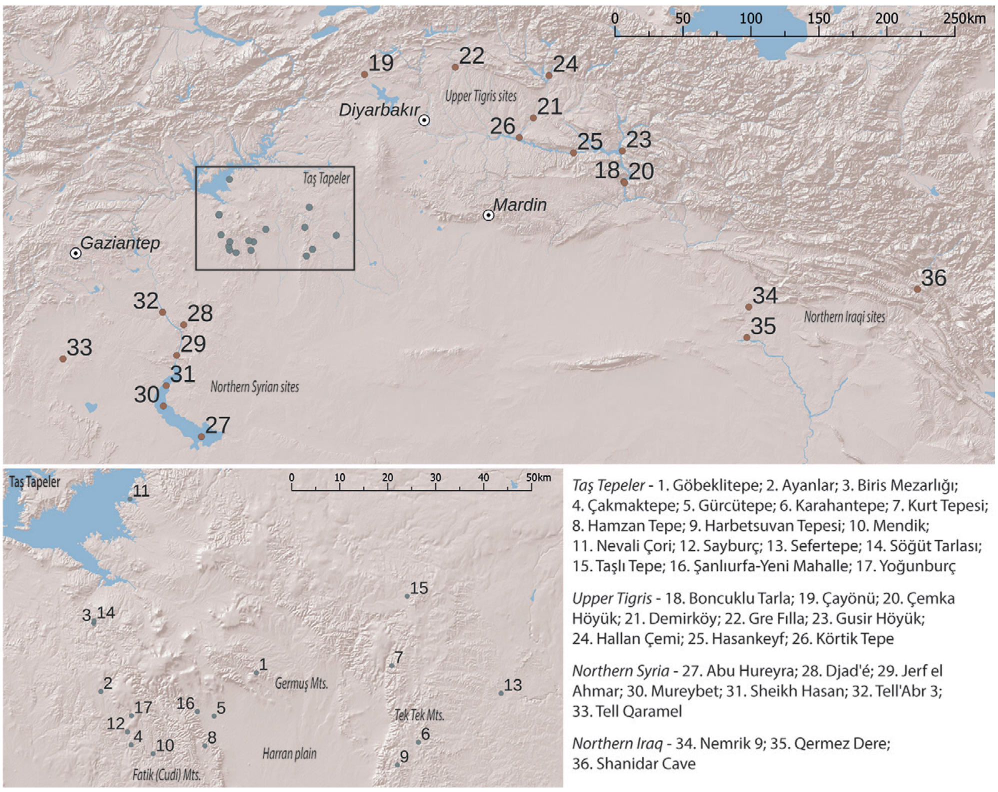

Fig. 1. Late Pleistocene and Early Holocene sites in southeastern Türkiye and northern parts of Syria and Iraq (upper Euphrates and Tigris basins) mentioned in the text (image L. Clare).

derway for decades, with some of the most notable contributions being the *transegalitarian feasting* model after Brian Hayden (*2014*), the *chief-led lineage* model after Christian Jeunesse (*2020*) and the *molar-molecular* model after Ian Hodder (*2022*). These different approaches will be discussed in more detail towards the end of this paper. Notably, perhaps the earliest reference to social hierarchisation in the PPN of Southwest Asia was made by Diana Kirkbride in the context of the Jordanian Early Neolithic site of Beidha, where differences in building sizes led her to propose an "*emerging village life* with *a hint at the presence of a privileged and not-so-privileged class*" (*Kirkbride 1967.8; cf. Özdoğan, Özdoğan 1998.587*).

Late Pleistocene and Early Holocene decision-makers: Who built Göbeklitepe?

Insights from first extensive excavations at a Neolithic site in the upper Tigris and Euphrates basins led Mehmet Özdoğan (*1997*) to propose the dominance of elite groups already in the PPNA at Çayönü. In support of his hypothesis, he noted the rigid order of the settlement, the intentional burial of houses, the construction of plaster floors and the organisation of extensive labour. He considered this societal system the forerunner of the *temple-controlled economy* of the later Syro-Mesopotamian historical cultures (*O.c.10–11*). Harald Hauptmann presented similar lines of interpretation in relation to the spatial organisation of Nevali Çori and Göbeklitepe, where, according to him, different areas of the sites were dedicated to tool production, sculpture and sanctuaries (Fig. 2); for Hauptmann, this was indicative of "*steps developmental to a central organisation in which the trade or barter of an elite class was restricted to sites with cult facilities*" (*Hauptmann 1999.82*). Meanwhile, Özdoğan (*e.g., Özdoğan 2001.316; 2018.36; 2024.39*) has continued to develop his line of interpretation, now placing the earliest *temple-controlled economies* (with priests who dictated the mode of living and economy) not in the historical cultures but, based on his interpretations of Göbeklitepe and Karahantepe, already in the Pre-Pottery Neolithic.

In line with the conclusions reached by Özdoğan and Hauptmann, Klaus Schmidt (*2000a.6*) wrote: "*It seems probable that the shamans of Göbekli Tepe had been 'at the edge'. The edge to cross the border from the animistic shaman to the established priest. Some motifs of the reliefs and of the sculptures are still the old ones, but they seem mixed with the dawn of representations of a new world, a world of temples with powerful rulers, a world of a classified society*". This statement expanded on a brief reference of Schmidt's from three years earlier in which he mentioned "*powerful people using religious imperatives to motivate*" (*Schmidt 1997.9*). Indeed, considering Schmidt's focus on the special buildings, this is not surprising. He was intrigued as to how the *cultic communities* (for this term, see *Schmidt 2005.16; 2006a.252–255; 2011.52–54; Dietrich* et al. *2012.684; Notroff* et al. *2015.72–73*) were motivated to build these monumental structures. In his 2006 monograph, '*Sie bauten die ersten Tempel*' (*Schmidt 2006a*), he still sought explanations for the amassed human resources in what he termed *spiritual driving forces*. He wrote: "*Quite obviously, the societal power – probably we will never know if it was a chief, a group of shamans or* [...] *priests, a council, or a collective* – [...] *was able to demand the workforce* [...] *fetched from the well of religious motivation* [...]" (German original, *Schmidt 2006a.247*; English translation, *Schmidt 2012.233*). This scenario defined his later writings and was also pivotal in contributions by members of his research team in the years following his death.

In an approach centred more on economic factors and reminiscent of the proposal by Hauptmann, Ofer Bar-Yosef stressed the role of prestige objects in attaining wealth, rank and position at Göbeklitepe (*Bar-Yosef 2014*). He described the site as "*a relatively short-lived social experiment in creating a chiefdom*" that incorporated "*kin-based lineages and alliances entailing ritual feasting through which prestige items were exchanged and accumulated resulting in the rise of individual entrepreneurs and creating a social ranking*" (*O.c.73–74*). So far, however, there is no evidence that *prestige items* were used to attain or mark wealth at Göbeklitepe, and recent years have also seen a clear overemphasis on the role of feasting in archaeological explanation (*cf. Bangsgaard* et al. *2019.443*), including its part in the construction of the special buildings at Göbeklitepe (*e.g., Dietrich* et al. *2012; 2017; Dietrich, Dietrich 2019*). Notably, one of the earliest formulations of the feasting hypothesis stemmed from Schmidt, who suggested that vast quantities of meat could have been consumed within the frame of large feasts as an incentive to the workforce, thus explaining the large amounts of animal bone recovered from the excavations of these structures, stemming from the time of their intentional burial (*e.g., Schmidt 2010a.18; 2011.53*). Not only does the feasting hypothesis at Göbeklitepe paint a dangerously over-simplistic picture, including a workforce control-

Fig. 2. Nevali Çori. The first ever discovered T-pillar structure ('Kultgebäude'). View from the southeast looking northwest, also giving an impression of the landscape around the site: excavations were undertaken by Hauptmann between 1983 and 1991. The site now lies submerged in the Atatürk Reservoir (photo M. Akman; German Archaeological Institute, Euphrates Archive).

led by its insatiable lust for meat, but it has lost much of its credibility in recent years following revelations that the animal bones from the special buildings came from midden accumulations displaced by erosion events from higher-lying parts of the mound (*cf. Clare 2020.86; Kinzel, Clare 2020.33; Breuers, Kinzel 2022.479*, and below).

Despite the occurrence of objects interpreted as prestige items and subtle differences in grave goods in some burials in the Upper Tigris Basin, *e.g.*, Körtiktepe (*Özkaya* et al. *2013; Erdal 2015*), Hasankeyf Höyük (*Uluçam 2021*) and Boncuklu Tarla (*Kodaş* et al. *2022a*), archaeological evidence for vertical social differentiation in the PPNA and EPPNB remains tentative. In the case of two EPPNB burials found at Göbeklitepe, these have also failed to provide any signs of the social status of the interred individuals (*Gresky* et al. *forthcoming*). There is also no clear indication of hierarchies in the architecture, unless we follow suggestions that the special buildings were the homes of clan leaders (*Banning 2011*). As for the '*dominant governance*' *by* '*spiritual leaders*' and the '*elite competition*' proposed by Özdoğan (*2024.39*) and the '*kin-based lineages*' of '*individual entrepreneurs*' suggested by Bar-Yosef (*2014.73–74*), these hypotheses are difficult to corroborate. Indeed, the available evidence for social elites, or rather the lack thereof, is more in line with a less rigid form of social differentiation, much like the one proposed by Jacques Cauvin in his seminal work *Naissance des divinities – Naissance d'agriculture*. In the context of the PPNB sanctuaries in the Southern Levant, he writes: "*The most primitive societies always find in their midst some* ***inspired individuals*** [...] *whose function simply results from a spontaneous recognition among their fellows of a 'natural' superiority that applies in certain defined circumstances, in the same way a war leader in certain paleo-Indian tribes only remained chief as long as the war continued. No more than for the sanctuaries in Palaeolithic caves does the specialisation of place imply some irregular and institutionalised specialisation of one element within the society, nor any 'power' other than that which results from the occasional exploitation of personal competencies, which must always have existed. We should not therefore attribute to the PPNB sanctuaries more than they speak for, nor because of them push back the date of the process of urbanisation. The concept of an egalitarian structure for Neolithic societies does not seem to us, therefore, to be threatened in the least*" (French original, *Cauvin 1997.163–164;* English translation, *Cauvin 2007.120*, emphasis added).

Cauvin's conclusion is as valid today as when it was written nearly three decades ago, especially if we consider the recent proposal by Ian Hodder (*2022.634*), who suggests that societal mechanisms at Göbeklitepe were in place to subconsciously preserve egalitarian social systems. Based on current insights, exemplified by the newly discovered wild boar statue in Special Building D at Göbeklitepe (this paper), the narrative scenes found in a special building at Sayburç (*Özdoğan E. 2022; Özdoğan, Uludağ 2022*), and some of the significant recent discoveries from Karahantepe (*Karul 2021; 2022a*), this paper seeks to identify some of Cauvin's '*inspired individuals*' who as a result of their skills, experience and charisma advanced to become influential in their respective communities, although these individuals never became an institutionalised ruling class, being held back by prevailing societal constraints, likely harking back to egalitarian Palaeolithic roots (*cf. Boehm 1993*). We return to this discussion following a short overview of recent excavation results from Göbeklitepe.

Göbeklitepe: Recent excavation results

Göbeklitepe is among the most significant archaeological discoveries of the 20th century (Fig. 3). Inscribed as a UNESCO World Heritage Site in 2018, the Early Holocene hilltop settlement lies 15km northeast of Şanlıurfa in the Germuş mountains (approx. 770m above sea level). It features commanding views over the Harran plain to the south, and the Eastern Taurus mountains and the Karacadağ are visible on the horizon to the north and east-northeast, respectively. Several monumental (special) buildings (labelled A to H) feature large, monolithic T-shaped pillars quarried from the local limestone, some adorned with depictions of wild animals, occasional humans, geometric patterns and symbols. Constructed by hunter-forager groups at the onset of the Early Holocene, these multiphase and long-lived structures are among the earliest megalithic buildings ever discovered (*Clare* et al. *2019a*). The topography of the artificial hill comprises three large low-lying basins (or hollows) in the southeast, northeast and northwest, separated by higher-lying knolls and their slopes, a topography dictated by the underlying bedrock formation (*Kinzel* et al. *2020*). The special buildings are generally located in the lower-lying basins, with the oldest phases of some structures (*e.g.*, special buildings A, B, C and D) constructed in the PPNA, with later phases attributed to the PPNB (*Kinzel, Clare 2020.Fig. 3.2*) (Fig. 4).

Available radiocarbon dates, combined with the results from lithic and building archaeological studies, show that the archaeological deposits accumulated upon the stepped limestone plateau over some 1600 years in the Pre-Pottery Neolithic A (PPNA; 9600–8700 cal BC) and Early/Middle Pre-Pottery Neolithic B (EPPNB/MPPNB; 8700–8000 cal BC), though a more prolonged duration could be indicated by the presence of chipped stones with gloss which could be obliquely inserted sickles from curved shafts that only appear in the M/LPPNB (*Breuers, Kinzel 2022.478*). Excavations at Göbeklitepe commenced in 1995 and have focused on the southeastern hollow of the site (*main excavation area*), which is meanwhile covered by a large permanent shelter (Fig. 3). Fieldwork has also been undertaken in the northwestern hollow, now covered by the second permanent shelter, and on the northwestern and western mounds (*cf. Clare 2020.Fig. 1*).

The discovery of dwellings and a domestic activity zone in the earliest (PPNA) occupation levels in the northwestern part of the site in 2015, combined with a re-evaluation of earlier excavation records, led to a reinterpretation of Göbeklitepe as a settlement rather than a purely ritual site, as initially suggested by Schmidt (*Clare 2020*). It is still inconclusive whether the earliest PPNA occupation was permanent; however, ongoing excavations of EPPNB domestic spaces from the mid-ninth millennium cal BC suggest that by this time Göbeklitepe had become a large and flourishing settlement, as testified by dense aggregations of rectilinear residential spaces in the main excavation area (Fig. 5). Unfortunately, as it is still unknown whether the entire mound was occupied simultaneously or whether occupation shifted to different parts of the mound at different times, even tentative estimations of population size can still not be made. As such, this question can only be approached when reliable radiocarbon dates on short-lived samples from residential buildings become available, but these are still not forthcoming. Indeed, even with a large and reliable number of radiocarbon dates any detailed reconstruction of the building history will not be quickly resolved, as highlighted, for example, by evidence of active rebuilding and conversion of round-oval PPNA-type structures into more trapezoid and rectangular EPPNB-type buildings (*e.g.*, Space 16, *Breuers, Kinzel 2022.472–474*). Be this as it may, it is still essential to emphasize the temporal overlap of the EPPNB domestic spaces on the slopes with the later phases of the long-lived special buildings in the lower-lying basins (*Kinzel, Clare 2020; Breuers, Kinzel 2022. 471–472*).

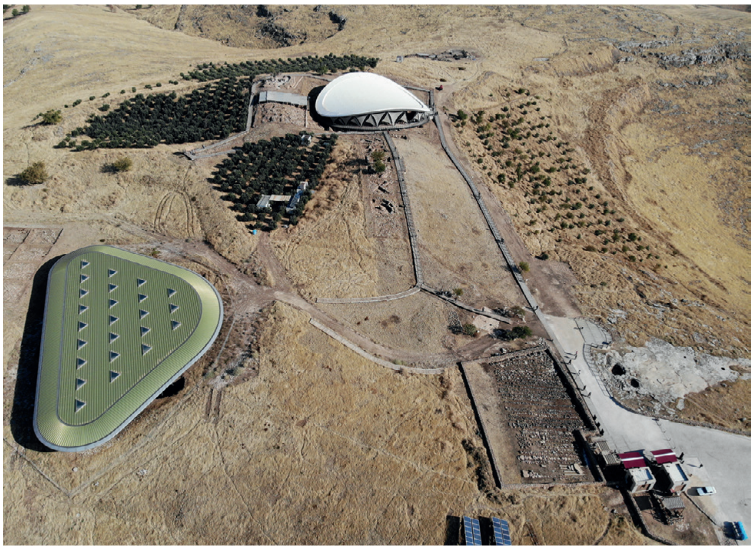

Fig. 3. Göbeklitepe. Aerial view from the west (looking east) showing the two permanent protective shelters. In the background, the white shelter covers the southeastern hollow ('main excavation area'); the second shelter (left foreground) stands over the northwestern hollow (photo German Archaeological Institute, Göbeklitepe Project 2019).

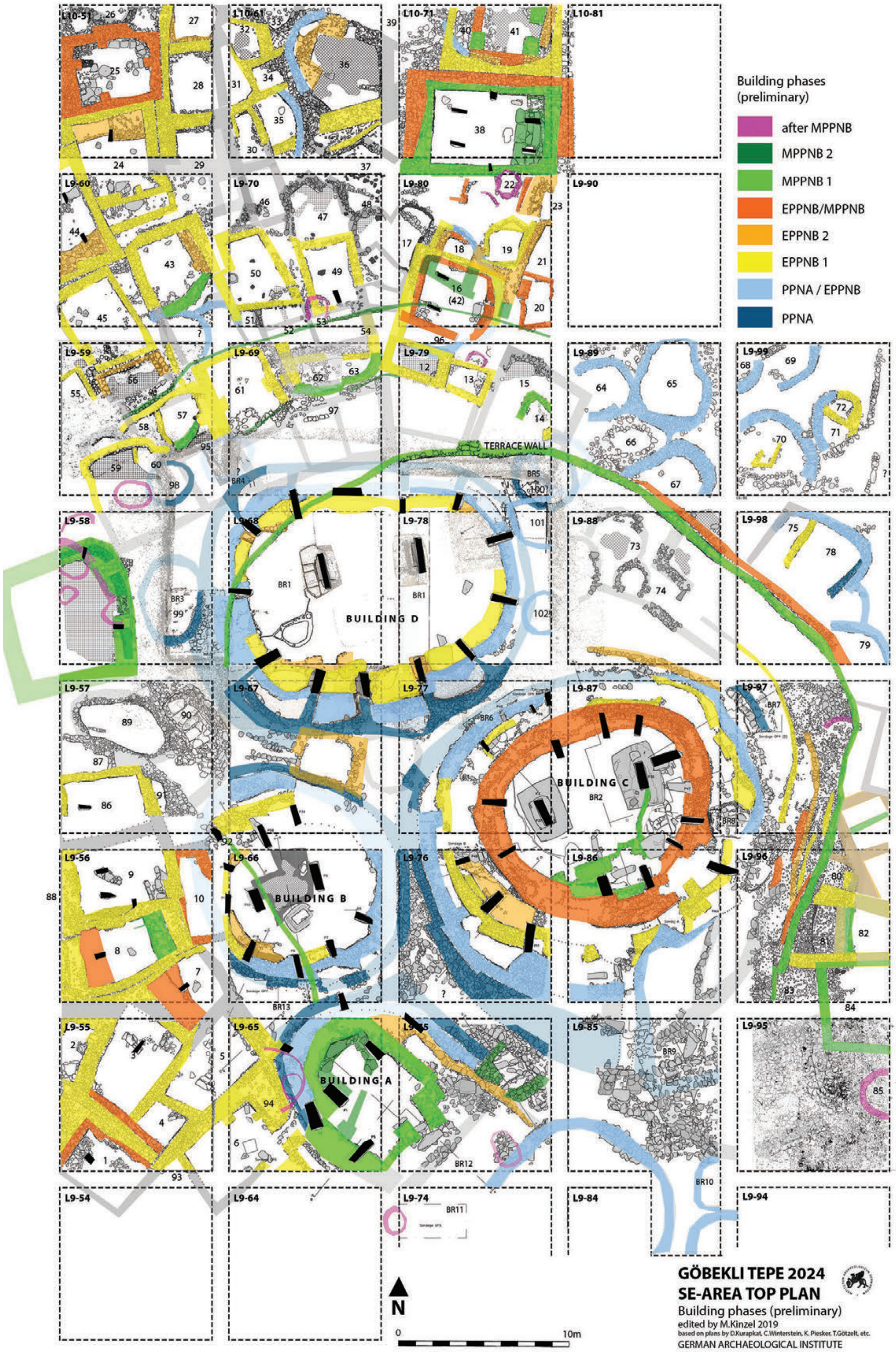

Fig. 4. Göbeklitepe. Plan of the southeast hollow (main excavation area) showing the (preliminary) building phases based on building archaeological research combined with available radiocarbon ages. N.b. the special buildings (A, B, C and D) are multi-phase structures that decrease in size over time, their latter phases being contemporaneous with the rectangular/trapezoid (residentual) structures located on the adjacent slopes to the north, west and east (image M. Kinzel, German Archaeological Institute, Göbeklitepe Project 2024).

Special Building D

In 2001, excavations in trenches L09-77 and L09-78 led to the discovery of Special Building D and the partial exposure of the eastern side of this structure (*Schmidt 2002a; 2002b*) (Fig. 6). Special Building D is among the most impressive of the discovered structures at the site, featuring two well-preserved quasi centrally placed T-shaped limestone pillars measuring some 5.50m in height and featuring low reliefs of arms, hands, and items of clothing (belts, loincloths) and bodily adornment (necklaces), thus highlighting their human identities (*cf. Becker* et al. *2012*). In addition to these two monoliths, smaller upright T-pillars occur at regular intervals incorporated into the innermost wall of the building. All these pillars were revealed between 2001 and 2005 (*Schmidt 2003; 2007*). Special Building D is one of three special buildings (C, D and E) erected directly upon the artificially smoothed natural limestone plateau; all feature low pedestals painstakingly carved from the natural plateau and into which the two quasi-central T-shaped pillars were slotted.

Fig. 5. Göbeklitepe. Overview of EPPNB residential structures on the slope to the north of Special Building D (trenches L09-60, L09-70; cf. Figure 4). In the middle ground are (from left to right) spaces 45, 43, 50 and 49, each characterised by plaster floors and grinding stones resting at floor-level; these are either* in situ *or fell from the roof or an upper storey when the building collapsed. In Space 50, a large limestone storage vessel is visible in the southwestern corner. Narrow corridor-like spaces separate the spaces. In the foreground, the remains of further residential buildings excavated in 2021 and 2022 are visible. View from the southeast looking northwest (image H. Yıldız, German Archaeological Institute, Göbeklitepe Project 2021).

Special Building D has still not been fully exposed. Indeed, this is the case with all the special buildings, except for Building E, which was discovered under a very thin layer of sediment and vegetation in 1995 on the plateau at the southwestern foot of the tell. The remains of this building comprised just its carved foundations in the natural bedrock (*Beile-Bohn* et al. *1998. 47–50; Schmidt 2006a.109; 2008a.66–67; Kurapkat 2015*).

The aims of fieldwork at Göbeklitepe in 2023 were twofold: firstly, through the continued excavation of Special Building D to increase knowledge of this structure (and special buildings in general) while at the same time rendering it more visually accessible to the growing number of visitors to the UNESCO World Heritage Site (*Souvatzi 2023.563–565*). In addition to exposing benches and walls in its northern and eastern interior, a focus of the excavations included a more careful analysis of the sediment deposits and the related fill processes that culminated in the excellent preservation of the architecture (Fig. 7).

In the southeast hollow (*main excavation area*), there is growing evidence of the unintentional inundation

Fig. 6. Göbeklitepe. Special Building D. Trench L09-78 (foreground) with the partially exposed eastern side of the structure. Architecture (now interpreted as predominantly residential) is visible on the slope in the northerly adjoining trenches (L09-79, L09-80; cf. Figure 4) (image German Archaeological Institute, Göbeklitepe Project 2001).

of the special buildings by slope slides issuing from adjacent and higher-lying slopes, where continuous building activities had led to tell formation (*Clare 2020.86; Kinzel, Clare 2020.33; Breuers, Kinzel 2022.479*). This model contradicts earlier proposed scenarios that envisaged an intentional (ritual) backfilling of the buildings in the frame of large-scale celebrations and feasts (*e.g.*, *Schmidt 2000b.37; 2000c.46, ft. 12; 2002b.8–9*; see also *Özdoğan, Özdoğan 1998* for Çayönü Tepesi). The destructive slope slide(s), perhaps triggered by periods of heavy rainfall, possibly combined with seismic activity, inundated the lower-lying special buildings with rubble from the superstructures of buildings located on the slopes, and mixed PPNA and EPPNB deposits, including middens and sub-floor burials. Therefore, earlier claims that particular objects were deposited on the floors of the buildings before or during an intentional filling process now appear untenable (*e.g.*, *Schmidt 2010b.249; Dietrich* et al. *2019.156*). If anything, these items were either already *in situ* at the time of inundation or they stem from buildings or deposits that became displaced and redeposited during the slope slide event(s).

Observations made in Special Building D in 2023 support the slope slide hypothesis; these include damage to its architectural structure, air pockets in the rubble, the discovery of negatives of wooden beams from its collapsed roof, and preserved areas of roof plaster in the rubble matrix (Fig. 7.1, 7.2, 7.3, and Fig. 8). Furthermore, evidence for rebuilding and modification in special buildings B and D could testify to attempts made to resolve structural inadequacies in the face of increasing slope pressure (for Building B, see *Kinzel, Clare 2020*; and for Building D, *Breuers, Kinzel 2022*). The discovery of hardened horizontal (walking) surfaces in the fill of Building D also suggests that more than one slope slide event led to the complete inundation of this building, with walking horizons becoming established within the half-buried structures in the interim phases.

The newly discovered wild boar statue

The fieldwork in the northern area of Special Building D that led to the discovery of the wild boar statue saw the removal of a sediment block measuring 5.0 metres in length (west-east), 2.0 metres in width (north-south) and with a depth of 1.2 metres from against the northern internal wall between two T-shaped monoliths, pillar 43 (P43) in the west and pillar 78 (P78) in the east (Fig. 7). A further pillar (P67) located behind the sediment block differs from others in that it stands with its broadside facing the interior, missing its T-shaped head, and with a round niche carved into its shaft (Fig. 9). Around the niche, a diffuse incised decoration is discernible, which, on closer inspection, could be the depiction of two seated individuals (missing their heads) facing one another and holding whatever object was placed in the niche in their hands (pers. comm. O. Torun). Removing the sediment block revealed not only the statue of the wild boar but also the lower part of P67 and the northern bench of the building.

Fig. 7. Göbeklitepe. Aerial view of Special Building D after the completion of fieldwork in 2023. The numbers mark the positions of features and finds excavated in recent years and discussed in the text:* 1 *slope slide deposits (*cf. *Fig. 8.1);* 2 *air pockets in the rubble (*cf. *Fig. 8.2);* 3 *negatives of wooden roof beams in the rubble matrix (*cf. *Fig. 8.3);* 4 *the newly discovered wild boar statue (*cf. *Figs. 9 and 10);* 5 *the bench beneath the statue (Figs. 9, 10 and 11);* 6 *the western extension of northern-central bench (*cf. *Fig. 12);* 7 *a decorated wall stone with H-shaped symbol (*cf. *Fig. 23. bottom right);* 8 *a pit-feature with adjacent incised H-shaped-symbol (*cf. *Fig. 25) (orthophoto B. Waszk, German Archaeological Institute, Göbeklitepe Project 2023/2024).

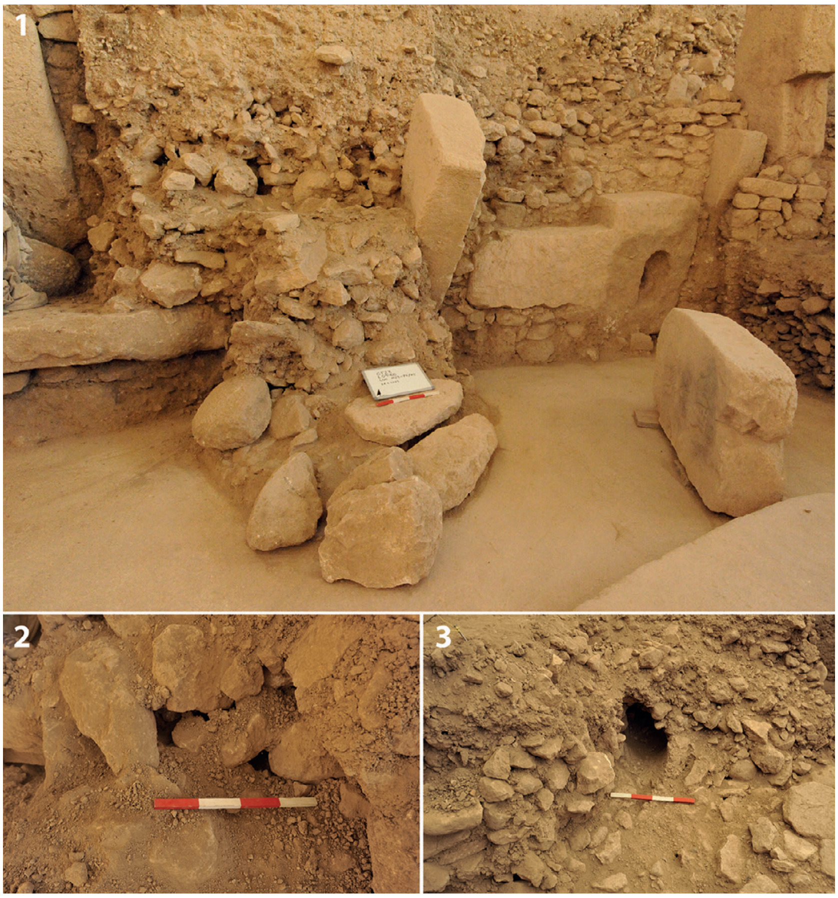

Fig. 8. Göbeklitepe. Evidence for slope slides discovered in 2023 in Special Building D includes: 1 *damage to the architectural structure (*cf. *Fig. 7.1); 2 air pockets in the rubble (*cf. *Fig. 7.2); and 3 the negatives of wooden beams from the collapsed roof in the rubble matrix (*cf. *Fig. 7.3) (photos L. Clare (1, 3), M. Kinzel (2), German Archaeological Institute, Göbeklitepe Project 2023).*

The wild boar statue is a near-life-size representation (1.35m long; maximum height 0.70m) (Fig. 7.4 and Fig. 10). Its forelegs are well-defined in low relief, bent at the elbow and with a strong shoulder. The eyes of the animal are small and close-set, and there is no indication that these had been inlaid with obsidian, as was the case with the roughly contemporaneous life-size human statue (the so-called *Urfa Man*) discovered in Şanlıurfa-Yeni Mahalle in 1993 (*Çelik 2014*) (Fig. 22). While the snout is elaborately carved, the nostrils are asymmetrical, one slightly higher than the other. Multiple horizontal incised lines represent skin folds running along the top of the snout towards the top of the head. Two small round ears are depicted. The jaw is open, and the tongue extends forward and upward, with a high level of detail given to the teeth and the tusks. The characteristic dorsal bristles are visible, running from just behind the head along the length of the spine. The rear extremities of the boar, including its hind legs (and phallus), are not depicted; instead, the hindquarters of the statue are rounded and reminiscent of a protome, a shape that decreases the height of the figure to the rear, raising the head and giving the impression that the animal is seated. The underbelly is slightly convex and rises slightly above the bench in a shallow arch. The boar holds what appears to be a sphere, perhaps a human head, between its front trotters. Numerous examples of this type of human-animal composition, with the head of a human clasped between the paws of a wild animal or the talons of a bird, are known not only from Göbeklitepe but also from other sites, such as Nevali Çori (*Hauptmann 2011.99, Fig. 14a-b; Dietrich* et al. *2019.157*) and more recently Karahantepe.

The occurrence of small drill holes and perforations in the shafts of some T-shaped pillars already suggested that materials and objects were attached to them, perhaps as decorative elements applied in the frame of ritual performances (*Schmidt 1998.42–43; 2006a.164; Becker* et al. *2012.25, Fig. 12*). Remnants of colouring on the newly discovered wild boar statue now confirm that pigments were also used for this purpose. While the colour red is evident around the mouth of the animal, small patches of black are visible on the torso. Analyses of the pigments are still in progress, but small fragments of red ochre (from so far unknown sources) occur frequently in the excavated deposits at Göbeklitepe, and studies of grinding stones at the site have already pointed to the use of these tools for processing minerals (*Peters* et al. *2019.5*).

The bench upon which the wild boar stands appears to be a re-used monolith with a maximum visible length of 2.80m and a maximum thickness of 0.31m; it extends 1.38m away from the wall of the building, though it is certainly wider, it continuing beneath the headless pillar (P67) for which it served as a base. The bench is adorned with numerous depictions in low re-

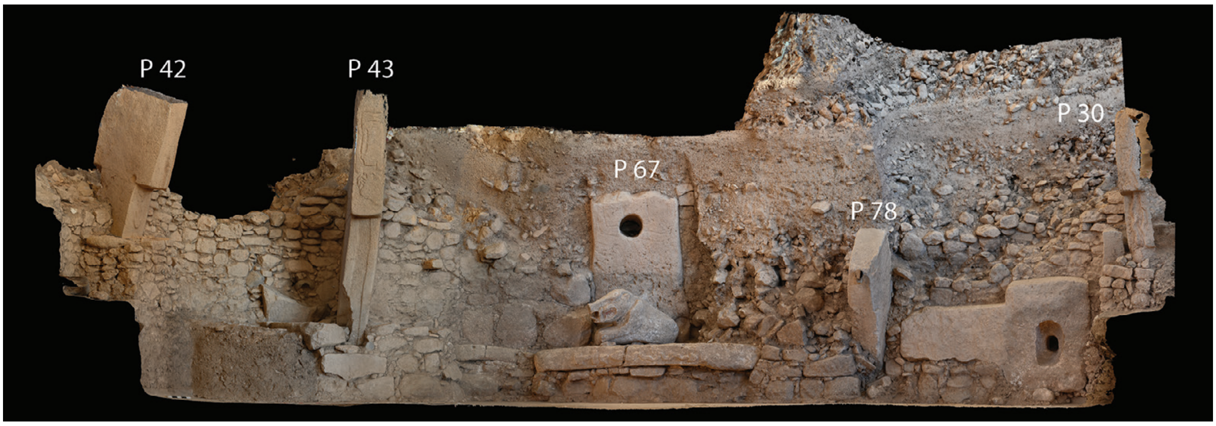

Fig. 9. Göbeklitepe. Special Building D. Northern interior wall of Special Building D following the completion of excavations in 2023. This section of the innermost enclosing wall features six vertical monoliths (from left to right): Pillar 42 (P42), Pillar 43 (P43), Pillar 67 (P67), Pillar 78 (P78) and Pillar 30 (P30). A further T-shaped monolith with an oval-shaped niche in its head lies horizontally between P78 and P30, constituting part of the wall of the building (photogrammetry B. Waszk, German Archaeological Institute, Göbeklitepe Project 2023/2024).

lief on its visible inward-facing narrow side. The motifs include an H-shaped symbol, a crescent, three snakes and four human faces or masks (Figs. 7.5 and 11). The upper surface of the bench features a cup mark and a circular-shaped incision. The front legs of the statue stood in a shallow round-oval depression and the statue was supported by the addition of stone wedges, one under its front left leg and two under its belly. Although it is unclear whether this was the original location of the statue, it was likely placed here in a late phase of the special building, in the second half of the ninth millennium cal BC (*cf. Kinzel, Clare 2020.Fig. 3.2*).

The westward extension of the decorated bench is formed by a smaller stone slab (Figs. 7.6 and 12). This slab features a sturdy diagonal perforation at its front upper edge, the function of which is unknown. Additionally, there is a stick-like depiction of a predator, most probably a leopard, incised into its upper surface, just several centimetres west of the perforation. The head of the leopard (length: 10.0cm; max. width: 6.0 cm) is formed by a round, shallow indentation (diameter: 2.0cm).

The opposite easterly adjacent section of the bench incurred visible damage from the slope slide; it remains unexcavated and still covered by rubble. The wall of the building in this area was wholly destroyed,

Fig. 10. Göbeklitepe. Special Building D. The newly discovered wild boar statue in Special Building D (*cf.* Figs. 7.4 and 9). The statue stood on a decorated bench (likely a re-used T-shaped pillar, Fig. 11) and in front of Pillar 67 (P67), which stands out from other monoliths in the building due to its orientation (broad side facing inwards) and the round niche in its shaft. The wild boar statue and P67 are a clear focal point of the building (photogrammetry B. Waszk, German Archaeological Institute, Göbeklitepe Project 2023/2024).

Fig. 11. Göbeklitepe. Detail of the bench beneath the wild boar statue in Special Building D (*cf. *Figs. 7.5, 9, and 10). This re-used limestone T-shaped pillar carries several images in low relief, including (from left to right) an H-symbol, a crescent, three snakes and four human faces or masks (photogrammetry B. Waszk, German Archaeological Institute, Göbeklitepe Project 2024).

and the adjacent T-shaped pillar (P78) was pushed inwards by the force of the inundation (Figs. 7.1, 8.1, and 9).

Other wild boar imagery at Göbeklitepe

A total of six further (complete and fragmented) limestone wild boar statues were previously known from Göbeklitepe. However, these are smaller and less skilfully crafted than the (seventh) newly discovered statue from Special Building D. Besides the statues, other depictions of wild boars are known from ten low reliefs, one incised depiction and one protome. Most of these images were discovered in special buildings, the majority in Special Building C, where four statues, eight low reliefs, and the protome were revealed; the comparatively high frequency of wild boar depictions in this structure led Klaus Schmidt (*2006a.146*) to refer to it as the '*Kreis der Keller*' ('*Circle of the Wild Boars*' in English). Further images of wild boars have undoubtedly been discovered over the years, though poor preservation may have led to their classification as '*unidentified quadrupeds*'.

Statues and statue fragments

The first of the six previously discovered wild boar statues was a large fragment (max. length: 68.0cm, max. height: 55.0cm, max. thickness: 23.0cm) found leaning against a wall on the eastern side of Special Building A in 1997 (Figs. 13.1 and 14.1). Its identification as a wild boar was based on the shape of the head and the poorly preserved but still visible tusks (*Schmidt 1999a.11; Peters, Schmidt 2004.184*).

An extension of fieldwork to the north in 1998/1999 led to the discovery of Special Building C in 1998/1999 and the first of four wild boar statues so far discovered in this structure (Figs. 13.2 and 14.2). Unearthed adjacent to pillar 12 (P12), the statue is completely preserved (max. length: 48.0cm) and was found in fill deposits close to the monolith and above the internal bench of the building. A fracture at its base suggests that it was originally part of a larger composition (*Schmidt 1999b.13–14, Fig. 18; 2000b.25–26; 2008b.64; Peters, Schmidt 2004.184, Fig. 115*). A second complete but

Fig. 12. Göbeklitepe. The continuation of the bench to the west of the newly discovered wild boar statue in Special Building D (*cf. *Fig. 7.6). The limestone slab used for this purpose features a large double-conical perforation and an incised leopard depiction on its top surface (bottom) (photos L. Clare, German Archaeological Institute, Göbeklitepe Project 2024).

less well preserved statue (max. length: 95.0cm, max. height 60.0cm high, max. thickness 25.0cm) was revealed in 2001, standing upright in a conglomeration of stones above (or upon) an outer enclosing wall (Figs. 13.3 and 14.3). In the following year, the well-preserved head of a third boar was discovered in the fill of the building, approximately 50cm southeast of pillar 24 (P24) (*Peters, Schmidt 2004.184, Fig. 116*); with a length of 53.0cm, this fragment is comparable in size to the head of the newly discovered statue in Building D (Figs. 13.4 and 14.4). Finally, a complete fourth statue (max. length: 48.0cm, max. height: 28.0cm) excavated in 2008 was one item in a group of objects (including two stone plates and a crude vessel) found arranged on the platform of Pillar 35 (Figs. 13.5 and 14.5); a fracture at its base suggests that it, too, was originally part of a larger composition (*Schmidt 2008c.28–29*).

A final wild boar statue was recovered from trench DR1 in 2018 (Figs. 13.6 and 14.6). This trench was excavated to install a rainwater drainage pipe from the

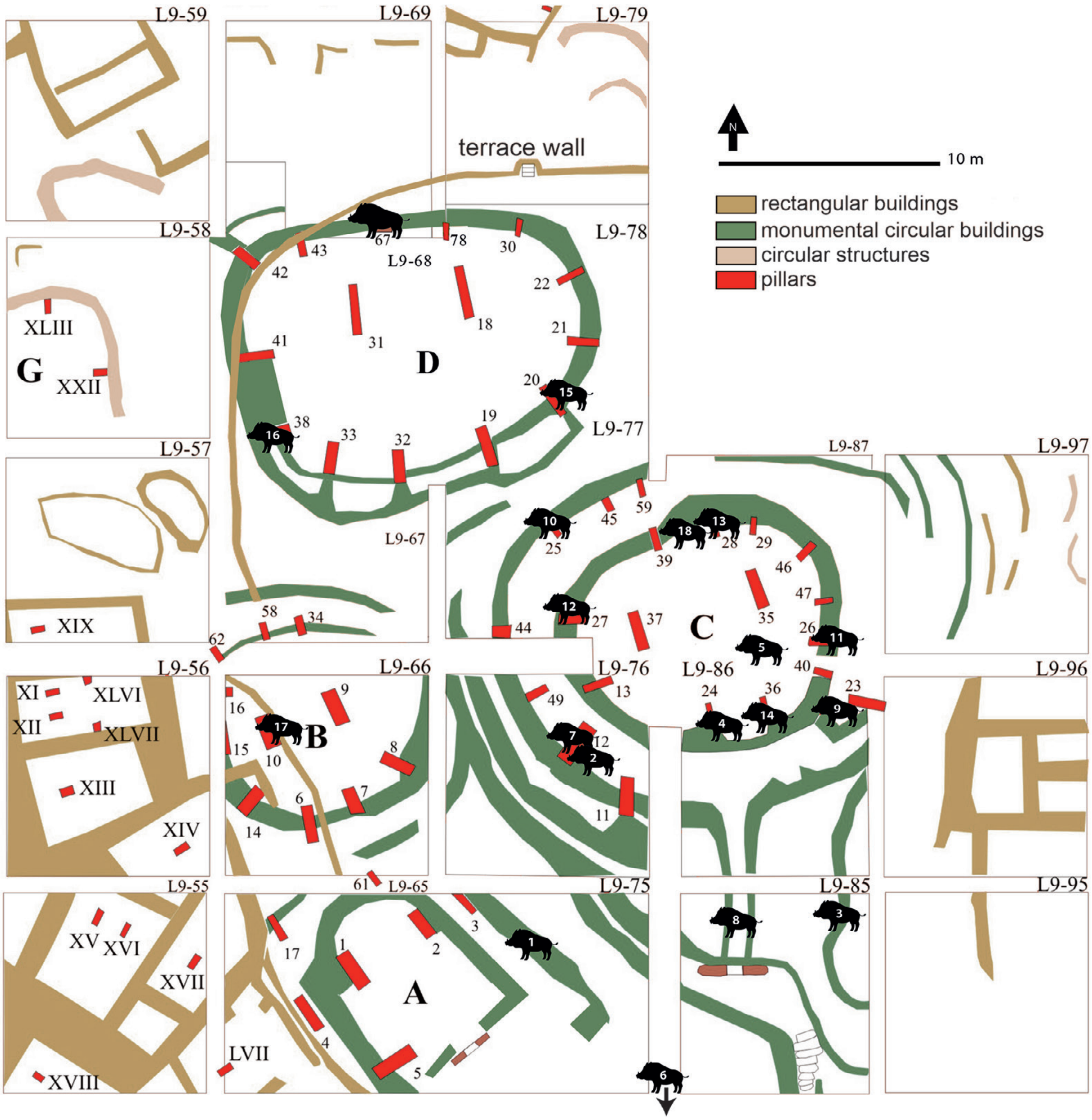

Fig. 13. Göbeklitepe. Spatial occurrence of wild boar depictions in special buildings A, B, C and D and adjacent areas. Numbered wild boar silhouettes refer to the statues, low reliefs, protome and incised depiction described in the text. The largest wild boar silhouette marks the position of the newly discovered statue in Special Building D (image M. Kinzel; changes and additions by L. Clare, 2024, German Archaeological Institute, Göbeklitepe Project).

then newly constructed protective canopy over the main excavation area. Although missing its head, the statue is otherwise complete, the shape of its body and legs mirroring other wild boar depictions. The statue fragment, which is 42.0cm long, with a maximum height of 27.0cm and a maximum width of 16.0cm, was discovered incorporated into a wall enclosing a rectangular space attributed to the EPPNB (*Kinzel 2023.226, Fig. 226*).

Low reliefs

Ten low reliefs of wild boars have been uncovered in special buildings at Göbeklitepe. Eight low reliefs of wild boars have been discovered in Special Building C, where seven adorn the surfaces of T-shaped pillars in the walls of the structure, and one a *portal stone* (a window-like frame carved from a limestone slab and associated with the construction of niches and entrances/exits of buildings). Two further low reliefs, both on T-shaped pillars, are known from Special Building D.

In Special Building C, the first relief of a wild boar was found on the southeast-facing broad side of pillar 12 (P12) (Figs. 13.7 and 15.7). While the second was discovered on the *portal stone* (Figs. 13.8 and 16), further depictions were found on pillars 23, 25, 26, 27, 28 and 36 (P23, P25, P26, P27, P28, P36) (Fig. 13.9–14).

In addition to the newly discovered statue in Special Building D, other wild boar depictions in this structure are limited to two low reliefs on pillars 20 and 38 (P20 and P38) (Fig. 13.15–16). Combined with the newly discovered statue, the wild boar images in this building form a triangular arrangement.

While some wild boar low reliefs are comparatively small and simple in their implementation, others are more elaborate, and in these cases particular attention is given to depicting the mouth and tusks. All low reliefs show the wild boar in profile, facing either to the left or the right and, in one case, facing downwards (P25). Examples of simpler representations are found on P25, P26 (Figs. 13.11 and 15.11), P27 (Figs. 13.12 and 15.12), P28 (Figs. 13.13 and 15.13),and P36 in Special Building C, and on P20 in Special Building D. Among these depictions, the wild boar on P27 stands out, positioned below the high relief of a leopard on the front narrow side of the pillar, in what appears to be a hunting scene. The body posture of the predator suggests that it is about to pounce on its prey.

The more elaborate wild boar low reliefs on P12 (Figs. 13.7 and Fig. 15.7) (*Schmidt 1999b.13–14, Fig. 17; Peters, Schmidt 2004.184, Fig. 113*), P23 (Figs. 13.9 and 15.9) (*Schmidt 2006a.146*) and P38 (Fig. 13.16) (*cf. Schmidt 2006b. 344, Fig. 347*) are comparable in their implementation. The exceptionally well-crafted wild boar on

Fig. 14. Göbeklitepe. Limestone wild boar statues:* 1 *a head fragment from Special Building A (A15);* 2 *a complete statue from Special Building C (A25);* 3 *a complete but poorly preserved statue from Special Building C (A29);* 4 *a head fragment from Special Building C (A34);* 5 *a complete statue from Special Building C (A62);* 6 *a headless statue from the wall of a rectangular structure in DR1. For details of find contexts and dimensions, see text. The numbers in the silhouettes refer to the find spots in Fig. 13 (all photos German Archaeological Institute, Göbeklitepe Project).

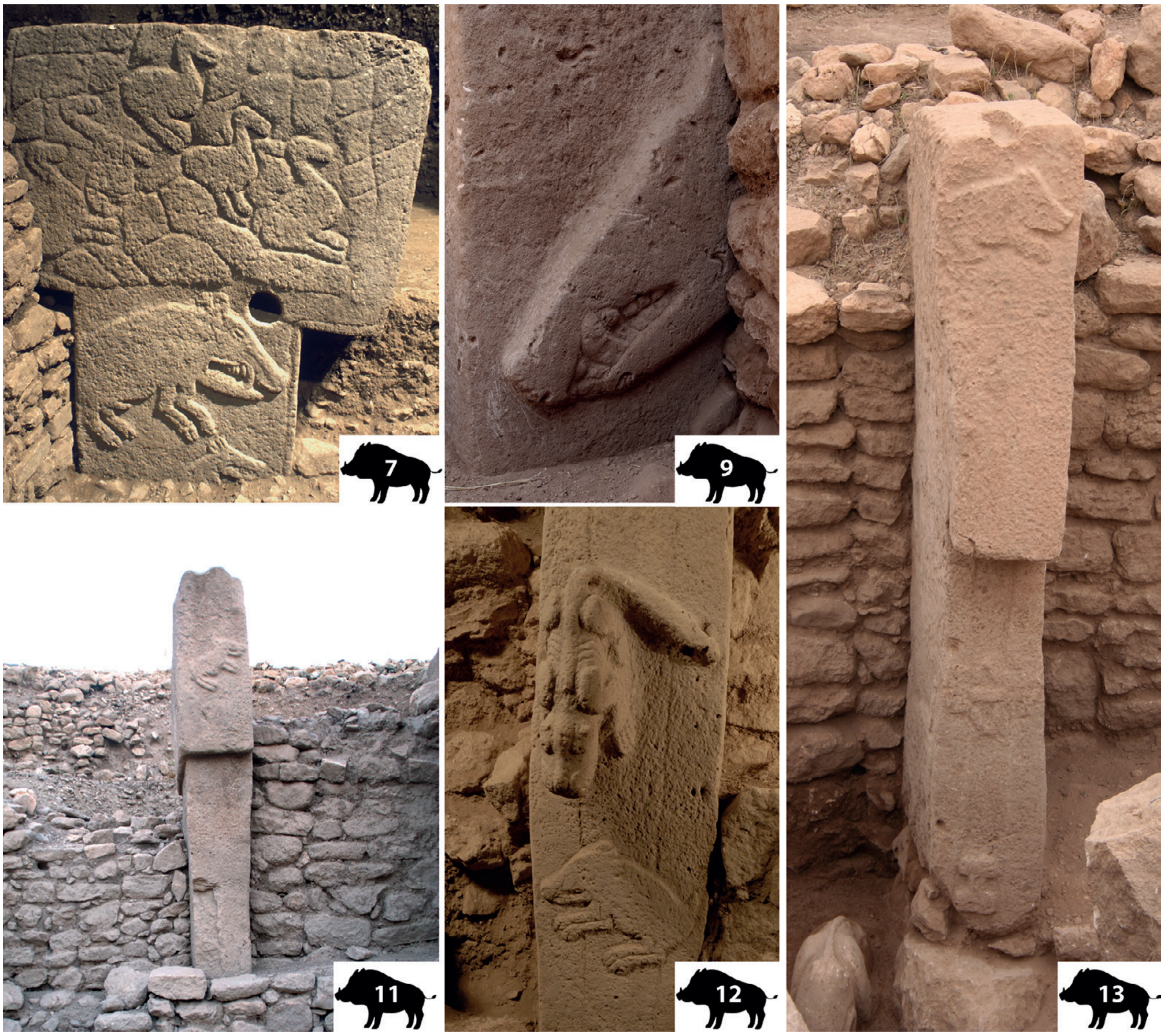

Fig. 15. Göbeklitepe. A selection of wild boar low reliefs in Special Building C:* 7 *an elaborate depiction on P12;* 9 *a partially visible representation of high quality on the broad side of P23;* 11 *a simple wild boar depiction on the front narrow side of P26;* 12 *a simple low relief of a wild boar on P27, possibly as part of a hunting narrative in combination with the high relief of a leopard;* 13 *a simple low relief on P28. The numbers in the silhouettes also refer to the find spots in Figure 13 (all photos German Archaeological Institute, Göbeklitepe Project).

P12 takes its place on the pillar shaft, below depictions of four vultures and above a fox. Finally, the low relief on the *portal stone* in Special Building C (Figs. 13.8 and 16) is unusual because the animal was positioned upside down, its trotters pointing upwards, perhaps symbolising death (*Peters, Schmidt 2004.184, Fig. 117; Schmidt 2006a.155, Fig. 67; 2010b.253, Fig. 226*).

A hunting scene in Special Building B

The only wild boar depiction in Special Building B is perhaps one of the most animated. It is a small and comparatively coarsely produced image incised into the broad eastern side of pillar 10 (P10), the westerly of the two quasi-centrally placed monoliths (Figs. 13.17 and 17). Revealed during excavations in 1999 below the more dominant low relief of an ithyphallic fox, the wild boar is part of a larger narrative scene that includes a small pack of dogs, identified by their tails bent forwards above the body. The dogs appear to be pursuing the boar (max. length: 20.0cm; height: 12.5cm) in what could be interpreted as a hunting scene with trained domesticated animals (*Schmidt 2000b.23, Fig. 10; Yeomans* et al. *2019*).

A protome from Special Building C

A protome featuring the front half of a wild boar is among the most impressive testimonies to the abilities of the prehistoric artisans at Göbeklitepe (Figs. 13.18 and 18). Produced by a highly skilled stonemason, the protome (length: 97.0cm, max. width: 28.0cm) was found *in situ* between P28 and P39, protruding inwards from the bench in Special Building C (*Schmidt 2008c.29, Fig. 26*). Resembling Gothic-style gargoyles, complete and partially preserved examples of protomes of different animals have been discovered at Göbeklitepe. The cone-shaped rear part of the objects served the horizontal and vertical fixture of the carvings into the walls and benches of the special buildings.

Fig. 16. Göbeklitepe. The low relief of an upside down wild boar on the portal stone of the dromos in Special Building C. The number in the silhouette also refers to the find spot in Fig. 13 (photo D. Johanes, German Archaeological Institute, Göbeklitepe Project).

In summary, many of the depictions of wild boar (*Sus scrofa*) from Göbeklitepe emphasise the behaviours displayed by fighting animals, including, for example, an open mouth with tusks bared and the vertically erected dorsal crest of hair (*Barrette 1986*) which are also evident on the newly discovered statue in Special Building D. Another characteristic is the rearing up on the hind legs, a behaviour portrayed in some of the low reliefs (*e.g.*, Fig. 15.11–12). However, due to the lack of genital (phallus) depictions, it is impossible to ascertain whether all images show male individuals, especially as females can be equally aggressive, though the tusks in females usually do not protrude. Finally, in light of insights from archaeozoological studies, which have shown that goitered gazelle (*Gazella subgutturosa*) and Asiatic wild ass (*Equus hemionus*) were the most important quarry of the Göbeklitepe hunters, the abundance of wild boar depictions in the context of the special buidings might suggest that this animal, whilst also eaten, was of greater symbolic importance (*Peters, Schmidt 2004.209*). Indeed, the comparative absence of gazelle and wild ass depictions in the repertoire of images adorning T-shaped pillars underlines that the importance of animals as quarry was not a guarantee for their inclusion in the symbolic/ritual contexts. On the other hand, the prominent position of the wild boar in the Göbeklitepe symbolism could reflect the suitability of the species to be loosely controlled, ultimately leading to its domestication elsewhere (*Price, Evin 2019*).

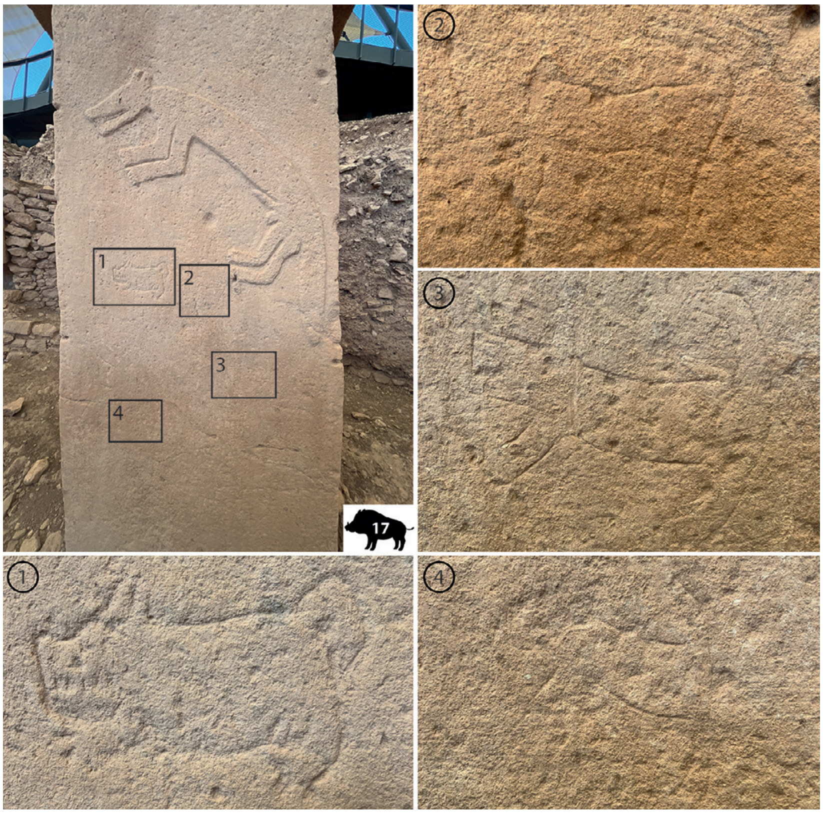

Fig. 17. Göbeklitepe. An incised depiction of a wild boar on P10 in Special Building B. The animal is being pursued by a small pack of dogs in a possible hunting scene. The number in the silhouette refers to the find spot in Fig. 13 (photos L. Clare, German Archaeological Institute, Göbeklitepe Project).

An invisible social elite

We now return to the discussion of social hierarchies at Late Pleistocene and Early Holocene sites in the upper Tigris and Euphrates basins. Based on insights from the available archaeological sources, it is proposed here that potential leaders (‘*inspired individuals*’ in the sense of Cauvin, see above) could have emerged from three groups in the settled hunter-gatherer communities: the storytellers, hunters and ritual adepts. We will approach each of these groups individually and consider the crucial parts they played in society. Finally, the rise and fall of late hunter-forager ‘*charismatic leaders*’ will be addressed in the context of an adaptive cycle spanning the tenth and ninth millennia cal BC.

Fig. 18. Göbeklitepe. Limestone protome of a wild boar **in situ** ***in Special Building C (top) and following its removal (bottom). The number in the silhouette refers to the find spot in Fig. 13 (photos German Archaeological Institute, Göbeklitepe Project).***

The storytellers

Ethnographical studies in traditional societies in different parts of the world have provided a wide range of insights into the multiple functions of oral narratives, ranging from the transmission of traditions that dictate social behaviour, *i.e.* the promotion of shared identities and values (*e.g.*, *Georges 1969.314–315; Sobel, Bettles 2000*) to ‘*sensemaking*’, *i.e.* giving meaning to unusual and unexpected experiences (*Tonkin 1992.66–70; Nowell 2023.16–17*). Especially in societies lacking ‘*moralising high gods*’, (oral) narratives (and therefore storytellers) are known to contribute to the long-term evolution and promotion of cooperative behaviour (*Smith* et al. *2017; Nowell 2023.14–15*). No less significant are other observations that highlight how storytelling can be used as a conditioning mechanism and as an instrument of social control, often implemented to serve the personal gains of the narrators. This is expressed in some indigenous societies by the status of storytellers as preferred social partners, sometimes resulting in their greater reproductive success (*Smith* et al. *2017.3–4*).

The Göbeklitepe narratives

The imagery adorning the Göbeklitepe small finds and T-shaped pillars goes far beyond the random and coincidental. The depictions of wild animals, humans and symbols represent ‘*petrified*’ oral narratives, thus providing a unique record of the myths, beliefs and worldviews of hunter-forager society, the roots of which most likely pre-date Göbeklitepe itself. Previous studies have suggested that these narratives could have centred around the existence of a death cult (*e.g.*, *Schmidt 2006a.125–127; Notroff* et al. *2015.73–78*) or be indicative of totemic systems (*e.g.*, *Schmidt 2006a.124; Becker* et al. *2012.37*). Alternativevely, they might show human actors attempting to harness the vital forces and power of nonhuman (animal) actors (*Borić 2013*), or just express the multifaceted nature of human-nonhuman relations (*Busacca 2017*), possibly in the form of predator-victim dichotomies (*Clare* et al. *2019b*). Whatever the case, a common characteristic of all these interpretations is that they are rooted in animistic belief systems. Indeed, there is an overwhelming consensus that animism was the prevailing ontology in the upper Euphrates and Tigris basins in the Late Pleistocene and Early Holocene (*e.g.*, *Yakar 2012; Benz, Bauer 2015; Fagan 2017; Benz, Bauer 2022*).

Animism is the belief that all *natural* things, such as plants, animals and even such phenomena as thunder, have intentionality (or a vital force) and can have influence on human lives. Animism is considered fundamental to human religion and was very likely present in the last common ancestor of present-day hunter-gatherers (*Peoples* et al. *2016.266,270*). Following the definition by Marshall Sahlins (*2014*), grounded on the work of Philippe Descola (*2013*), animism can be subdivided into three different types: communal animism ('*animism*'), segmentary animism ('*totemism*') and hierarchical animism ('*analogism*'). At the same time, these three types include elements of the others, and all types are versions of anthropomorphism, characterised by decreasing levels of personhood among nonhuman beings (*Sahlins 2014. Fig. 1*). It is beyond the scope of this paper to delve further into the Göbeklitepe imagery to debate the presence and absence of the different types of animism attested therein. However, earlier and recent discoveries from Göbeklitepe and other Taş Tepeler sites suggest the existence of communal and segmentary animism in these communities.

While communal animism sees all human individuals share essentially the same relationships to all nonhuman persons, segmentary animism ('*totemism*') identifies nonhuman persons with different human collectives, such as lineages or clans (*Sahlins 2014.282*). In the case of the Sayburç relief, communal animism is perhaps inferred by what appears to be the shared (revered) behavioural attributes (strength, speed, bravery) of the human and nonhuman actors (aurochs and leopards; see below and Figure 21). In the case of the wild boar statue from Göbeklitepe, a totemistic interpretation could be implied by its size, quality and central placement within Special Building D (*cf. Becker* et al. *2012.37*).

Evidence for hierarchical animism (*analogism*) appears absent or, at best, difficult to identify in the prehistoric imagery. Hierarchical animism refers to the "*plenitude of what there is* [beings and things] *encompassed in the being of cosmocratic god-persons*" (*Sahlins 2014.282*), who can also take on an anthropomorphic form. Human depictions from Göbeklitepe, and also the newly discovered human statue from Karahantepe (*Karul 2023a. Fig. 7*), do not appear to exude the profound powers of cosmocratic god-persons (*cf. Sahlins 2014.287–288; 2017*). Nevertheless, some of the features of the new find from Karahantepe might infer that elements of analogism existed, reflected, for example, in the visible ribcage combined with an erect penis, characteristics also observed on some animal statues (Fig. 19; *cf. Schmidt 2013*). Admittedly this evidence is highly tentative, but if true it could mark a significant break with earlier (Epipalaeolithic/PPNA) belief systems.

A focus of Göbeklitepe narratives was the role of the ancestors, as expressed in previous references to the existence of a death cult (*e.g.*, *Schmidt 2006a.125–127; Notroff* et al. *2015.73–78*). Notably, the communication between the dead and the living (sometimes referred to as ancestor worship or veneration) is considered a quasi-universal aspect of religion among indigenous societies, especially in kinship-based systems (*e.g.*, *Steadman* et al. *1996; Peoples* et al. *2016.266–267*). Communication with the dead can take on entirely different forms, but generally culminates in claims that the dead can aid or punish the living or that the living can invoke the dead to assist in earthly affairs. This shows that the universality of ancestor worship goes beyond the simple hypothesis that the belief in an afterlife fulfills the human need to reduce anxiety when confronted with death. Instead, ethnographic studies show that the role of the dead as a source of social traditions lies at the heart of ancestor veneration. It serves to strengthen not only kinship ties but also the traditions upon which they depend: "*no one questions the wisdom and authority of an ancestor*" (*Steadman* et al. *1996.73*). Notably, ancestor worship is congruent with animistic beliefs, which, as in some examples from modern hunter-gatherer societies, see the dead take on the forms of nonhuman persons (animals) (*e.g.*, *Steadman* et al. *1996*). Indeed, statue fragments from EPPNB Nevali Çori depicting human-bird combinations, have been previously interpreted as the metamorphosis of the human dead into nonhuman persons (*Morsch 2002.159*).

Material expressions for the practice of ancestor veneration at Göbeklitepe are manifold. One notable example is the existence of a skull cult, in the frame of which the heads of some individuals were exhumed from burials, cleaned and displayed (*Gresky* et al. *2017*). Additionally, the T-shaped pillars in the special buildings have been interpreted as the embodiments of forebears (*e.g.*, *Schmidt 2000c.49; 2005.14*). Naturally, we cannot rule out that the human depictions from other Taş Tepeler sites, including the newly discovered human statue from Karahantepe, the human figure depicted in the Sayburç relief, as well as the so-called Urfa Man recovered from Şanlıurfa-Yeni Mahalle (*Çelik 2000*), are also in the image of ancestors or even representations of the same (mythological) ancestor individual (*cf.* Fig. 22).

Special buildings as 'narrative arenas'

The ground plan and internal arrangement of the special buildings underline the narrative act and the interpretation of these structures as *narrative arenas* (Fig. 20). Previous estimations have put the number of people who could comfortably fit into these buildings at around 25–30 individuals, with the entrance and exit regulated via one or more small openings (*portal stones*) in their roofs (*Kinzel, Clare 2020.44*). Based on the documentation of unique narratives in each of the special buildings, albeit with evident general underlying themes, these communal structures likely *belonged* to defined groups in the community. The oval-circular shape and the interior benches, upon which the radially arranged anthropomorphic T-shaped pillars appear to be seated, suggest performance and group participation. Furthermore, as the carved images are not visible from a single location, participants would have needed to move around the structure to view them all, perhaps indicating the incorporation of dance (and music) into the narratives or suggesting that individual pillars acted as different stations on a journey to be guided by the storyteller (*McBride 2013.54, Fig. 55*).

The impact of the narrated words and the carved depictions were likely enhanced by artificial lighting (lamps, torches, hearths). The archaeological evidence for roofs covering the special buildings at Göbeklitepe has increased in recent years (see above), suggesting that their interiors were places of (artificial) darkness even during daylight hours, and therefore comparable to situations encountered in natural cave environments. The emotional resonance of darkness is well known from studies investigating Palaeolithic cave art sites (*Nowell 2018*). Furthermore, ethnographic studies have highlighted the difference between '*day talk*' and '*night talk*' among hunter-forager societies, where the former generally involves gossip and economic issues, but where the onset of darkness sees people engage in qualitatively different forms of social communication with conversations that evoke the imagination, help people remember and understand others in their external networks and convey information about cultural institutions that generate regularity of behaviour and corresponding trust (*Wiessner 2014; Nowell 2018.32*).

Fig. 19. Limestone human statue (height: 2.30m) discovered at Karahantepe in 2023 (left) and the statue of a predator (length: 68.0cm) found on a wall in Special Building A at Göbeklitepe in 1996 (**Schmidt 2012.Fig. 42*****). The visible rib cage and the erect penis are common to both the human and animal depiction (images L. Clare, courtesy of N. Karul (left); German Archaeological Institute, Göbeklitepe Project (right)).***

The hunters

Although nothing is known about the ratio of plant to animal-based calorie input at Göbeklitepe, hunters would have played a crucial role in securing at least one part of the subsistence in this pre-farming community. Indeed, the success of Early Holocene societies in the upper Tigris and Euphrates basins was dependent on the expertise and knowledge of hunters, *i.e.* their abilities to provide sufficient meat and other animal products (bone, skin, horn) to the populations of the ever-expanding settlements. The discovery of large-scale hunting traps, also called '*desert kites*', for which an Epipalaeolithic/PPN age is generally assumed, testify to this knowledge and expertise (for a critical review of desert kites, see *Shakhmuradyan 2020*). Numerous such structures are now known from locations close to many of the Taş Tepeler settlements, particularly in the mountains to the east (Tektek Dağları) and west (Fatik/Cudi Dağları) of the Harran plain (*Çelik, Tolon 2018; Çelik, Ayaz 2022.150–151; Şahin* et al. *2023; Şahin 2024*). Additionally, it is perhaps no coincidence that the first appearance of domesticated dogs in Southwest Asia coincides with the Late Epipalaeolithic (*Yeomans* et al. *2019*); indeed, these animals would have been an effective means of driving herds of gazelle into the '*kites*'. Evidence for the use of dogs in the hunt was already proposed in the context of the wild boar hunting narrative incised on the eastern broad side of P10 in Special Building B at Göbeklitepe (*Schmidt 2000b. 23, Fig. 10*) (Fig. 17).

In contrast to the crucial role of hunters in securing subsistence, their social roles (as with the storytellers) are less frequently discussed, particularly in the context of leadership. However, there are numerous indigenous societies around the globe in which hunters, significantly the better hunters, assume leadership functions under some circumstances, albeit the group would employ power-curbing mechanisms (sanctions) to subdue overly assertive individuals and those with leadership aspirations (*Boehm 1993*). The prehistoric hunters of the Late Pleistocene and Early Holocene in the upper Tigris and Euphrates basins likely constituted a distinct and tight-knit social group within their communities, underlined by shared experiences and instilled values, thus heightening their eligibility to slip into the role of a leader should the need arise. In this context, the recently discovered relief in Special Building AA at Sayburç is of special note, it perhaps being the first '*petrified*' narrative of hunter initiation rites (*Özdoğan E. 2022; Özdoğan, Uludağ 2022;* see also *Ayaz 2023a. 374; 2023b*).

Hunter initiation at Sayburç

The Sayburç relief is comprised of two frames (Fig. 21). The first frame shows a human interacting with an aurochs, while the second shows a male, probably the same individual, flanked by two leopards. In the first, the human figure faces the aurochs with both arms raised above his head, brandishing an object in his right hand, his legs bent at the knees. The aurochs faces the human figure and is depicted with its head turned to one side, its horns evident to the observer, and its body in profile. This twisted form is typical of depictions of aurochs adorning some T-pillars at Göbeklitepe and could indicate that it is charging (*cf. Benz, Bauer 2013.14*). The human figure appears to be taunting the aurochs through dance or gesture, although his raised arms are also suggestive of supplication, reminiscent of scenes from Saharan Neolithic rock art (*cf. Cauvin 2007.Fig. 22*). The item in his right hand has been interpreted as a rattle (*Özdoğan E. 2022.1601*), a snake (*Özdoğan E. 2022.1601; Özdoğan, Uludağ 2022: 21*), a sling (*Özdoğan, Uludağ 2022: 21*) or the tail of another animal (*Ayaz 2023b.197*). Alternatively, it could be the severed penis and testicles of this (or another) aurochs, an interpretation that would be in agreement with the sexual symbolism evident in the second frame, where the (same) human individual

Fig. 20. Göbeklitepe. Special Building D before the onset of excavations in 2023. The anthropomorphic T-shaped pillars in the encompassing wall are positioned as if seated on the bench, looking inwards, towards the two central monoliths; in combination with the manifold low reliefs and carvings adorning these pillars, this indicates that this (and other) special buildings served as narrative arenas. View from the southwest looking northeast (photo L. Clare, German Archaeological Institute, Göbeklitepe Project, August 2023).

appears to have attained higher status, most certainly through the actions depicted in the first. Subsequently, his successful initiation is implied by the two flanking leopards and his own erect penis, which he holds in his right hand as if masturbating.

In some indigenous societies, the first ejaculation (*thorarche*) is often taken to mark the passage of boys into adulthood (*Chad 2020*). In others, there is a strong association between hunting and sex, usually arising from the mimesis involved in seducing the prey (*cf. Lahelma 2019.5–9*). Initiation rites have already been discussed in the context of the 'phallus pit' at Karahantepe (*Karul 2021*), and masturbation has been proposed concerning the Kilisik statue from Adıyaman (*cf. Hodder, Meskell 2011.238*). The ubiquity of penis depictions at Göbeklitepe and culturally related sites has also led to speculation that society considered masculinity as a source of power or was obsessed with fertility (*e.g.*, *Uludağ* et al. *2018.23*), with some authors even suggesting ritual acts of sexual intercourse (*Verit* et al. *2005*). However, the phallocentrism (observable in humans and animals alike) was more likely an expression of complex animal-human relations (*cf. Hodder, Meskell 2011*). Humans were not the dominant actors in this deep-rooted animistic belief system; indeed, they considered themselves part of and undetached from the animal world (communal animism; see above). In the case of Göbeklitepe, Hauptmann and Schmidt (*2000.265–266*) already stressed the close connection between hunters and animals which they saw expressed in the pictorial repertoire at the site. In this context, one of the recent interpretations of the Sayburç relief by Eylem Özdoğan and Celal Uludağ (*2022.22*) as representing the human struggle against nature (man with aurochs) and emerging human domination over animals (man flanked by leopards), as a metaphor for Neolithisation, appears unlikely.

Ancestral huntsman or supernatural gamekeeper

The similarities between the high relief from Sayburç and human statuary from other Şanlıurfa sites are striking (Figs. 19 and 22). This observation begs the question as to whether these ithyphallic individuals are depictions of the same person, *i.e.* a revered ancestral huntsman or even a so-called *supernatural gamekeeper*. The latter is known among numerous indigenous societies on many continents and grants hunting success to those who perform specific rituals and adhere to various restrictions. Conversely, hunters who violate established restrictions may experience a loss of hunting luck, sickness, and, in some cases, even death (*Chacon 2023*). Notably, the belief in supernatural gamekeepers was likely a nearly universal step in the prehistoric past at the transition from animism to deism (*Smith 2023*) and has already been approached in a recent contribution by Diana L. Stein (*2023*).

The ritual adepts

Similar to the concept of '*feasts*' and '*feasting*', in recent years, '*shamanism*' has become a buzzword in prehistoric studies, including in the context of the Pre-Pottery Neolithic. Numerous contributions have already focussed on the archaeological evidence for shamans from Early Neolithic sites in Southwest Asia (*Benz, Bauer 2015; Mithen 2022; Dietrich 2023*). As such, yet another presentation of the same materials is superfluous, especially as even the best archaeological sources for these individuals are often ambiguous. This is best exemplified by the case of prehistoric human burials attributed to shamans (*e.g.*, *Grosman* et al. *2008*), where the wearing of shamanic attire and the presence of sacra do not necessarily mean that an individual was a shaman (*cf. Stépanoff 2015.171*). Indeed, "[...] *shamanism is not always the domain of a few special individuals, but can be communal. Anthropologically the best-known case of communal shamanism is probably the San shamanism of south-*

Fig. 21. Sayburç. The relief in Special Building AA is comprised of two related scenes. While the first features a human figure and an aurochs, the second shows the (same) human flanked by two leopards. It is proposed that this relief recounts either a hunter's initiation or the heroic deeds of an ancestor or a supernatural gamekeeper (photo B. Köşker, courtesy of E. Özdoğan).

ern Africa […], *but it occurs also in Northern Eurasia, such as among the Siberian Itelmen, who have no specialised shamans with elaborate paraphernalia; instead, almost anyone with the skill of falling into trance can be a shaman*" (*Lahelma 2019.10*).

Despite the uncertainties connected with the archaeological evidence of shamans, the collation of potential material expressions for their existence remains a worthwhile exercise. This process is undoubtedly aided by a broader understanding of shamanism itself, making it possible, for example, to better identify the activities undertaken by ritual adepts in prehistoric societies. Shamanism might be defined as a family of traditions whose practitioners focus on voluntarily entering altered states of consciousness in which they experience themselves or their spirit(s), travelling to other realms at will and interacting with other entities to serve their community (*Walsh 1989.5*). It follows that the essential function of these individuals is to provide information about uncertain outcomes, and in this context, they typically undertake tasks such as divination, healing, and weather control (*Singh 2018. Fig. 3*). Based on insights from the Late Pleistocene and Early Holocene in the upper Tigris and Euphrates basins, additional functions could have included overseeing rituals, including rites of passage (initiations), acting as mediators between the living and the dead, or as human counterparts of the aforementioned supernatural gamekeeper.

Newly available archaeological evidence for activities undertaken by ritual adepts at Göbeklitepe stems from the excavations in 2023, specifically in the context of the bench on the northern side of Special Building D, upon which the wild boar statue was discovered. In addition to the cup mark and a circular-shaped incision on the upper-facing surface of the slab, and the drilled diagonal incision with accompanying leopard depiction on its westward extension, there was the unexpected find of the jawbone of a young wild boar (pers. comm. Stephanie Emra) in the rubble matrix just 1.5 metres to the east of the statue and just above the level of the bench. It cannot be ruled out that the jawbone was originally lying on the surface of the bench and became displaced by the slope slide that led to the (partial) inundation of the special building (see above). This being the case, questions must arise as to the original context of this object: Was it a food offering, or could it be evidence of animal sacrifice? Notably, according to anthropologists and historians of religion, sacrifice only begins with the domestication of plants and animals, and so animal sacrifice does not exist in hunter-forager societies (*cf. Hénaff 2012.332; Beriain 2020*). In pre-farming communities *sacrifice* occurs in the frame of the hunt (*Valeri 1994*). However, if some form of sacrifice in the special buildings at Göbeklitepe had been required for the appeasement of the ancestors (*cf. Steadman* et al. *1996; Peoples* et al. *2016.266*), this would suggest that crucial changes were occurring in religious and ritual spheres, perhaps marking the gradual transition from communal and segmentary animism (totemism) to hierarchical animism (analogism), as already tentatively suggested in the context of the human statue from Karahantepe (see above). The ritual adepts would have been key players in this process.

Fig. 22. A selection of Pre-Pottery Neolithic human depictions; from left to right: The so-called Urfa Man (Şanlıurfa-Yeni Mahalle, height: 1.93m); a seated figurine with phallus and animal on the left shoulder (Göbeklitepe, height: 5.1cm); a statue with phallus but without limbs (Göbeklitepe, height: 38.0cm); and a human protome (Göbeklitepe, height 60.0cm) (photos I. Wagner, D. Johannes, and N. Becker, German Archaeological Institute, Göbeklitepe Project).

Finally, in contrast to the storytellers and hunters, ritual adepts are more commonly thought of as natural leaders of indigenous societies. However, this assumption is not supported by comparative ethnographic evidence. Based on data from 21 indigenous societies compiled by Michael Winkelman and Douglas White (*1987*), shamans only irregularly contributed to certain aspects of social life, outside of providing information about uncertain outcomes (*Singh 2018Fig. 3*). Therefore, although they sometimes assist in various life cycle activities, including births, funerals and initiations, and enjoy leadership roles, shamans serve these roles much less frequently. According to Manvir Singh, in only 14% of the indigenous societies did shamans take on the role of a *charismatic leader* (see below). Other decision-making domains fulfilled by shamans included *judiciary power* (52%), *economic power* (29%), *military power* (38%) and *political power* (29%).

Inspired individuals as charismatic leaders

Supposing then that individuals, be they storytellers, skilled hunters, or ritual adepts (including healers and medicine-persons), were part of an archaeologically invisible group of decision-makers at Göbeklitepe in the late tenth and ninth millennia cal BC, what can anthropological discourse tell us about the roles played by these individuals or groups of individuals in their communities? Were they larger-than-life leaders, perhaps comparable to the famous 'medicine men' of the American Plains Indians (*e.g.*, Sitting Bull of the Lakota Sioux; *cf. Dunbar 2022*)? Did they wield authority over their devotees, having them construct monumental buildings with limestone monoliths and statues in the likeness of the ancestors? And if so, how did they achieve this? Indeed, some storytellers, hunters and ritual adepts could have possessed a high level of what is termed '*charisma*' in the sociological and anthropological literature, and referred to by Charles Lindholm (*2013.1*) as "*the most important driver of religious transformation and certainly one of the most powerful emotional relationships possible in human life*". Lindholm continues, "*It can inspire true believers to renounce family and friends and embrace suffering, degradation, and ostracism for the sake of their beloved redeemer. In extreme cases, devotees may even be willing to die – or kill – at their leader's command*". As such, charisma allows us to go beyond the paradigm of our modern (capitalist) understanding of leader-follower relationships, which sees these as comparable to an economic transaction, whereby the follower attains a goal (*e.g.*, financial advantage or status) by supporting the leader, and the leader deploys his followers to gain more influence in society. The concept of '*charisma*' allows us to consider such aspects as the emotional appeal of spiritual authority.

Charisma has been a focus of studies by sociologists and later by anthropologists ever since the pioneering work of Max Weber, with other models also formulated, for example, by Émile Durkheim and Sigmund Freud. However, it is the Weberian theory of charisma that has been the most influential among modern anthropologists (for a comprehensive review, see *Lindholm 2013*). Weber divided political power into three types of action orientations: '*traditional*' (an unthinking adherence to custom), '*legitimate*' (rational-legal) and '*charismatic*' (commitment to a specific person), each of which corresponds to three primal motivations for action: '*habit*', '*cognition*' and '*emotion*'. Notably, Weber describes charisma as the most potent and dangerous of the three action orientations, whereby the '*emotional*' attraction of followers to '*charismatic*' individuals, such as shamans, prophets and revolutionary leaders, stems from religious experience and the affective commitment of devotees to the leader's supernatural powers. Weber also refers to this category of charisma as '*genuine*' or '*pure*', in contrast to a second sense used in the context of '*transformed*' and '*routinized*' charisma: The flame ignited by a charismatic figure is likely to burn out following death, and the few cults that endure do so only if surviving devotees can turn the pure charisma of their leader into the secondary charisma of the '*institution*'.

The most common modes for transitioning from primary to secondary charisma are genealogy (blood offspring), appointment (designation of a disciple as successor) and magical signs; such charismas are found in all societies, irrespective of their levels of complexity (*Greenfield 1985; Lindholm 2013*). However, in the Pre-Pottery Neolithic (PPN) it is proposed that any attempts made to institutionalise charismatic leaders may have been curbed by social mechanisms designed to uphold egalitarian social systems (*e.g.*, *Hodder 2022*); in other words, *genuine* and *pure* charisma never became *transformed* and *routinised* charisma (*cf. Flannery, Marcus 2012; Çilingiroğlu 2023*).

The H-symbol

Despite the general absence of archaeological evidence associated with PPN decision-makers, one symbol does exist which should be discussed in this context: H-shaped low reliefs found adorning architectural elements, including T-shaped pillars, at Göbeklitepe. In Special Building D there is an especially rich repertoire of this particular symbol, for example as low relief depictions on numerous T-shaped pillars and as elements incorporated into the accessories (necklace, belts) of the two quasi-centrally placed anthropomorphic T-shaped monoliths in Special Building D (Fig. 23) (*cf. Becker* et al. *2012*). In recent years, this assemblage has increased in number, with further examples found on a wall stone on the eastern side of this building (Figs. 7.7 and 23.bottom right), incised into its artificially smoothed limestone floor (Figs. 7.8 and 24) and adorning the bench below the wild boar statue (Figs. 7.5 and 11).

A unique and very notable object in this context is a syenite sceptre found at Göbeklitepe in 1997 with two H-shaped motifs incised into its narrow proximal end (Find-Nr.: GT97-27; Fig. 24). The object, from an undocumented context, is 25.5cm long, with a maximum diameter of 3.0cm and an oval cross-section. Polished stone sceptres, some with carved animal heads, have been found at numerous PPN settlement sites in Southwest Asia, including Göbeklitepe. These objects are among very few items commonly thought of as symbols of power brandished by social elites (*Köksal-Schmidt, Schmidt 2007.99*). As such, this particular example, with its two incised H-shapes, is of unprecedented significance for the interpretation of this motif as a symbol that was potentially associated with inspired individuals and charismatic leaders.

Following the removal of sediment from Special Building D in 2021, one of two H-symbols incised into the floor of Special Building D was revealed easterly adjacent to a round pit-like feature (94.0x98.0cm) that was covered by a trapeze-shaped limestone slab, held in place by several stone wedges (one of basalt, one of flint and the rest of limestone). The northern edge of the feature showed the last remnants of red colouring, attesting to its significance, as already indicated by its central position in the special building (Figs. 7.8 and 25). The excavation of the feature in 2022 revealed an extremely shallow pit (max. length: 40.0cm, max. width: 21.0cm), not much deeper than the covering slab (5.0cm), though with a deeper, apparently natural cavity in its northern part into which fist-sized fragments of limestone rubble had been inserted. The sediment directly beneath the slab was an extremely loose silt void of finds (except for one small flint blade). Following the removal of this sediment, the cavity appeared as an area with a hardened and crumbly white deposit resembling plaster, and it is unclear whether this sealing had resulted from natural processes or was intentional. From a pragmatic standpoint, this feature appears to have been the repair of a natural fault encountered in the otherwise flawless limestone bedrock; however, the remnants of red pigment and the adjacent incised H-symbol could equally attest to a quite different (ritual) function.

Inspired individuals in the context of PPN social organisation models

Any discussion of the social fabric of PPN society at Göbeklitepe, and the place of inspired individuals and charismatic leaders therein, must first come to terms with what was originally considered to be the great paradox of the archaeology at the site, namely megalithic structures constructed by a hunter-forager community. At the time of the initial discovery of the special buildings in the mid-1990s, it was this ambiguity which sparked so much wonder, ultimately culminating in Schmidt's hypothesis that the ritual activities at Göbeklitepe were the *smoking gun* of Neolithisation (domestication of plants and animals) in Southeast Anatolia: "*A major driving force behind the process of plant and animal domestication may have been provided by the spiritual concept of these PPN people, in particular the investment of effort by generations of PPNA groups in the materialization of their complex immaterial world.*" […] "*For the construction of one of the megalithic enclosures several hundreds of people must have gathered for many weeks. Without doubt one can expect that these meetings were arranged as extended feastings. It seems inescapable that for non-food producing communities such meetings meant a big logistical problem. Could the need to feed many people for weeks be the reason for the invention of farming, especially of cereals, in order to provide a huge amount of food just in time?*" (*Schmidt 2011.53*).

Meanwhile, several models have been proposed with which we can approach the social fabric of PPN societies (some have already been mentioned above). These models are also consistent with the realisation of *construction projects* (special buildings) by a hunter-gatherer community. The first of these is the *transegalitarian feasting* model after Hayden (*2014*), which, despite the absence of sound archaeological evidence for large-scale feasting at Göbeklitepe and the oversimplified picture it paints of the processes involved (see

Fig. 23. Göbeklitepe. Selection of H-symbols adorning architectural elements in Special Building D. Top left: on the shaft (inward-facing narrow side) of Pillar 33 (P33); top right: incorporated into the belt of the eastern central pillar 18 (P18); bottom left: on the head (inward-facing narrow side) of Pillar 30 (P30); and bottom right: on a wall stone revealed in the southeastern part of the inward-facing enclosing wall in 2021 (Fig. 7.7). For pillar positions in Special Building D, see Fig 7 (photos L. Clare, German Archaeological Institute, Göbeklitepe Project).

my criticism above), still provides some tantalizing insights. Complex (transegalitarian) hunter-gatherers are described as non-egalitarian as they allow, under some circumstances, expressions of aggrandising behaviour by individuals. Aggrandisers use surplus resources to try to benefit themselves and create social hierarchies. Of all the schemes devised and widely used by aggrandisers, feasting is perhaps the most widespread and is a powerful means of attracting people and converting surpluses into other desired goods or relationships (*Hayden 2014.49*). However, the presence of aggrandizers ultimately leads to the emergence of competing factions (kin-based corporate groups) within communities, bringing with them new ideological concepts, such as private property, debt obligations and the importance of ancestors, leaving weaker parts of the community (*i.e.* less-wealthy and with weaker networks) open to abuse and violence, especially at the hands of despots (*O.c.50–52*). Indeed, the construction of the special buildings at Göbeklitepe would fit well with Hayden's model, especially if each special building were built by a competing faction within the community (*cf. Peters, Schmidt 2004.210; Flannery, Marcus 2012.130*). What speaks against this scenario is the apparent absence of archaeological evidence for warfare in the PPN (*Clare* et al. *2019b*) and, to a certain extent, the missing material evidence associated with more affluent parts of society, especially storage facilities.

Similar to Hayden, Jeunesse (*2020*) bases his *chief-led lineage* model on ethnographical observations of traditional societies. Focussing specifically on Göbeklitepe, he sees the construction of the special buildings occurring in a stratified community with hereditary chiefs from different descent groups whose prestige is probably linked to divine ancestry or proximity to the supernatural. Material expressions of this social fabric are architectural and intra-village variability, true megalithic architecture and sophisticated art, differences in the wealth of grave goods (*memorialising*), the production of precious (prestige) objects, and genealogical anchoring (*ancestor house model*) (*cf. Clare, Kinzel 2020.Fig. 7.1*). This model is reminiscent of the scenario proposed by Bar-Yosef (*2014*; see above) and again proves difficult to substantiate owing to the lack of corroborative archaeological evidence for *chiefs*.

Assigning the inspired individuals and charismatic leaders discussed in this contribution to any of the models presented here is problematic. Indeed, the presence of chiefdoms (*Jeunesse 2020*) at Göbeklitepe is far less convincing than the *transegalitarian feasting* model of Hayden (*2014*). However, for the reasons already stated, there remains some doubt as to whether Göbeklitepe was the settlement of a truly transegalitarian community comprised of contesting kin-based corporate groups. Certainly, some aspects of transegalitarian (complex) hunter-gatherers ring true for the archaeological record, *e.g.*, the community lived in an area with presumably high resource abundance, exhibited seasonal or full sedentism and group sizes were typically larger than those of *simple hunter-gatherers* (*cf. Hayden 2014*). On the other hand, there is no evidence of the private ownership of food resources, long-term storage facilities or private wealth items. Therefore, we could also expect behaviours that align with those of *simple hunter-gatherers*, *i.e.* where there is an egalitarian ethic concerning food resources. Indeed, Göbeklitepe might even mark the tipping point between the two constellations, *i.e.* from *simple hunter-gatherers* to transegalitarian (complex) hunter-gatherers.

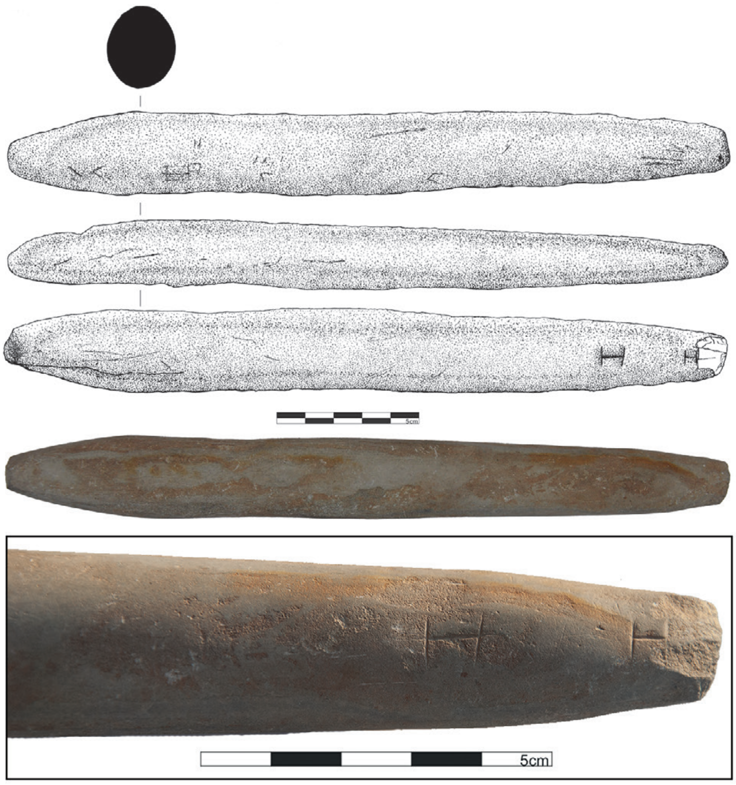

Fig. 24. Göbeklitepe. Sceptre (length: 25.5cm) with two incised H- shaped symbols at its proximal end (drawing and photos O. Torun, G. Kaynak, German Archaeological Institute, Göbeklitepe Project. Courtesy of O. Torun).

Of particular interest at this point is the *molar-molecular* hypothesis, recently formulated by Hodder (*2022*), where he uses these two terms to describe the ways by which egalitarian and hierarchical impulses were brought into play to combat inequalities in Neolithic society (*O.c.633*). Molar and moelcular refer to modalities of community participation, either with a highly complex and burdensome overlay of demands on the constituent individual units (*molar*) or as a mode of articulation allowing greater independence and autonomy of parts (*molecular*). In the frame of his *molar-molecular* hypothesis, Hodder suggests that Göbeklitepe is a candidate for an early molar mode gradually shifting into a more molecular version, as testified by "*the tension between the social differentiation that presumably lay behind the organizational feat to construct the circles* [special buildings] *and the evidence for multiple circles and their 'internal' layout (radially segmented benches)*" (*O.c.634*). Potentially, this shift could reflect the transition from *simple hunter-gatherers* to transegalitarian (complex) hunter-gatherers, with the inspired individuals and charismatic leaders as a further testimony to the molar and molecular impulses used to combat inequalities in this PPN community.

Inspired individuals and the hunter-gatherer crisis (HGC)

The emergence of archaeologically invisible decision-makers from the ranks of inspired and charismatic individuals, their changing role in society over time, and their fall from grace in the late ninth millennium cal BC can only be understood when considered in the context of broader socio-environmental processes spanning the Late Pleistocene and Early Holocene.

The first sedentary hunter-gatherer settlements in the upper Tigris and Euphrates basins appear in the Late Pleistocene (Younger Dryas) at sites on these two major rivers (Fig. 26). Especially in the course of salvage excavations in the frame of the Ilısu dam construction project, the number of excavations at earliest residential sites along the Tigris has increased. Additionally, archaeological surveys have led to the discovery of further localities with Epipalaeolithic assemblages in Şanlıurfa (*Şahin* et al. *2023*) and Mardin (*Kodaş* et al. *2022b*). It is posited that the roots of the non-institutionalised charismatic leaders might be sought in this period, perhaps as a reaction (conscious or unconscious) to increasingly settled lifeways and changing demographics. Ever-decreasing levels of direct contact between demographically expanding communities may have been exacerbated by pressures on locally available natural resources, leading to increased competition between groups, culminating in higher

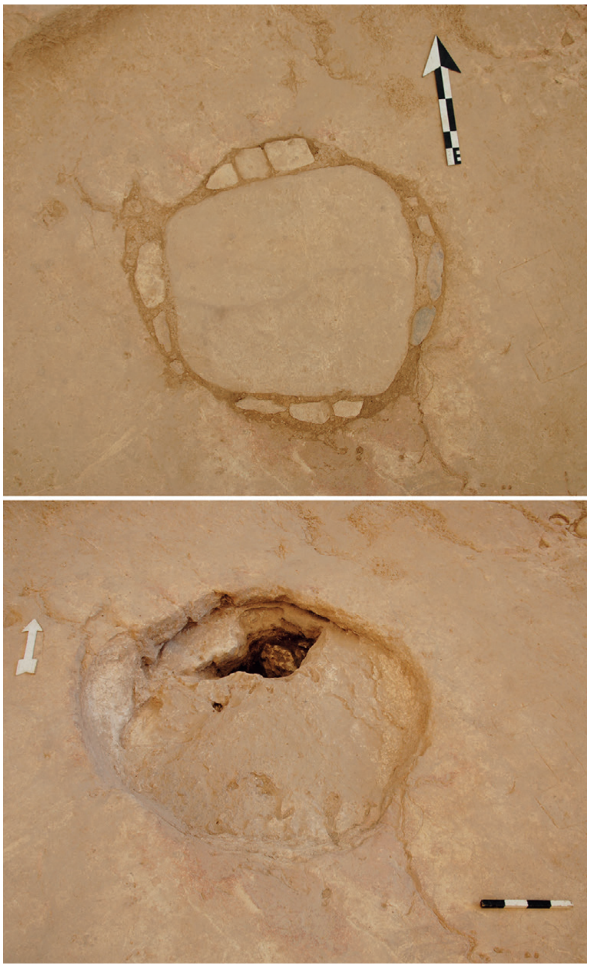

Fig. 25. Göbeklitepe. The pit-like feature in Special Building D (Fig. 7.8) before and during excavation. The H-shaped symbol engraved into the floor of the building is visible to the southeast of the feature (photos L. Clare, German Archaeological Institute, Göbeklitepe Project).

levels of territoriality and conflict potential. On the other hand, the comparative absence of inter-group conflict in the archaeological record testifies to the existence of some mitigating instances.

The continued increase in the number of sites in the PPNA testifies to the success of the late hunter-forager communities in dealing with the initial challenges of sedentary life and changing environmental conditions associated with Holocene climate amelioration (*Emra* et al. *2022*) (Fig. 27). However, in the centuries on either side of 9000 cal BC, the upper Euphrates and Tigris basins appear to have experienced a period of upheaval, a development that is reflected in the decrease of radiocarbon data from Late Pleistocene and Early Holocene sites (*Clare, Kinzel 2020.Fig. 7.1*). Already in the late PPNA, several long-lived permanent settlements had become abandoned (Körtik Tepe and Hallan Çemi on the Tigris; Abu Hureyra on the Euphrates), with the settlement focus shifting to a few central places (Çayönü Tepesi, Gusir Höyük, Boncuklu Tarla and Çemka Höyük on the Tigris; Sheikh Hasan, Jerf el Ahmar and Tell Qaramel on the Euphrates), some of which were already in state of decline (*cf. O.c. 62–63*). At the same time, the Şanlıurfa region witnesses a relative explosion of settlements, albeit that the majority of these sites are unexcavated and their assignment to the EPPNB is based on analogies with excavated sites such as Sayburç, Harbetsuvan Tepesi and Sefertepe (Fig. 28). Previously, I have referred to this period as the '*hunter-gatherer crisis*' (HGC) (*O.c.*).

Although the processes leading to the abandonment of sites along the Tigris and Euphrates in the late PPNA plausibly lie in the continued adaptation of communities to the challenges connected with increasing sedentism and changing demographics, a further causal factor could be rapid climate change (RCC). While the Holocene amelioration ushered in more favourable environmental conditions, with the gradual return of oak woodland to southeastern Anatolia following a stark reduction during the Younger Dryas and an expansion of local waterways (*Rössner* et al. *2018. Fig. 6*), this amelioration was by no means constant. The Holocene has been punctuated by a whole series of so-called Rapid Climate Change (RCC) intervals, some lasting several centuries (*Weninger* et al. *2014; Clare 2016.34–47; Weninger 2017; Budja 2023*). RCC intervals are associated with extreme winter conditions, linked to phases with prolonged and intense Siberian High pressure, as documented by higher concentrations of non-sea-salt potassium in Greenland ice (storminess over the North Atlantic, GISP2, *Mayewski* et al. *1997*), and a cooling in the Aegean Sea (infiltration of cold air masses into the Eastern Mediterranean), as inferred by changing ratios of deposited foraminifera species in marine sediments (LC21, *Rohling* et al. *2002*). Notably, a short RCC signal is visible in these proxies around 8800/8700 cal BC and also in a more recent speleothem record (LoNAP514) from a cave located in a tributary of the Tigris River in the Kurdistan Region of Iraq, where cooler and drier conditions appear to have prevailed at around this time (*Regattieri* et al. *2023*).

Notwithstanding the tentative evidence for a short-lived period of climate instability (RCC) at the PPNA-EPPNB transition, climate, environment and socio-cultural mechanisms are deeply intertwined and can never be thoroughly disentangled. Climate change can be

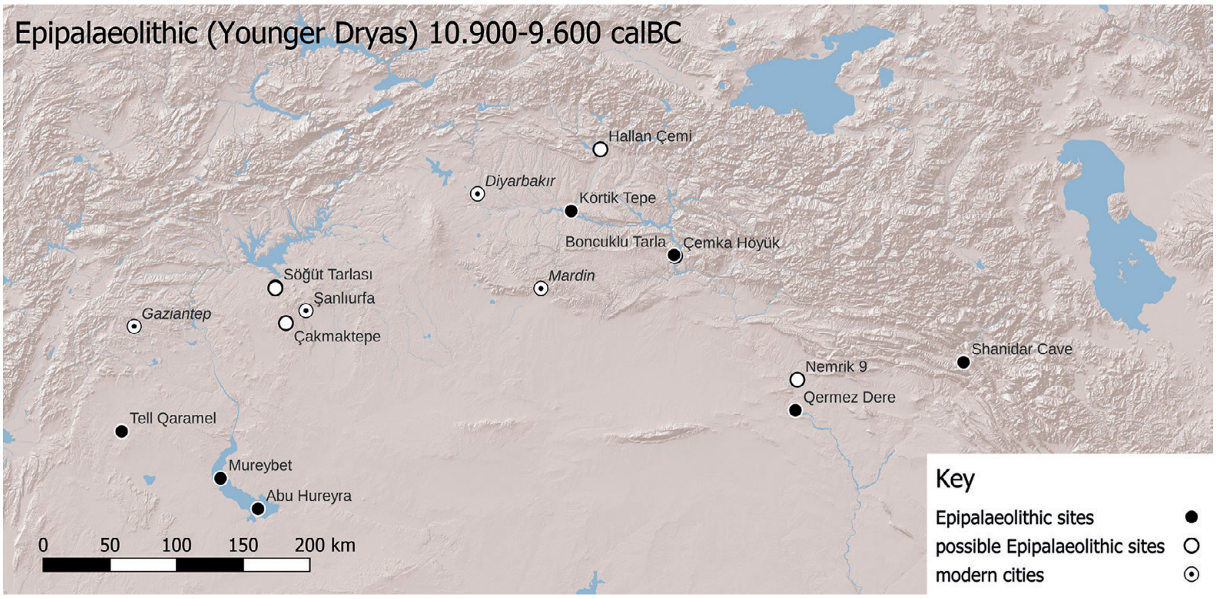

Fig. 26. Map showing Epipalaeolithic settlements in the upper Tigris and Euphrates basins. A small number of sites show continued occupation from the Younger Dryas into the Early Holocene (*cf. *Fig. 27) (image L. Clare, German Archaeological Institute, Göbeklitepe Project).

long and gradual or short and abrupt, and it can affect the environmental conditions of local geographies quite differently. The impacts of climate change on socioeconomic systems also varies according to the biophysical and social vulnerability of an affected society (*Clare, Weninger 2010*). In other words, the individuals and groups at higher risk are usually those already living risky lives in dangerous locations (*Clare 2016. 52–53*). In any case, any continued discussion of RCC impact during the HGC must be adjourned until additional (local) palaeoclimate data becomes available.

The mechanisms behind the apparent explosion in the number of settlements in the Şanlıurfa (Taş Tepeler) region in the first half of the ninth millennium cal BC (EPPNB) remain elusive. It is unclear whether the human influx resulted from migration from the nearby Tigris and Euphrates valleys (or elsewhere) or local population growth, or even a combination of these factors. A lack of well-preserved burials and human remains from the new Taş Tepeler sites also means it is too early to seek answers from genetic and stable isotope studies. Whatever the causes were, the increase in

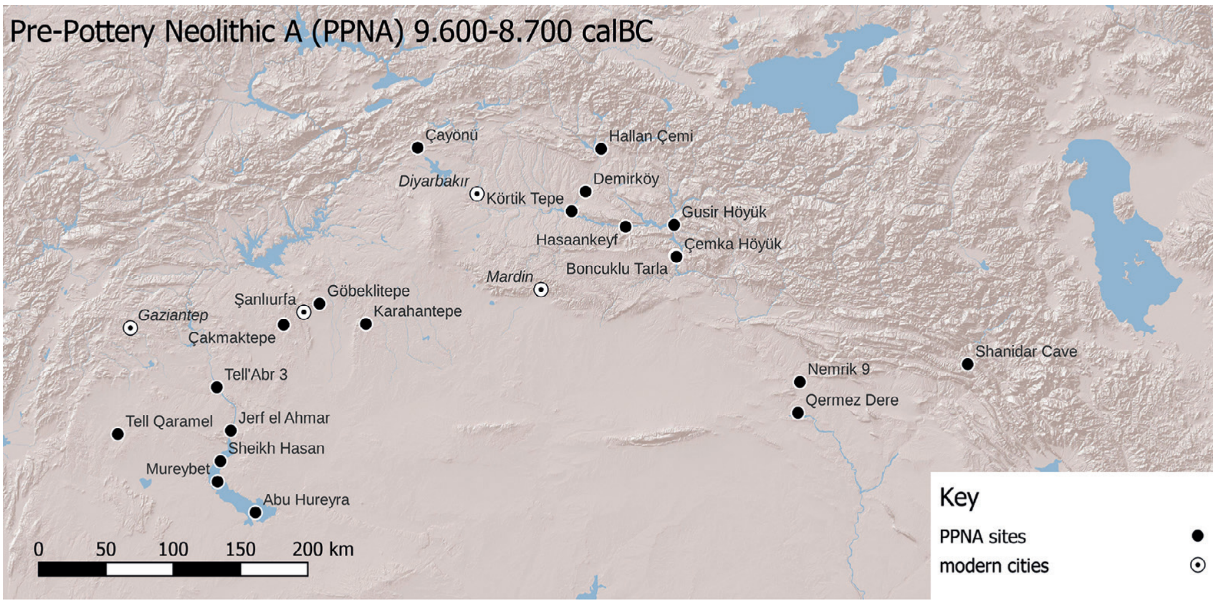

Fig. 27. Map showing Pre-Pottery Neolithic A (PPNA) settlements in the upper Tigris and Euphrates basins (image L. Clare, German Archaeological Institute, Göbeklitepe Project).

settlements around modern-day Şanlıurfa went hand in hand with the construction of the later phases of the special buildings at Göbeklitepe, when many of the monolithic T-shaped pillars and examples of large statuary were incorporated into these structures. However, it would be an oversight to interpret this explosion of creativity as an expression of Neolithic innovation. As already noted, morphologically domesticated plant and animal species are still unknown at the Taş Tepeler sites, except for Nevali Çori, suggesting that the late hunter-gatherer population at Göbeklitepe, and perhaps at other sites too, placed more value on deep-rooted Palaeolithic traditions instead. This hypothesis is in line with results from earlier studies, which have interpreted Göbeklitepe as the pinnacle of Palaeolithic culture rather than connected with the emergence of new ideas (*Goring-Morris, Belfer-Cohen 2002.73; Schmidt 2005.18; Clare, Kinzel 2020; Zimmermann 2020*).

Against this background, it is helpful to consider the different phases of the socio-cultural development of settled hunter-forager communities in the upper Tigris and Euphrates basins in the context of adaptive cycles (*Holling, Gunderson 2002; Redman, Kinzig 2003*) and boom-bust dynamics (*Tainter 1988*). In the absence of *big data* from this region, and as a simple alternative, the more readily available archaeological demographic proxies (radiocarbon data and settlement counts) can illustrate some basic trends. Certainly,

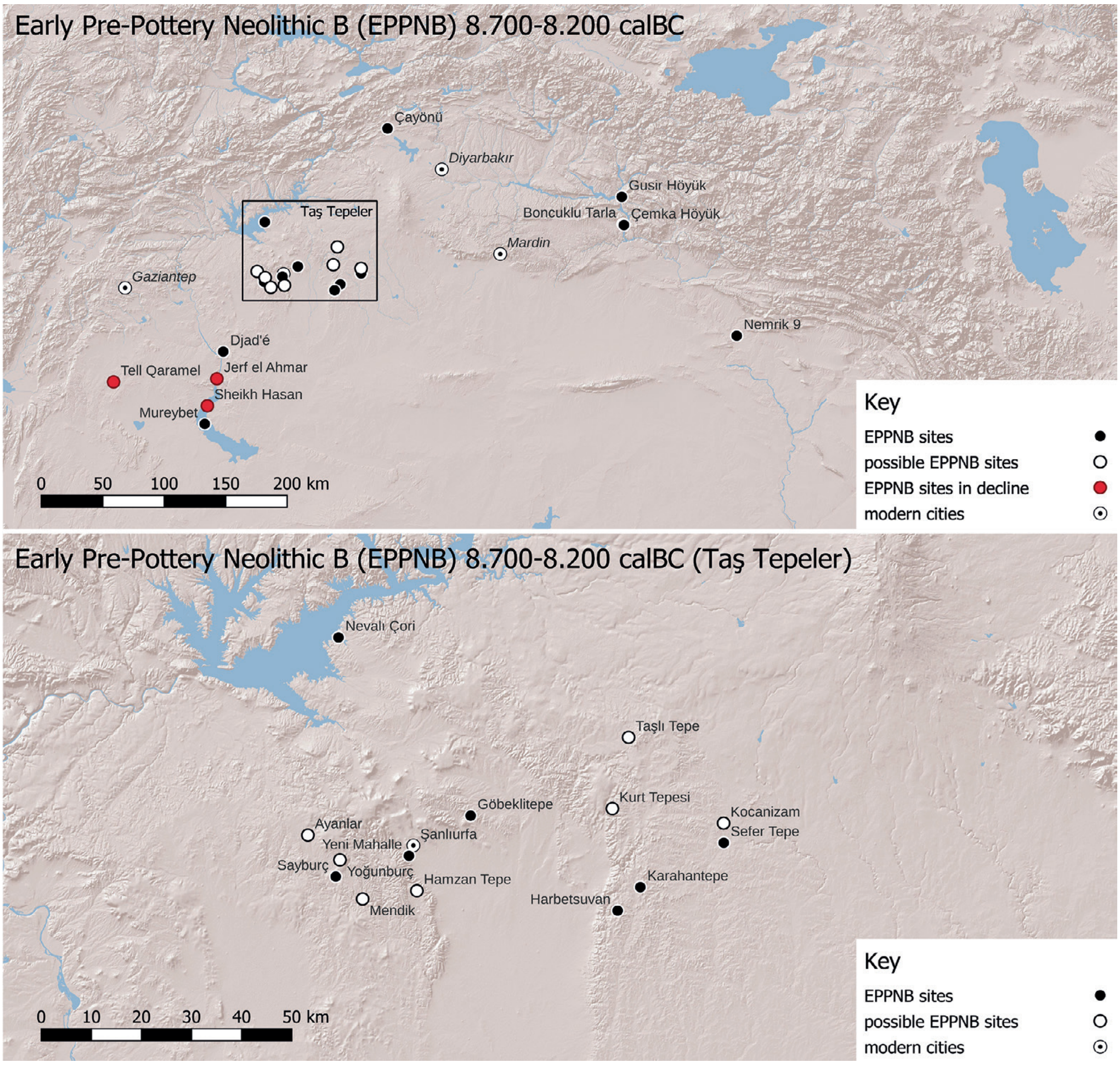

Fig. 28. Maps showing Early Pre-Pottery Neolithic B (EPPNB) settlements in the upper Tigris and Euphrates basins (top) and the Taş Tepeler region around Şanlıurfa (bottom) (images L. Clare, German Archaeological Institute, Göbeklitepe Project).

the realisation that regional population *boom and busts* have been detected elsewhere, especially in the context of Neolithisation, and that these have been pro ven to be influenced by underlying socio-environmental forcing factors, is encouraging (*Shennan* et al. *2013; Kondor* et al. *2023*). Therefore, it is proposed that the Epipalaeolithic (Younger Dryas) be equated with the reorganisation (a) phase of the adaptive cycle, the PPNA with the growth/interaction (r) phase, and the EPPNB with the rigidity (K) phase. Accordingly, the post-EPPNB period coincides with the cycle's release (Ω) phase (*cf. Redman, Kinzig 2003. Fig. 1*).

Whereas the reorganisation (a) phase (Epipalaeolithic/ Younger Dryas) is characterised by spatial dispersal, the establishment of new residential rules and the construction of new traditions, the growth/interaction (r) phase (PPNA) witnesses demographic expansion, emerging cultural homogeneity, and the distribution of surplus through new hierarchical systems and kinship groups. The subsequent rigidity (K) phase (EPPNB) is the period preceding the decline and is characterised by stagnation and specialisation, expressed in low vertical social mobility, culminating in social tensions (due to reduced access to resources) and with rigid references to traditions (*conservative values)*. Moreover, compared to the previous (r) phase it is associated with increasing regionalisation due to the gradual disbandment of cultural homogeneity.

Following this model, the inspired individuals and charismatic leaders could have emerged in the Younger Dryas (a -phase), gaining traction in the course of the PPNA (r-phase), and finally being entrusted with upholding conservative values in the EPPNB (K-phase). Their influence on society in the latter phase could be reflected in the *petrification* of orally transmitted myths and legends in the context of the monumental *narrative arenas* (special buildings). The rigid reference to tradition, characteristic of this phase, might even explain the absence of domesticated plants and animals at Göbeklitepe, at a time when first morphologically domesticated species might even be expected (Nevali Çori). In this context, special buildings and rituals were used to reinforce hunter-gatherer identities, whereby the differences observed in the motifs of some sites (*e.g.*, more animal depictions at Göbeklitepe and more human depictions at Karahantepe) could be linked to an increasing regionalisation characteristic of a pre-decline system. Remarkably, recent bioarchaeological analyses on human and animal bone from nearby Nevali Çori have suggested a decline in mobility at this site around this time, likely associated with a growing reliance on domesticates, a development that coincided with the site's increasing social detachment from Göbeklitepe and its underlying system of living and associated worldviews (*Wang* et al. *2023*).

Ultimately, the settled hunter-forager communities of the Early Holocene collapsed (Ω-phase). Although relatively little is known about the final settlement phase at Göbeklitepe, a few small circular structures superimposing EPPNB buildings have been found and documented (Fig. 29). These have so far failed to produce organic remains for absolute dating, meaning that, for the time being, only a post-EPPNB age can be proposed. The inundation of the special buildings (A-D) in the southeastern part of the site by slope slides was perhaps not the end of the occupation sequence; nevertheless, it marked a crucial turning point, ultimately leading to the abandonment of the settlement and the disappearance of its invisible elite.

Fig. 29. Göbeklitepe. The remains (northeastern quarter) of a small circular-oval structure (diameter: ~1.80m) excavated on the western slope of the southeastern hollow (main excavation area; trench L09-58) in 2022. This structure superimposes (*i.e.* post-dates) the EPPNB architecture at this location; as such, it is among the last known prehistoric structures ever constructed at the site (image L. Clare, German Archaeological Institute, Göbeklitepe Project, June 2022).

Summary

This contribution has discussed the evidence for archaeologically invisible decision-makers in the late Pleistocene and Early Holocene communities in the upper Tigris and Euphrates basins. Despite many decades of excavations at an ever-growing number of sites, evidence of social elites is not forthcoming. Of course, an absence of evidence is not evidence of absence, and one potential explanation for the lack of archaeology associated with such individuals over some two millennia of settlement history could lie in the nature of the leadership system itself. Following a proposal by Cauvin (*2007.120*), leadership could have been realised by *inspired individuals* who, through their skills, experience and charisma, advanced to become influential in their respective communities. It is proposed that these individuals emerged from particular social groups, including storytellers, hunters and ritual adepts (shamans). However, their leadership roles never became institutionalised, most likely due to power-curbing mechanisms inherent to the deep-rooted egalitarian hunter-forager social systems founded on animism and ancestor veneration.

The discussions around inspired individuals and charismatic leaders have also touched on some broader topics relating to late hunter-gatherer communities and highlighted the roles of archaeologically invisible leaders in historical processes during a proposed adaptive cycle spanning the late Pleistocene and Early Holocene. It is proposed that the inspired individuals and charismatic leaders considered above were a product of the unprecedented demographic changes linked to increasingly settled lifeways in the tenth and ninth millennia cal BC. This leadership system, the roots of which were securely anchored in the Palaeolithic past, needed to adapt to the challenges faced by growing settled hunter-forager communities in a core zone of Neolithic genesis while at the same time preserving older traditions (at least in appearance). They were part of a mechanism which sought to combat inequalities in Neolithic society, as expressed by concerted attempts to reinforce *simple hunter-gatherer* beliefs and worldviews. This period, roughly at the transition from the late PPNA to EPPNB (*c.* first half of the ninth millennium cal BC), has been termed the *hunter-gatherer crisis*. The subsequent disappearance (in the late ninth millennium cal BC) from the prehistoric stage of the motifs, symbolism, monumental structures and narratives which defined the identities of the leaders and their respective communities coincided with the widespread acceptance of domesticated plants and animals. It is hoped that the hunter-gatherer crisis will be a focus of future research in the frame of the expanding Taş Tepeler project.

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Sayburç a mid-9th millennium BC site in the foothills of the Eastern Taurus

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ABSTRACT - *A Pre-Pottery Neolithic site at Sayburç is currently being studied as part of the Şanlıurfa Neolithic Research Project – Taş Tepler (Türkiye), which is focused on the Neolithic Period at the Şanlıurfa Plateau. The settlement belongs to the early sedentary societies on the plateau, characterized by monumental buildings, T-shaped pillars, and rich symbolic elements that distinguish the region from its contemporaries in Southwest Asia. A growing body of evidence indicates that rituals and the associated symbolism and narratives play a pivotal role in the formation of the region's early sedentary societies. The construction of special buildings in Sayburç, situated close to dwellings and accompanied by associated symbolism, illustrates the intertwining of the sacred with everyday life. This paper presents the preliminary results of the first three years of research on the site and discusses the cultural dimension of the region itself.*

KEY WORDS – *Early PPNB; Eastern Taurus; Neolithic architecture; special buildings; Sayburç reliefs*

Sayburç, najdišče iz sredine 9. tisočletja pr. n. št. ob vznožju Vzhodnega Taurusa

IZVLEČEK – *Najdišče iz predkeramičnega neolitika v Sayburçu raziskujemo v okviru neolitskega raziskovalnega projekta Şanlıurfa – Taş Tepler (Turčija), ki je osredotočen na obdobje neolitika na planoti Şanlıurfa. Naselbina pripada zgodnji sedentarni skupnosti z značilnimi monumentalnimi zgradbami, stebri v obliki črke T in bogato simboliko, ki jih ločuje od sočasnih skupnosti v jugozahodni Aziji. Vse več je dokazov, da so obredi in z njimi povezana simbolika ter pripovedi ključni pri oblikovanju zgodnjih sedentarnih družb v regiji. Gradnja posebnih zgradb v Sayburçu, ki so umeščene v bližino hiš in so povezane s simboliko, kaže na prepletanje svetega in vsakdanjega življenja. V prispevku predstavljamo preliminarne rezultate prvih treh let raziskav in razpravljamo o kulturni razsežnosti regije.*

KLJUČNE BESEDE – *zgodnji predkeramični neolitik B; Vzhodni Taurus; neolitska arhitektura; posebne zgradbe; reliefi iz Sayburça*

Introduction

The early Neolithic settlements in the Euphrates and Tigris Valleys, particularly in the region considered the transition between the Eastern Taurus Mountains and the Mesopotamian plains, appeared rather suddenly as early as in the mid-10th millennium BC. These include Körtik Tepe (*Benz* et al. *2015*), Boncuklu Tarla (*Kodaş 2023*) and Çemka (*Kodaş* et al. *2022*) in the Tigris Valley, and Söğüt Tarlası-Biris Mezarlığı (*Özdoğan M. 1995*) in the Euphrates Valley, which have been dated to the late Pleistocene. However, none of these sites recorded a longstanding Epi-Palaeolithic tradition developed by mobile hunter-gatherers. Consequently,

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data on the Upper Palaeolithic are also lacking, and the origins of sedentism in the northern frontier remain unknown. The Neolithic in the foothills of the Eastern Taurus shared many similarities with that in most of Southwest Asia, and technological developments as well as the transition to food production can be observed as simultaneous developments over a wide area.

The construction of dams and reservoirs on the Euphrates and Tigris Rivers has facilitated the study of the valleys within Turkey's borders (*Rosenberg, Erim-Özdoğan 2011; Hauptman 2011; Özdoğan M. 2017; Özdoğan E., Karul 2020*; see also *Özdoğan M.* et al. *2011a; 2011b*). However, the plateaus and plains between the two river valleys and the plains extending into Mesopotamia remain poorly studied regarding the prehistoric periods. The Şanlıurfa Plateau, the subject of recent research, offers invaluable insights into Neolithic societies beyond the river valleys (*Çelik, Tolon 2018; Şahin* et al. *2023*). In particular, the archaeological studies at Göbeklitepe, which began in 1995 (*Schmidt 2006*), have yielded significant insights into the characteristics of the early settlements on the plateau. A review of the archaeological evidence from the sites on the plateau reveals a striking continuity in the existing settlement density, extending from the mid-10th millennium BC to the end of the 8th millennium BC. Notably, none of the currently excavated or surveyed settlements on the plateau have yielded evidence of occupation during the Pottery Neolithic period. This indicates that the hilltop settlements on the plateau were abandoned before the production of pottery and perhaps before agriculture and animal domestication became the primary economic activities. It is also important to note that none of these settlements have yet yielded any data reflecting the transition between the two periods. The settlements where the transition phase is located in the Euphrates Valley include Mezraa Teleliat (*Özdoğan M. 2011*) and Akarçay Tepe (*Özbaşaran, Duru 2011*), while those situated on the passage to the plains environment include Gürcütepe (*Erdalkıran* et al. *2023*). Consequently, it can be postulated that the evidence for food production in plateau settlements may be less robust than in other areas. However, the lack of comprehensive research on the plains may result in overlooking any settled societies that may have commenced during the Pre-Pottery Neolithic.

The research conducted on the Şanlıurfa Plateau has yielded insights into the social dimensions of Neolithic societies in Southwest Asia (Fig. 1). The daily lives of these societies were intricately intertwined with rituals, narratives, and associated symbolism. The area in question is notable for its exceptional density of monumental structures and strong symbolic elements that were important to Neolithic communities (*Schmidt 2006; 2010; Karul 2022; Karul* et al. *2023*). From the beginning of sedentary life, these features demonstrate the significance of spaces that facilitate the formation of bonds and the symbolic representation of social values and traditions. Many studies have indicated that symbols, rituals, and beliefs played a significant role in the adaptation of Neolithic societies to complex social environments during the transition to sedentary life (*Rollefson 2000; Verhoeven 2002; Schmidt 2005; Peters, Schmidt 2004; Kuijt 2008; Whitehouse, Hodder 2010; Hodder, Pels 2010; Hodder, Meskell 2011; Finlayson* et al. *2011; Dietrich* et al. *2012; Benz, Bauer 2013; Watkins 2015; Benz 2017; Dietrich* et al. *2017; Benz, Sütterlin 2017; Özdoğan M. 2018; Makarewicz, Finlayson 2018; Becker* et al. *2019; Clare* et al. *2019; Karul 2021*). Nevertheless, it is worth emphasizing the challenge of understanding the worldview of prehistoric societies and the factors that sustained social cohesion. While the presence of tangible evidence of the social aspects of these societies is not always evident, the settlements on the Şanlıurfa Plateau offer a convenient vantage point for analysing Neolithic societies in this regard. In this context, it has the potential to facilitate a comprehensive understand-

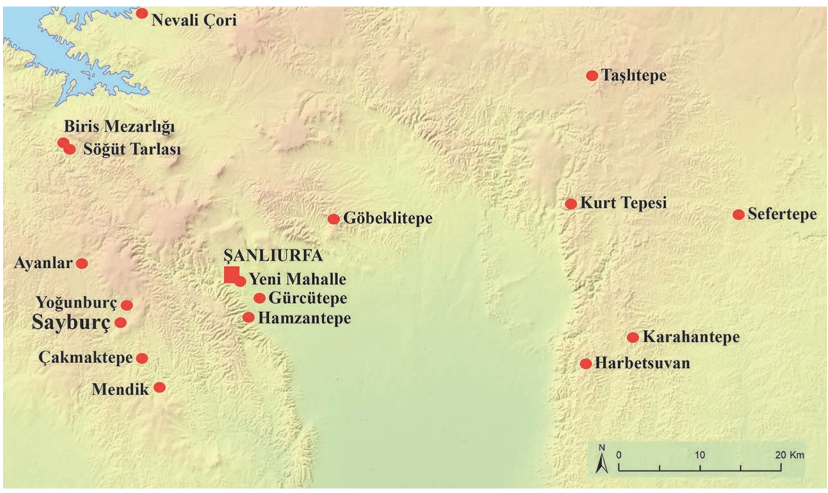

Fig. 1. Early Neolithic settlements on the Şanlıurfa plateau.

ing of the various dynamics involved in the emergence of Neolithic life.

The discovery of a special building and the exposed reliefs prompted immediate research at a Pre-Pottery Neolithic site in Sayburç in 2021 (*Özdoğan E., Uludağ 2022*). The reliefs discovered at Sayburç are notable for their clear descriptive scenes, which provide a distinctive context (*Özdoğan E. 2022*). The analysis of symbolic elements in artistic productions allows for an objective understanding of the basic worldviews and ideologies that unite society. Although smaller than Göbeklitepe or Karahantepe (*Karul 2022*), Sayburç has demonstrated the diversity of contemporary sites in terms of size and composition.

The site displays a horizontally oriented mound formation that is characteristic of numerous other sites in the region. Two nearby areas have been identified, and concurrent studies are being conducted in both to ascertain whether functional differences or chronological processes are the primary factors in the development of horizontal settlements. The data from the excavations has permitted a study of the mid-9th millennium BC on the plateau from various perspectives, including architectural development, space use, and daily life. The research conducted at Sayburç has the potential to provide valuable insights into several key fields, including animal domestication, plant cultivation, technological and architectural advances, as well as social changes in sedentary cultures within the plateau. The available data indicates the significance of symbols, rituals, and narratives in this transformation process.

This paper presents and evaluates the work carried out at Sayburç over the past three years. The site's chronological position and the main architectural elements are introduced within the context of the settlement's general characteristics. Furthermore, the discussion will encompass special buildings and ideas about associated symbolism that are still in their incipient stages of development.

The site

Sayburç is situated on the southern foothills of the Eastern Taurus Mountains, 20km southeast of the Şanlıurfa city centre on the Şanlıurfa Plateau (*Özdoğan E., Uludağ 2022; 2024; Özdoğan E.* et al. *2023*). The Neolithic settlement was constructed on two limestone hills, which were connected by a high ridge. One hill was situated to the north, while the other was located to the south (Fig. 2).

The total area of the Neolithic settlement is estimated to be approximately 3000 square metres. The northern hill is densely populated by local villagers, and the excavations were conducted to the southwest of this area. The northern half of a circular subterranean structure was excavated beneath a modern concrete building (Fig. 3). The structure (Str. AA) has a width of approximately 14 metres and was cut into the bedrock. The fill of the building was damaged by modern activities and mixed with Roman finds. Nevertheless, the presence of blade-based technology and projectile points suggests a date within the PPNB period. The oval AA structure was carved into bedrock, with only a small portion of the walls remaining, possibly as a freestanding structure. On the interior of the wall is a bench constructed from bedrock that runs parallel to the wall. The presence of cavities on the bench indicates that there were pillars on it. The bedrock floor of the structure has been meticulously smoothed and levelled. The inner face of the bench on the north side is decorated with five figures, which extend across an area measuring approximately 70–90cm in height and 370cm in length (*Özdoğan E. 2022*).

A second structure, designated Str. AB was located to the east of the special building and exhibited considerable damage. The construction of Str. AB was undertaken directly on the bedrock surface. Due to the inclination of the hillside, the structure has sustained significant damage. The remains include a circular

Fig. 2. View of the village of Sayburç and the archaeological sites from the south.

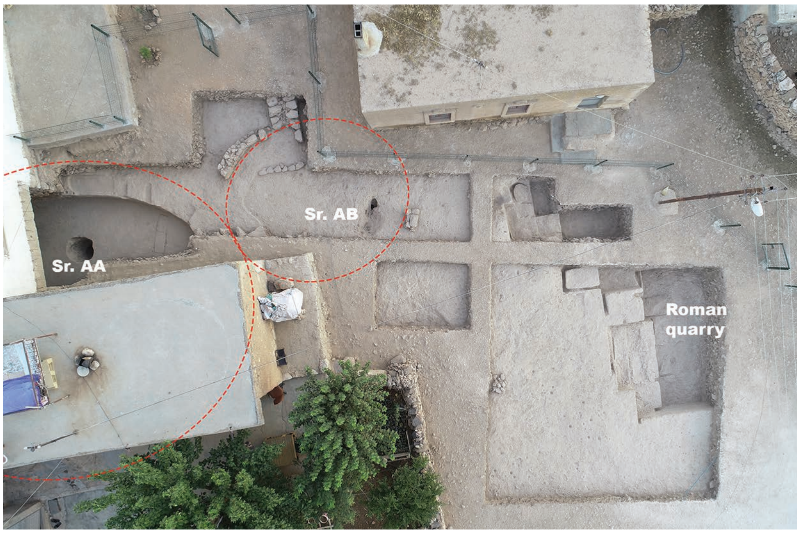

Fig. 3. The northern part of the excavation area consists of structures built on the bedrock and of Roman quarries.

wall and a bench constructed in front of the wall of the building. The eastern and southeastern parts of the area, where the fill is only 20–30cm deep, were utilized as a quarry during the Roman period.

The second and third excavation areas are located on the southern hill (Fig. 4). The concentration of modern occupation in the southern hill is limited to the foot of the hill. The settlement pattern throughout the area follows an agglomerative model, whereby the settlement expands by way of adjacency. The buildings are constructed on bedrock and add to each other, resulting in a lack of standardization in size and layout. Nevertheless, it is possible to distinguish buildings with a rounded or oval plan or a roughly quadrangular plan. The site contains buildings with straight walls on one side and an oval or rounded plan on the opposite side, which is similar to an apsidal plan. Currently, there are no discernible gaps or open spaces. Nevertheless, the multiple walls allowed gaps to form between the roofs of the buildings, which served to circulate within the settlement.

Datings

In contrast to the larger settlements in the vicinity, Sayburç does not exhibit vertical stratification, suggesting that it was inhabited for a single period. Radiocarbon dating indicates that the period of occupation spans approximately 300 years. The temporal relationship between the structures in the southern and northern areas remains uncertain. Nevertheless, 11 radiocarbon dates were obtained from above the floors of the structures in the south (Fig. 5). All of the dates are consistent with one another and indicate a date in the middle of the 9th millennium BC. These dates correspond with the early PPNB period and are consistent with the assemblage of chipped stones and architectural features found at the site. The consistency of the architecture and, in particular, the chipped stone technology between the northern and southern areas indicate that there would be no significant temporal discrepancy between the two parts of the settlement.

Structural features of the architecture

The relatively well-constructed corners indicate that the inhabitants had experience in the construction of corners and the robust masonry (Fig. 6). The walls were constructed directly on bedrock and subsequent-

Fig. 4. Excavations at two locations on the southern hill revealed that the same architectural pattern was consistently present throughout the entire area.

ly elevated with a mortared stone wall until they reached the level at which the roofing commenced. In certain instances, the structures display the presence of double rows of walls in addition to shared walls. The walls are remarkably well-preserved, exhibiting overlapping stone masonry in the upper parts, which can also be observed in some fallen debris. This indicates that the drop joints of the walls were slightly extended inward on the upper portion. A system was likely installed between the roof and the wall to prevent water infiltration and facilitate drainage.

The primary construction material utilized was limestone, a prevalent geological formation in the region. The stone was meticulously selected from medium-sized flat stones or irregularly from large or small stones. In addition to stone, adobe mortar was also employed. The structures feature buttresses, which were constructed on both curved and rectilinear walls. In some instances, the buttresses were constructed in conjunction with the walls, while in others they were subsequently added to the bare walls. As they do not extend into the interior of the structure, they do not create divisions within the interior space. Nevertheless, the incorporation of buttresses did result in the formation of some niches. During the excavation, a layer of earth was identified at the surface of certain walls. It was observed that in certain cases, the soil layer was covered with a layer of high-quality clay or lime plaster, which was sometimes as thick as 1.5 to 2cm.

To date, only one building has been fully excavated (Fig. 7). The floor was constructed by levelling the surface of the limestone bedrock on which the settlement was built. The floor surface was meticulously smoothed, and the sides, which constituted the foundation for

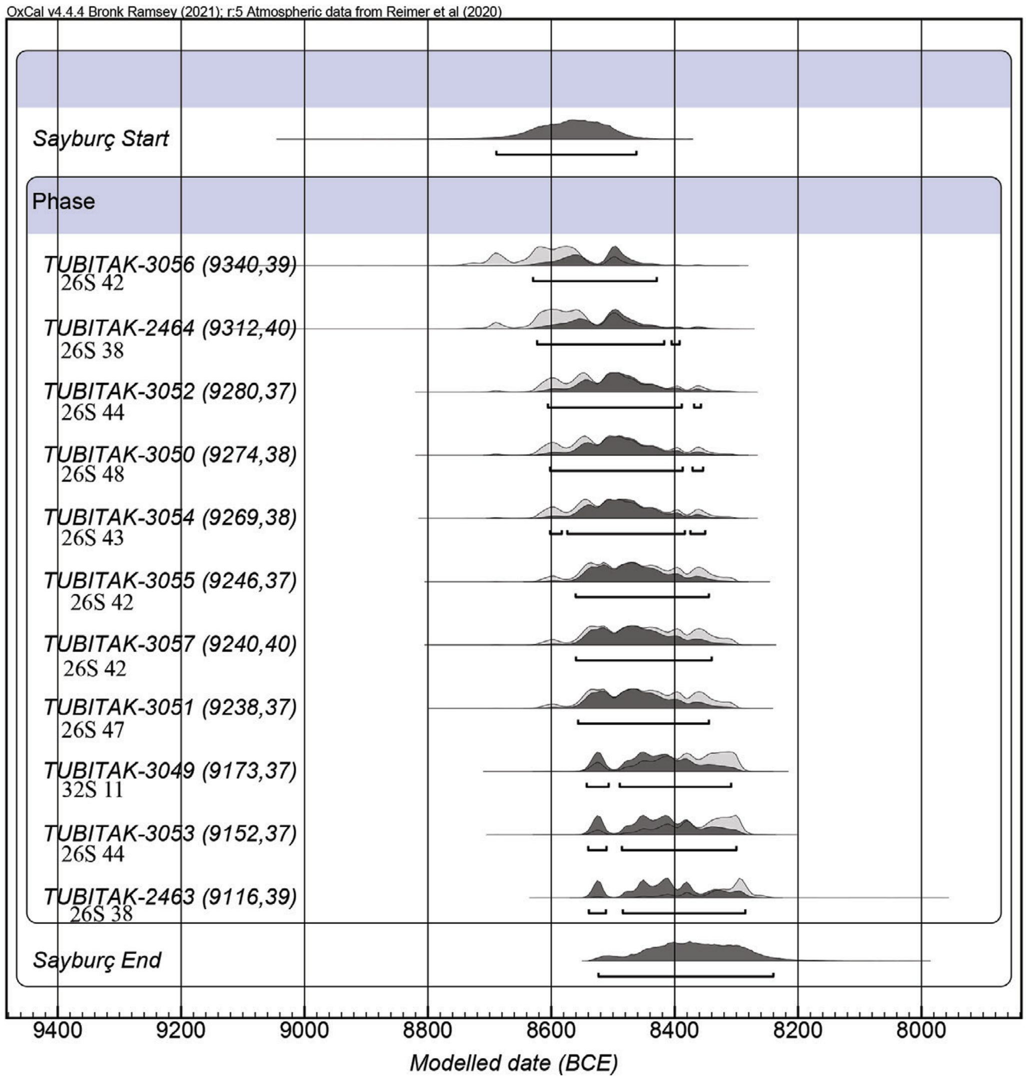

Fig. 5. The radiocarbon dates were obtained from the charcoal remains found above the floors of the buildings (prepared by E. Altınışık).

Fig. 6. The structures in Sayburç were constructed in an adjacent manner through the addition of one upon the other.

the walls, were constructed with rounded curves extending from the floor. The eastern section of the floor was coated with lime plaster, as it is assumed that the natural roughness of the bedrock was filled with plaster, which made it flat and smooth. Furthermore, clay and terrazzo floors were discovered in Sayburç. The majority of the clay floors were observed in elevated areas, which may be considered analogous to benches. The surface finish is hard and smooth. Moreover, terrazzo floors were identified within the fill of the buildings. One of the discovered floor pieces measuring approximately 1.80 x 0.75m, was found among the debris inside the building and fell from west to east.

The interior arrangement of the dwellings

The dwellings have been identified by their dimensions, building elements, and artefacts. The practice of utilizing anthropomorphic T-pillars and stone benches, designated as special buildings, was also observed in dwellings. Although the buildings are modest in scale, the presence of work areas, niches, benches, and a hearth indicates the functional and conceptual existence of the home (Fig. 8).

Fig. 7. The excavation of a single dwelling at Sayburç has been fully completed.

Due to the limited number of completely excavated dwellings at Sayburç, some building elements are only known from a single example, including hearths. In the Str. BB, a hearth was constructed at the northern end of the eastern wall in the form of a niche opening into the wall. The hearth features a domed structure and narrows upwards (Fig. 9). A potential chimney also opens into the wall, although this section has not been preserved due to destruction.

The majority of niches are located within the shorter walls of the building. In certain instances, the wall of a building may recede outward in the area where the niche is situated, creating a recessed space. In another structure, the construction of niches was facilitated by the addition of buttresses, which provided support and stability to the wall. In one case, two pillars were positioned near the wall to create a niche (Fig. 10).

Two distinct types of benches were identified within the structures. The first type of bench is the clay-plastered bench, which was discovered in buildings that have not yet been fully excavated. These benches were likely constructed by plastering clay on a stone-built platform next to the wall. However, due to the incomplete nature of the excavation the specific features

Fig. 8. A T-shaped pillar with human features was placed in the centre of the building, which has a bench, a niche, and a hearth adjacent to the wall.

of these benches remain uncertain. The benches are elevated to a degree that is significantly above the expected floor level. The second type of bench was formed by carving bedrock. One particularly illustrative example that was discovered in Str. Building BB is a completely excavated structure. The floor of the structure is carved into the bedrock. During the process of carving the floor, a bench was formed in the west, in front of the east wall, running parallel to it. The bench was extended in front of the north wall, forming an L-shaped structure that was limited by a buttress. To the east of this structure, another bench of a similar nature is situated at a slightly elevated level.

A number of domestic structures feature pillars that are approximately two metres in height. It is challenging to establish a standard in terms of size and shape, as the parameters appear to be variable. Some of the pillars exhibit decorations, including an arm and a V on the collar, which may be interpreted as symbols of human beings. Two examples of pillars with fingers, a belt, and a pelt hanging from underneath have been discovered. In addition, undecorated pillars were also discovered at the site. T-shaped pillars have only been identified in a limited number of buildings. It is crucial to acknowledge here that the majority of the structures have yet to be fully excavated, and therefore it is possible that additional fallen pillars may be discovered on the floors during further excavation. The number and position of these elements are not uniform. In the fully excavated building, Str. BB, the pillar, which exhibits discernible human characteristics, is situated in the centre of the room. Furthermore, pillars were discovered in the centre of other buildings. Moreover, two pillars were situated in close proximity to one another and aligned with the wall, thereby creating a recess at the narrow end of an oval-shaped structure. In another building, which appears to be a special building in the southern area, the pillars were placed along the wall with a central pillar in the middle. As the building has not yet been fully excavated, the pillars serve to distinguish it from the other dwellings in the area. To date, only one hearth has been excavated on the site, located in Str. BB, which – as noted above, is the only building that has been completely excavated thus far. The hearth is of a domed construction and is situated within the eastern wall. The hearth's floor is constructed from bedrock and is situated approximately 10cm above the floor level. The upper portion of the

Fig. 9. The domed hearth, situated within the wall of the building, has been destroyed from above, although the portion adjacent to the vent is discernible.

Fig. 10. T-shaped pillars are found both in special buildings and dwellings.

chimney, where the hearth's domed walls narrowed, is absent due to damage to the wall. In the same building, the concentration of finds associated with food preparation, such as grinding stones and pestles, is observed in the northern section. A single grinding stone was discovered on the bench to the west, while two additional grinding stones were located on the floor close to it. In addition, grinding stones were placed on a low bench deposited in front of the eastern wall.

The special buildings

In Sayburç, a discernible differentiation between special buildings and dwellings is not readily apparent. The special buildings are distinguished from the others by several characteristics, including their relatively larger size, the number of pillars incorporated into their design, the presence of double-tiered benches or the inclusion of artistic elements. The initial discovery of a special building at Sayburç was made in the northern area. This building, which has been partially excavated, contains reliefs. Upon the initial discovery of this special building, excavations in the southern area were just beginning, and all the structures were presumed to be dwellings. Consequently, it was postulated that a specific area of the settlement at Sayburç, analogous to those observed at Çayönü (*Özdoğan M., Özdoğan A. 1990*) and Nevali Çori (*Hauptmann 1993*), was designated for special structures. However, as the excavations in the southern area progressed, it became evident that special buildings were present in this area as well. It was observed that they were constructed in an intertwined pattern with dwellings. This is not unexpected, given that a comparable phenomenon was observed at Göbeklitepe (*Clare 2020*) and Karahantepe (*Karul* et al. *2023*). The special building in the north, with a maximum width of 14 metres, is larger than the dwellings excavated thus far. The bench, which extends along the wall on which the pillars were placed, and the reliefs on the bench, provide clear evidence that the building was a special structure. Consequently, it exemplifies the characteristics of special buildings in the region.

As noted above, the building is of a larger scale than that of the other structures in the vicinity. The floor was carved into the limestone bedrock, with a depth of 80 to 90 centimetres in the west and 50 to 60 centimetres in the east. The bench, which encircles the wall, appears to be divided by the pillars. The reliefs on the bench façade facing the space, the bench's non-standardized height, and the upper surface's arrangements indicate that the bench was not intended for sitting or standing. Rather, it served as an installation that enhanced the building's overall aesthetic appeal. The absence of *in situ* fill makes it challenging to comprehend the interior design and utilization of the space. Nonetheless, it is anticipated that the results of further excavations in the remaining portions of the structure will provide a more comprehensive insight into the matter.

The reliefs on display exemplify a technical and narrative style that is characteristic of Neolithic art in the region (Fig. 11). Except for a single figure in high relief, the remaining figures are incised. The figures are presented in a linear sequence, from left to right. Nevertheless, two scenes can be differentiated by the figures' postures. The initial scene on the left depicts a bull and a male figure facing each other. To the right of the scene are three figures: two leopards and a male. The male figure situated in the centre of the composition is depicted in high relief. The other figures are gazing at each other, but the male figure in the centre is looking at the room, at the people gathered here. The surface of the bench, oriented towards the wall, including the reliefs, exhibits a coarser texture than the floor, which is marked by the presence of construction traces.

Fig. 11. The Sayburç reliefs are two side-by-side scenes with five figures arranged horizontally (photo B. Köşker).

Upon focusing on the depictions within this structure, several important characteristics emerge. Firstly, the figures depicted are leopards and bulls, two species that are commonly represented in Early Neolithic iconography of the region. Secondly, the depictions place a significant emphasis on the dangerous limbs of these wild species. Thirdly, all the depicted figures, which are identifiable as male, are shown with phallic symbols. Finally, all the figures are depicted in motion. The animals are depicted in an aggressive posture, while the human figure on the left is shown crouching in a nearly dance-like pose. The seated human figure in high relief is depicted holding his phallus (Fig. 12). The figures are situated in a moment of an event that may be interpreted as recounting a story or myth, which distinguishes the piece from its contemporaries. The reliefs are composed of two scenes, which flow from left to right in a horizontal sequence. The horizontally flowing scenes represent a notable departure from the typical depiction of figures on T-shaped pillars, composite statues, and human figures carrying animals on their backs in a vertical perspective.

The composition includes two male figures, both of whom display ithyphallic features, but have different expressions as they are placed in the centre of different scenes. The male figure on the right is depicted in high relief, from the facing side, in a realistic style. On either side of the figure are two leopards oriented towards him. The leopard on the left is also depicted with an erect phallus. The other male human figure is shown in a roughly drawn side view. The line extending from the abdomen represents an erect phallus. The bull, which also has an erect phallus, stands on the opposite side of it. Although the bull is shown from the side, its head is carved in such a way that both horns are visible from above.

The two scenes are distinct and deliberately placed side by side, as evidenced by the blank sidewalls. Nevertheless, the significance of these scenes remains opaque. The narrative presents a harmonious relationship between humans and animals. The plot of this narrative can be interpreted from a variety of perspectives, including a before-and-after analysis or as a series of interrelated scenes. The Sayburç reliefs represent the most comprehensive and revealing visual representations made by Early Neolithic people in the region.

In the southern area, at least three special buildings remain among the dwellings. The structures in question were only partially excavated. In an oval struc-

Fig. 12. The most striking figure is the seated male figure, which is distinguished from the others by its high-relief technique and the direction of its view.

ture designated as Str. CB excavated 80cm from the top, and seven T-shaped pillars were placed in front of the walls, probably on a bench running parallel to the wall (Fig. 13). A central T-pillar was also placed in the middle. In the adjacent Str. CD, the same features were discovered, but only in a limited area. The third structure is located to the south. Str. DA is once again encircled by dwellings. The structure features a double-step bench in front of the wall and at least one central T-shaped pillar lying on the floor, which has been destroyed. Given that this building was also partially excavated, our understanding of it remains incomplete. Some of the structures can be identified as special buildings based on their size and plan. Further excavation is necessary to provide clear definitions.

The burials

Three clusters of human remains have thus far been recovered in the southern region within the domestic structures. All of the recovered human bones are secondary burials, and the bones exhibit signs of burning. It can be reasonably assumed that selected bones, particularly long bones and skull fragments, were placed within the structures. The initial cluster was excavated from the walls of the building, located just beneath the surface fill and partially buried within it. The second cluster is a secondary burial of six individuals. The bones were subjected to severe burning, and the skull and long bones were reburied in a niche. The structure with the burials in the niche is likely a dwelling. The niche is situated near the point at which the west wall of the structure makes a turn towards the south. As the structure was only excavated to a depth of 75cm, no information is available regarding the context of the building. Nevertheless, it is evident that following the placement of the bones within the niche, the front face was subsequently plastered. The most recently discovered cluster of burned bones were found on the northern side of a dwelling, with only the western half of which was excavated (Fig. 14). They were scattered on the bedrock bench and the floor in front of it. As the building has not yet been fully unearthed, it is difficult to make an assessment of its context. However, it seems that the bones were discarded before the building was abandoned. The number of individuals, their age and gender, as well as the treatment of the bones, are still under study and thus not yet fully understood. Nevertheless, observations made during the excavation indicate that they were composed primarily of long bones and skulls, and were initially secondary burials.

Discussion

The potential for comprehending the relationship between domestic and special buildings is evident in the study of Sayburç. The dwellings constructed on bedrock provide insights into the settlement pattern and structural features, while their well-preserved remains offer useful information about life in the past. As the research is still in its early stages, the place of the buildings in the technological novelties of architecture is emphasized here. The buildings in Sayburç exhibit a transition from a round to a quadrangular architectural form. Similarly, the use of buttresses, which are believed to have reinforced the structural integrity of the walls, is also evident at the site. The apsidal plan, rectilinear wall, well-constructed corner connections, buttresses, niches, and the dome-shaped hearth, situated within the wall, demonstrate the capacity of the community to create well-organized spaces as 'house' contexts. This was also achieved through the application of construction techniques that required a certain degree of technical expertise.

Fig. 13. One of the special buildings in Sayburç features a central and seven perimeter T-pillars against the wall.

The preliminary studies indicate that they are one-room structures built by attaching one to the other. However, some of the smaller rooms that have been uncovered may have been annexes associated with the structures. From the exterior, the settlements appears to be a vast island of contiguous structures. The buildings are constructed next to one another, resulting in a limited amount of open space and restricted access. The intersections of walls between different structures likely served as passageways. The considerable width of some multiple walls may be indicative of the presence of roads within the settlement, which facilitated internal circulation. The houses probably had thatched roofs over their stone walls. In some well-preserved houses, the walls have been extended inside. This suggests that the upper portions of the walls were positioned slightly inward to prevent rainwater from entering the buildings from outside. This also facilitates the drainage of water from a large building island.

Fig. 14. The human bones situated in front of the bench are composed of skull fragments and long bones. These bones, which are classified as secondary burial, have undergone burning.

It is crucial to acknowledge that none of the special buildings within the site have yet been fully excavated. A structure in the northern area appears to be larger than the other dwellings, and a bench along the wall with reliefs indicates its special function. At least three buildings in the southern area are considered 'special buildings' due to their interior equipment and arrangement of pillars. This pattern of intertwined dwellings and special buildings is noteworthy. This prompts the question of why there was more than one special building and whether there were any differences between them in terms of their use or users. While the answers to these questions may not be known until the buildings in the area are fully excavated, the special buildings and symbolic elements at Sayburç provide sufficient evidence to make an assessment. The symbolic artefacts in Sayburç extend beyond those observed within the context of the special structures. Additionally, personal body ornaments, such as beads and small stone objects, have been unearthed at the site (Fig. 15). Beads and ornaments represent the individual form of symbolic expression that was characteristic of past societies. It is evident that these forms of personal symbolism existed before the Neolithic period, but they increased in both material, type, and quantity with the Neolithic (*Özdoğan E. 2016*). Nevertheless, the appearance of public symbols during the Neolithic period is noteworthy. This is particularly obvious in the settlements of the Urfa region, where these symbols represent elements that are fundamental to social values. One of the most striking features of these symbols is that they often form contexts associated with special buildings. The presence of these symbols in gathering places also serves to highlight the relationships among these symbols, rituals, and narratives.

Fig. 15. Personal ornaments and secondary use grooved stone (photo Y. Aslan).

Fig. 16. Male human figure in a scene with a bull (photo B. Köşker).

The reliefs in the special building in Sayburç provide a compelling illustration of the public significance of symbolism. The figures display features typically associated with strong, predatory animals, the male gender, and ithyphallic features (*Schmidt 2006; Hodder, Meskell 2011*). They are carved in stone and depicted in a realistic style, indicating that they are the products of artistic production requiring labour and mastery. As exemplars of a long tradition, they are representative of the broader phenomenon, while at the same time constituting a unique and comprehensive scene that is characteristic of this region. The scenes are arranged horizontally, and the orientation of the figures serves to emphasize two different scenes. Although there is a space around them, the fact that they are depicted side by side makes them two related narratives.

It is of particular importance to consider the contexts in which these depictions take place. As in the case of Sayburç, both in Karahantepe and Göbeklitepe as well as in Nevali Çori, both depictions and sculptures are found in special structures. The fact that these depictions, which are clearly narrative in nature, are found in special structures – in other words, in structures with public functions – places them at the centre of public events and rituals. The coexistence of special buildings and symbols facilitates mutual understanding of the function of both symbols and buildings (Fig. 16). It seems that narratives, which are the subject of rituals, serve to maintain social cohesion and ensure the continuity of social values. In this regard, the depictions, special buildings, and related rituals serve an important function in the continuity of culture and the transmission of traditions to future generations. Although the narratives themselves are not readily comprehensible, their social implications can be discerned.

Conclusion

The Urfa region has been identified as the site of distinctive special buildings and related symbolism that go as far back as the mid-10th millennium, BC as evidenced by Göbeklitepe and Karahantepe (*Schmidt 2006; 2010; Karul 2021; 2022*). The discovery of special buildings and reliefs at Sayburç indicates that this tradition persisted until the mid-9th millennium BC. Furthermore, in Sayburç, as in the other sites, the special buildings are not singular, but rather multiple and integrated into the dwellings. The evidence suggests that the tradition of integrating special buildings and dwellings into settlements persisted for a considerable length of time. In addition to temporal distinction, Sayburç is also distinguished from the other two settlements in terms of size. While the other two settlements exhibit a shift in size and complexity over time, Sayburç remained a relatively small settlement throughout its history. This suggests that distinctive architectural features, special buildings, and high artistic productions are not exclusive to large and prominent settlements.

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First insights into the Mesolithic settlement of Southern Serbia: excavation of the Pešterija Cave in the Ponišavlje Region

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ABSTRACT - *Despite extensive research and excavations across the central Balkans, Early Holocene sites have so far been documented only in the Iron Gates region – for which there are several possible explanations. Some scholars argue that the apparent lack of Mesolithic sites is due to inadequate research efforts in the region, while others suggest that the ecological conditions in the central Balkans during the Early Holocene may not have been favourable to the subsistence of hunter-gatherer communities. Contrary to previous beliefs, recent investigations of caves in eastern Serbia have revealed that humans inhabited the region during the Mesolithic. Traces of settlement of Mesolithic groups, dating back to the 7th millennium cal BC and employing comparable technology and economic practices to Mesolithic communities in other parts of the Balkan Peninsula, have been documented at the Pešterija Cave, situated south of Pirot in southeastern Serbia. The fact that the site is located relatively close to the oldest Neolithic sites in the Iron Gates and northwest Bulgaria, and is potentially contemporaneous with them, offers a completely new perspective on the transition from the Mesolithic to the Neolithic in this part of the Balkans.*

KEY WORDS – *Mesolithic; Balkans; caves; Nišava; lithic assemblages; faunal remains*

Prvi vpogled v mezolitsko poselitev južne Srbije: izkopavanje jame Pešterija v Ponišavlju

IZVLEČEK – *Zgodnje holocenska najdišča na osrednjem Balkanu so bila kljub obsežnim raziskavam in izkopavanjem doslej dokumentirana le na območju Železnih vrat – za kar obstaja več možnih razlag. Nekateri raziskovalci trdijo, da je očitno pomanjkanje mezolitskih najdišč posledica neustreznih raziskovalnih prizadevanj v regiji, drugi menijo, da ekološke razmere na osrednjem Balkanu v zgodnjem holocenu morda niso bile naklonjene preživetju skupnosti lovcev in nabiralcev. V nasprotju s prejšnjimi prepričanji so nedavne raziskave jam v vzhodni Srbiji pokazale, da so ljudje to regijo naselili v mezolitiku. V jami Pešterija, ki se nahaja južno od Pirota v jugovzhodni Srbiji, so bili dokumentirani sledovi poselitve mezolitskih skupin, ki segajo v 7. tisočletje pr.n. št. Dejstvi, da so najdišča relativno blizu najstarejšim neolitskim najdiščem v Železnih vratih in v severozahodni Bolgariji ter da so jim potencialno sočasna, ponujata popolnoma nov pogled na prehod mezolitika v neolitik na tem delu Balkana.*

KLJUČNE BESEDE – *mezolitik; Balkan; jame; Nišava; kameni zbiri; živalski ostanki*

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Introduction

More than half a century has passed since the discovery of Mesolithic sites in the Iron Gates region, revealing traces of elaborate architecture, formal burial grounds, artistic artefacts (including those unearthed at Lepenski Vir), as well as numerous tools and faunal remains. At the time of discovery, it was hypothesized that the Lepenski Vir culture encompassed a vast territory across the Middle and Lower Danube Basin (*Srejović 1979*). Similar to the discoveries in the Iron Gates, the research conducted in the Adriatic, Ionian, and Aegean zones during the 1980s revealed a plethora of rich and multi-layered Epipalaeolithic and Mesolithic sites. The number of these sites significantly increased following the investigations in Istria and northern and central Dalmatia (*Komšo 2006*), and further south in the Greek islands during the 1990s (*Kaczanowska, Kozłowski 2014*). All of this indicates that the Balkan Peninsula as a whole was densely populated during theMesolithic period (Fig. 1).

However, subsequent research following the investigations in the Iron Gates did not confirm these expectations for the interior of the Balkans. In the interior of Slovenia, the Mesolithic period has only been documented at the Zalog pri Verdu (*Gaspari 2006*) and Breg pri Škofljici (*Turk 2022*) sites, while in the interior of Croatia it is only attested in the Zala Cave (*Vukosavljević, Karavanić 2015*). The Mesolithic has been also documented at a few sites in the northern part of Montenegro (*e.g.,* Odmut and Vrbička Cave – *Borić* et al. *2019*), as well as at the Kryegjata B and Neziri Cave in Albania (*Runnels* et al. *2007; Hauck* et al. *2017*). In Bulgaria and North Macedonia, no Mesolithic sites have been conclusively confirmed, while in Bosnia and Herzegovina traces of Mesolithic occupancy have been noted only in the Rastuša Cave (*Jovanović* et al. *2014*). A similar situation has been recorded in Serbia. Following intensive surveys of the Iron Gates hinterland, the Mesolithic has only been identified in Radujevac (*Radovanović* et al. *2014*). A layer containing fauna (including bones with cut marks) dated to the Early Holocene was confirmed at Bukovac (*Živaljević* et al. *2018*), while the Early Holocene age (8th millennium cal BC) has also been confirmed for human and animal remains at several sites in northern Serbia (*Živaljević* et al. *2021*).

The apparent paucity of Mesolithic sites in the interior of the Balkans has been subject to numerous discussions, with some authors suggesting that Mesolithic sites may be buried beneath thick alluvial deposits and therefore remain undetected (*Kotsakis 2001*), others argue that inadequate methods were used in the survey efforts (*Runnels 2003*), or that surveys did not cover areas where Mesolithic settlements could be expected (*Mihailović 2021*). Some have even suggested that the territory of Greece was sparsely populated during the Mesolithic (*Runnels 1995; Perlès 2003*). According to Catherine Perlès (*2003*), Mesolithic settlements where sedentarization occurred should be archaeologically visible, so the fact that they have not been discovered suggests that they may not exist at all.

Maria Gurova and Clive Bonsall (*2014*) proposed a compelling explanation for the absence of the Mesolithic in the Balkans. According to them, during the Early Holocene extensive forest growth made the central Balkans difficult to traverse, suggesting that favourable conditions for settlement existed only in the forest margins – in coastal areas and plateaus – if these areas were exploited seasonally, and that the communication between Mesolithic groups could have only occurred along river valleys. The authors argued that, since the region lacks waterways and glacial lakes, even this area could not have been densely populated. Although we concur with the majority of Gurova and Bonsall's (*2014*) conclusions, we disagree with the notion that the central Balkans lack waterways, as substantial portions of the region are defined by the valleys of major rivers such as the Danube, Sava, Morava, and Nišava, which likely provided favourable conditions for human settlement. Hence, we postulated that Mesolithic settlements in the valleys of these rivers have probably not been discovered because, unlike the Iron Gates, the lowest river terraces and profiles have not been systematically surveyed (*Mihailović 2021*).

In considering the potential distribution and settlement patterns of Mesolithic groups over time, the question has arisen as to how frequently hunter-gatherer communities, if concentrated along river courses, visited the upland mountainous hinterlands. For this reason, particularly in the central Balkans, our research has been focused on surveys and exploratory excavations of cave sites located on the outskirts of river valleys and places where the valleys are widest. Despite this effort, we did not detect Mesolithic remains in most of the caves we explored until 2022 when we discovered Mesolithic material in Pešterija, located in the far southeast of Serbia. The discovery of Pešterija necessitates a re-evaluation of hypotheses regarding the settlement patterns of the interior of the Balkans during the Late Mesolithic, and the current assumptions about cultural and social interactions between Mesolithic and Neolithic communities during the period of Neolithisation in the central Balkans.

Previous investigations of cave sites in southeastern Serbia

For several reasons, research on the Palaeolithic and Mesolithic in the central Balkans over the past few decades has primarily focused on eastern Serbia. This area encompasses the Iron Gates region at the extreme north, making it crucial to ascertain whether Mesolithic sites also appear in the hinterland of the Iron Gates. In addition, eastern Serbia is bordered by major natural communication routes which historically connected the southern Balkans and the Black Sea region with central and western Europe, making it significant for the study of the process of Neolithisation. Finally, eastern Serbia is characterized by a highly developed karst relief with numerous caves and natural shelters.

Systematic surveys of Palaeolithic and Mesolithic sites in the central Balkans have covered the entire territory of eastern Serbia since 2002, spanning from the Iron

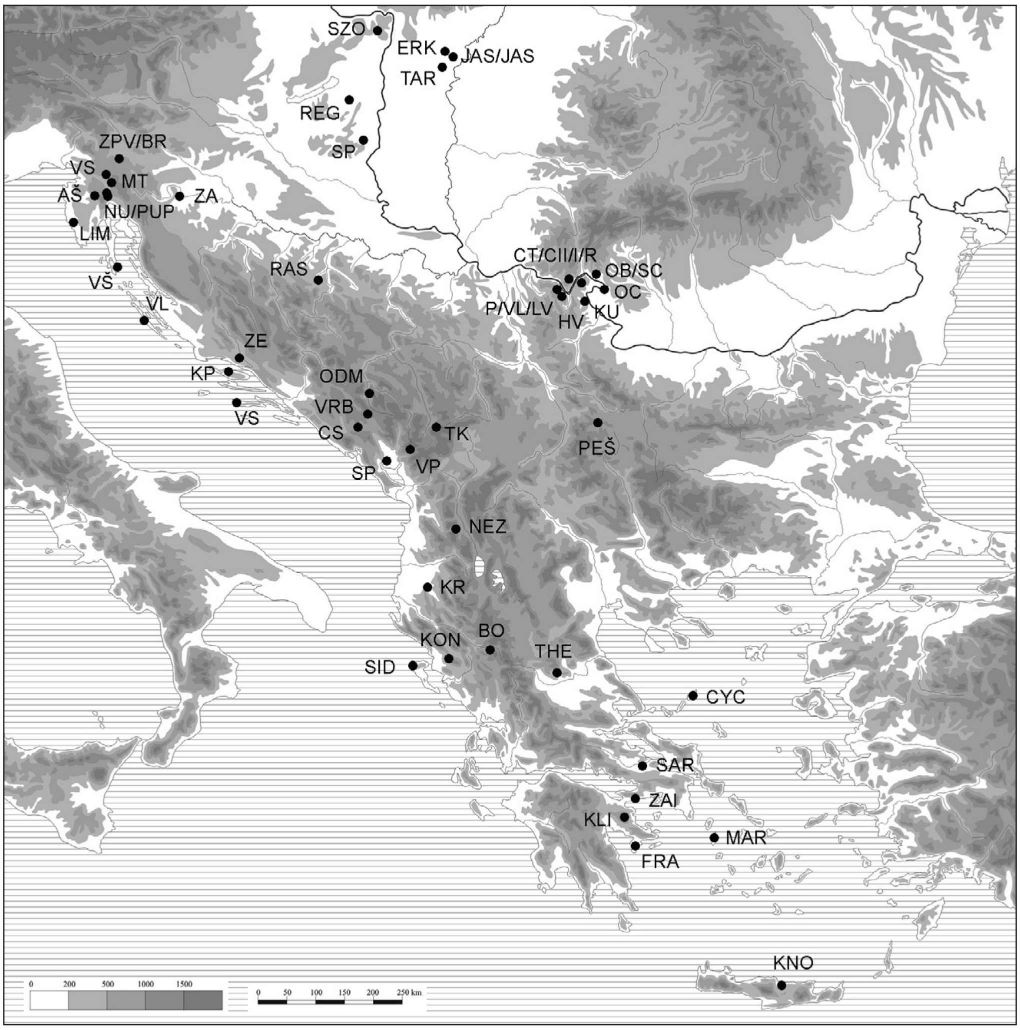

Fig. 1. Mesolithic sites in Southeast Europe: Zalog pri Verdu/Breg (ZPV/BR); Viktorjev Spodmol (VS); Mala Triglavica (MT); Abri Šebrn (AŠ); Nugljanska and Pupićina Cave (NU/PUP); Lim 001 (LIM); Zala (ZA); Vela Špilja (VŠ); Rastuša Cave (RAS); Vlakno (VL); Kopačina Pećina (KP); Zemunica (ZE); Vela Spila (VS); Sződliget (SZO); Regöly (REG); Szekszárd Palánk (SP); Erk (ERK); Jászberény/Jásztelek (JAS/JAS); Tarnaörs (TAR); Odmut (ODM); Vrbička Pećina (VRB); Crvena Stijena (CS); Seocka Pećina (SP); Vruća Pećina (VP); Trebački Krš (TK); Neziri Cave (NEZ); Kryegjata B (KR); Konispol Cave (KON); Sidari (SID); Boila (BO); Theopetra Cave (THE); Cyclope (CYC); Sarakenos Cave (SAR); Zaimis (ZAI); Klissoura Cave 1 (KLI); Franchthi Cave (FRA); Maroulas (MAR); Knossos (KNO); Cuina Turcului/Climente II/ Icona/Razvrata (CT/CII/I/R); Ostrovul Banului/Schela Cladovei (OB/SC); Ostrovul Corbului (OC); Padina/Vlasac/Lepenski Vir (P/VL/LV); Hajdučka vodenica (HV); Kula (KU); Pešterija (PEŠ).

Gates hinterland in the north, to the southern slopes of the Carpatho-Balkanides in the south, and from the valleys of the Great and South Morava rivers in the west to the Stara Planina mountain. in the east, encompassing various topographic and ecological zones. The surveys were conducted as part of several international projects lead by the Faculty of Philosophy (University of Belgrade, Serbia) in collaboration with multiple international institutions, including the University of Winnipeg, the University of Arizona in Tucson, the University of Kansas in Lawrence, and the Max Planck Institute for Evolutionary Anthropology in Leipzig.

During reconnaissance, over 100 potential cave sites were identified, presumed to have provided favourable conditions for settlement in the past. Around 30 of these sites were subjected to exploratory excavations, revealing predominantly pre-Neolithic materials. Lower and Middle Palaeolithic remains – including hominin fossils – have been mainly documented in southern Serbia (*Roksandic* et al. *2011; 2022; Radović* et al*. 2019; Lindal* et al. *2020; Mihailović* et al. *2022*), Aurignacian materials were found exclusively in the northern part of the country (*Mihailović* et al. *2011*), while Gravettian artefacts have been found throughout the surveyed territory. These studies have shown that the central Balkans were inhabited during all phases of the Middle Palaeolithic (*Mihailović, Mihailović 2023*), that anatomically modern humans settled the interior of the continent from the direction of the Danube (*Mihailović 2020*), and that the Balkans likely served as a refuge for Gravettian communities at the onset of the Last Glacial Maximum (LGM) (*Stiner* et al. *2022*). However, our research provided little evidence of settlement in this area during the late Upper Palaeolithic and Mesolithic periods. Located in the far south of eastern Serbia, the Nišava River basin represents a notable exception, where, alongside Gravettian sites dated to the period before the LGM (*i.e.* Meča Dupka, Pešturina, Potpeč, *Alex* et al. *2019; Plavšić, Popović 2019*), sites from the peak of the LGM were also discovered (such as Velika Vranovica – lower cave, and Pećina kod Stene, *Kuhn* et al. *2014; Mihailović* et al. *2017*), as well as the aforementioned remains dated to the Mesolithic period (Pešterija).

Physiographic, climatic, and ecological characteristics of the Ponišavlje region

The Nišava River basin covers an area of 2971.5km² (*Manojlović 2019*) and extends from southeast to northwest over a length of 218km, ranging from lowland (plain) to high mountainous terrain (>1500 m a.s.l.) (Fig. 2). The region belongs to the long Carpatho-Balkanides arch, which extends through the southeastern part of Europe. A significant geological feature of

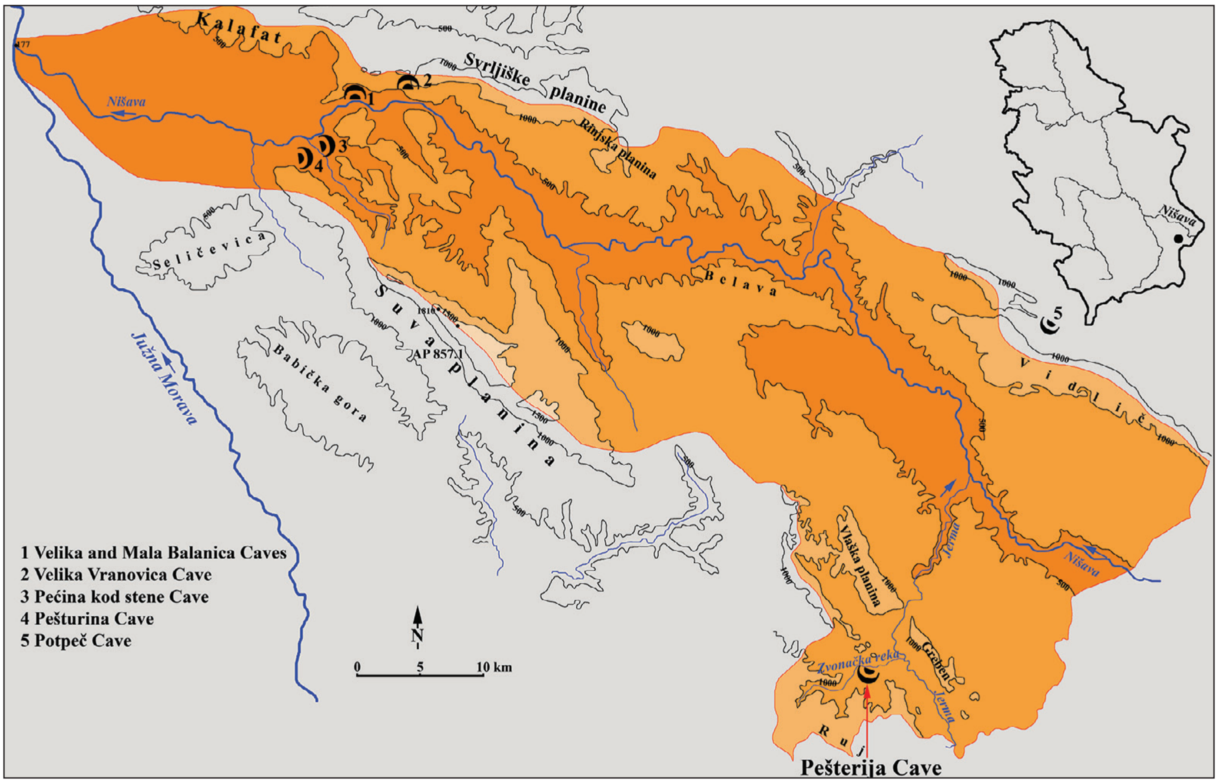

Fig. 2. Distribution of Palaeolithic and Mesolithic sites in the Ponišavlje region.

this region is the prominence of carbonate rocks, which serve as the basis for forming numerous caves (*Djurović 1998; 2018; 2022*). Limestone is consistently found in the peripheral areas of the region – including Suva Planina, Belava, Vlaška Planina, Kalafat, Svrljig Mt., and Vidlič – while its presence in other areas is often sporadic. The highest mean annual air temperatures are typical for the valley bottom of the Nišava River, where temperatures gradually decrease from 11.7°C in the northwest to 9.9°C in the southeast. Instrumental measurements and statistical calculations have revealed a significant decrease in air temperature from the valley bottom towards the peripheral mountainous areas in the southwest and northeast, where the annual difference ranges from 6 to 8°C (*Milovanović* et al. *2022*). The annual amount of precipitation in the valley increases slightly by about 50mm from the lowest northwest parts to the highest southeast parts, ranging from 592 to 642mm. The peripheral mountainous areas receive a higher annual amount of precipitation, ranging from around 800 to about 1000mm for the highest mountain areas (*Manojlović 2019; Milovanović* et al. *2022*).

Within the Nišava basin, karst terrain spans an area of 659.2km^2, constituting 22.1% of the basin. It is distributed across several elevation zones (*Manojlović 2019*). Its largest extent is found in the low mountainous area between 500 and 1000m a.s.l., covering 64.4% of this elevation zone or 424.7km^2. Karst is less prevalent in the mid-mountainous zone (1000–1500 m a.s.l.), where it occupies 23.3% or 153.3km^2. It is least represented in the low-hilly area below 500m a.s.l., covering 9.7% of the zone's surface area, or 63.7km^2. Karst terrain is minimally present in the high mountainous area above 1500m a.s.l., covering only 2.7% or 17.8km^2. In the southern part of Upper Ponišavlje, in the valley of the Zvonačka reka River, within the watershed of the Jerma River, a left tributary of the Nišava River, several smaller karst outcrops are located, formed in Triassic and Jurassic limestone. The largest karst outcrop is in the area of Asenovo Kale, situated south of the Zvonačka River (right valley side). The northern part of the karst outcrop is composed of Jurassic limestone, which is separated by faults from the southern part consisting of Jurassic limestone with chert nodules (Oxford, Kimmeridgian) (*Anđelković* et al. *1964–1968*). Within this karst outcrop, there are four caves arranged in a stepped manner, ranging from 7 to 55m in length. Apart from the lowest cave – in which there is a captured spring – the others have no hydrological function. Among this group of caves is Pešterija.

Positioning, appearance, exploration, and stratigraphy of Pešterija

The Pešterija Cave is situated in the southern part of the region discussed here, within the Zvonačka reka River valley (Fig. 3), in the basin of the Jerma River, a left tributary of the Nišava River (N 42.55819, E 22.35951). Pešterija is located on the right side of the valley, in the highest part of the short Cedilka canyon, 100m above the Zvonačka reka riverbed (Fig. 4), at 715 m a.s.l. The cave is set within Jurassic limestones which extend on both sides of the valley. The entrance is 13.5m wide and faces north, while the depth of the cave is approximately 15m (Fig. 5). The cave was identified as a potential archaeological site in 2011, with exploratory excavations conducted in 2022 and 2023. The excavations were organized on a grid system, delineated by squares and quadrants. Fragments of rocks, artefacts, and animal bones larger than 2cm were recorded *in situ*. The excavated sediment was dry-sieved using 3mm screens.

Upon arrival at the site in 2022, it was noted that geological layers were preserved only in the northern part of the cave, at the boundary of the sheltered area. This is due to the presence of a spring in the back of the cave, which has washed away the sediment from the southern part of the site. There was a pit – approximately 2m in diameter – excavated by the treasure hunters at the cave entrance, to the rocky base at a depth of 1.3m, revealing layers containing wheel-thrown pottery from historical periods. During the initial campaign, the pit profiles were aligned with the grid to potentially identify even older artefacts within the visible layers at the base of the profile (Fig. 6).

During the profile correction, geological layer 2 yielded a significant number of archaeological finds and faunal remains dating back to the historical periods, while layer 3 contained small, chipped stone artefacts (including one backed bladelet) and sporadic faunal remains (Fig. 7). Notably, the taxa exclusive to the Pleistocene were not identified among the faunal remains in this layer. Animal bones and several non-diagnostic artefacts were found in layer 4, characterized by coarse limestone debris and partial cementation. In contrast, only animal bones were found in layer 5, which consisted of clayey sediment. The initial observations were confirmed during the excavations in the subsequent 2023 field season. During this season, the excavation area was expanded towards the north and west, investigating a surface area of 5m^2 to a depth of

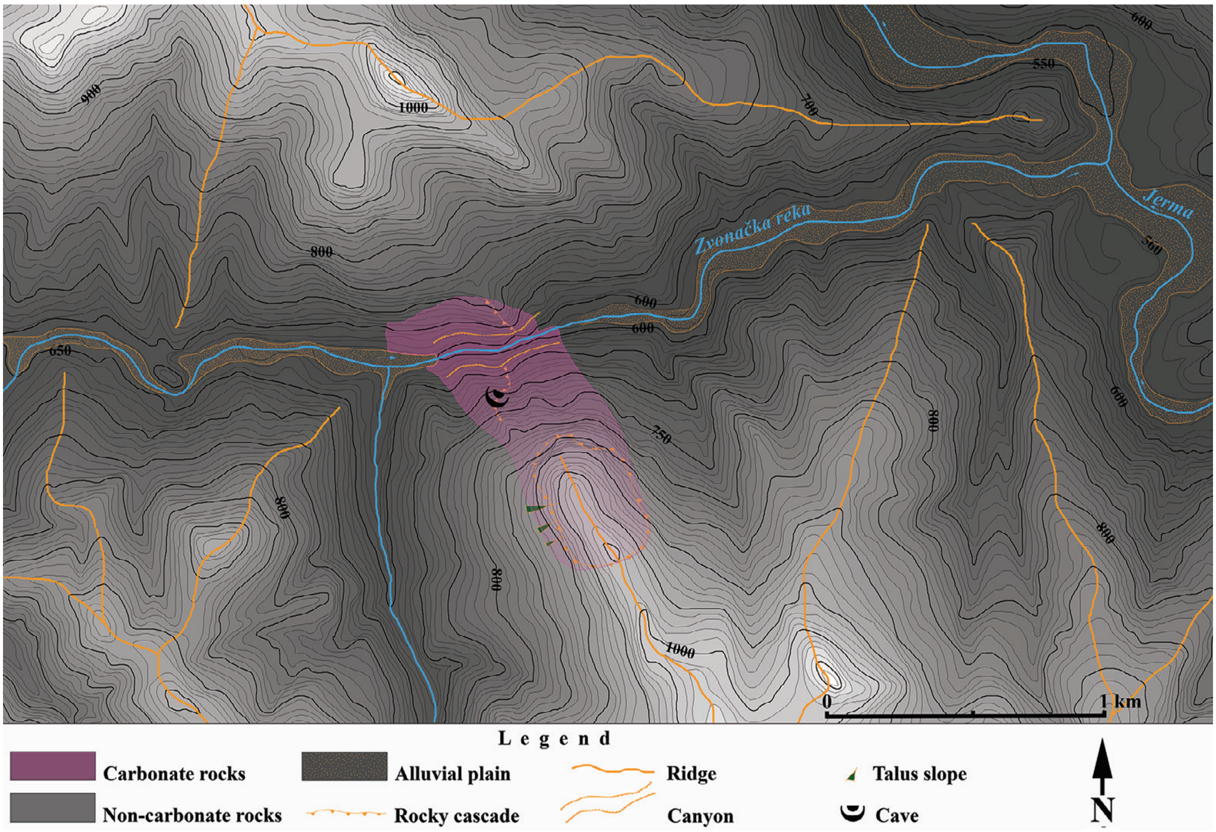

Fig. 3. Geomorphological map of the area around Pešterija Cave.

approximately 1m, reaching layer 4. At this stage of research, the age of the deepest layer at the site remains uncertain, primarily due to the absence of diagnostic artefacts.

Given the initial indications that layer 3 probably dated back to the late Upper Palaeolithic or Mesolithic, three bone samples from this layer were subjected to radiocarbon dating in the Ottawa laboratory in 2023 (Tab. 1). The bones were pretreated with the ultrafiltration step following the precise procedures outlined in Carley A. Crann *et al.* (*2017*). The first sample (PesP-2022-1) yielded an age corresponding to the early 6th millennium cal BC, the second sample (PesP-2022-2) provided an age corresponding to the middle of the 7th millennium cal BC, and the third sample (PesP-2022-3) indicated an age at the end of the 8th millennium cal BC. The samples were taken from the middle and lower parts of layer 3, where there were no intrusions (*e.g.,* pottery fragments) from the upper layers. In layer 3, no identifiable strata have been observed that could be linked to individual dated samples, which could account for the differing dates obtained for them.

Lab ID	Submitter ID	Material	Collagen yield %	^{14}C yr BP	±	cal BC
UOC-21631	PesP-2022-1	Animal bone	7.4	6993	24	5980–5946 (19.0%) 5922–5796 (76.5%)
UOC-21632	PesP-2022-2	Animal bone	6.1	7428	24	6380–6235 (95.4%)
UOC-21633	PesP-2022-3	Animal bone	3.9	8210	25	7322–7132 (84.3%) 7110–7078 (11.2%)

Tab. 1. Results of radiocarbon dating of layer 3 of Pešterija Cave. Calibration is performed using OxCal v4.4 (*Bronk Ramsey 2021*) and the IntCal20 calibration curve (*Reimer et al. 2020*).

Faunal remains

The context and taphonomy

The analysed faunal remains were collected from geological layers 3–5. The sample consists of 1358 identified specimens (NISP), with the vast majority (82.1%) originating from layer 3. The mammal bone assemblage exhibits a high degree of fragmentation; there were no complete bone specimens (except for small mammal bones), and there was only a small number of complete epiphyses. Fragments less than 2cm prevail

(n = 862, *i.e.* 69.1%), and no fragments were longer than 10cm.

A significant number of mammal bone specimens were burnt (n = 498, *i.e.* 39.9%), however, it should be noted that the traces of burning were often difficult to discern from mineral staining. The bones exhibited varying degrees of exposure to fire: the majority were (partly) burnt (67.1%), but extensively carbonized and calcined specimens also occurred (Fig. 8). One bone fragment from layer 3 (square N19/a) displayed light bluish-grey colouration, indicative of long and intense heating.

A small number of specimens (n = 5) bore visible gnawing marks. One red deer first phalanx was gnawed by a rodent, whereas four specimens – a ruminant first phalanx, a chamois first phalanx, a marten humerus fragment and a mammal rib fragment – bore carnivore teeth marks. Another chamois first phalanx and a ruminant third phalanx were digested. Other taphonomic modifications included root etching and/or microbial activity, visible on three bone specimens. Anthropogenic modifications will be further discussed below.

Taxonomic composition

The faunal sample from Pešterija exhibits significant diversity, encompassing the remains of large, medium-sized, and small mammals, micromammals (*i.e.* those weighing less than 1kg), birds, amphibians, fish, and molluscs (Tab. 2). The vast majority originate from large, medium-sized and small mammals (1249 specimens, *i.e.* 92%). However, only 42 specimens (3.4% of the mammal bone assemblage) could be identified to the species, genus, family or order level, due to the high degree of bone fragmentation.

In the case of large and medium-sized mammals, the remains of ruminants – mainly red deer (*Cervus elaphus*) and chamois (*Rupicapra rupicapra*) – were more numerous than carnivores. Whereas red deer was ubiquitous and commonly hunted in the Pleistocene and Holocene, the chamois was relatively rare during the Pleistocene, and its remains were documented at a limited number of mountain sites, usually in modest numbers. It was present in the Iron Gates during the Early Holocene, as evidenced by its occurrence in faunal assemblages from several Mesolithic sites in this area (Padina, Lepenski Vir, Vlasac, Hajdučka Vodenica and Icoana) (*Bolomey 1973; Bökönyi 1975; 1978; Clason 1980; Borić, Dimitrijević 2005; Dimitrijević 2008; Greenfield 2008; Bălășescu* et al. *2021*). Its presence was also con-

Fig. 4. View of the Cedilka canyon along the Zvonačka reka River (photo Dušan Mihailović).

Fig. 5. Pešterija – view from inside the cave (photo Dušan Mihailović).

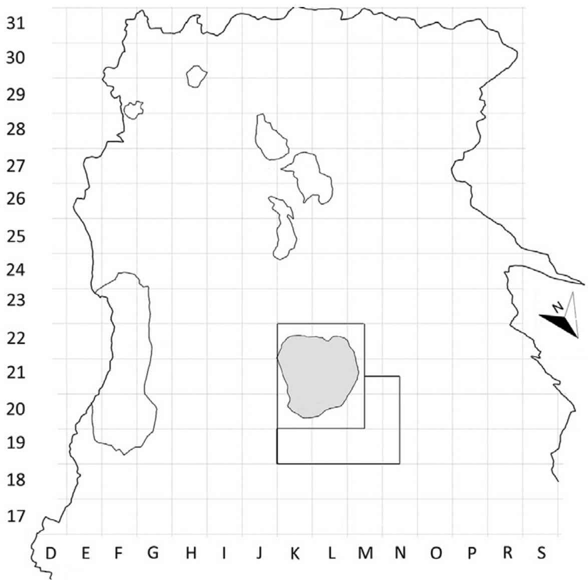

Fig. 6. Pešterija Cave ground plan (drawing Sofija Dragosavac).

firmed in Montenegro – in Mesolithic layers at Seocka pećina (*Vander Linden* et al. *2014; 2015*) and Mesolithic and Neolithic layers at the Odmut rock shelter (*Borić* et al. *2019*), as well as at the Early Neolithic site of Obre in Bosnia and Herzegovina, and the Late Neolithic site of Sitagroi in Northeastern Greece (*Bökönyi 1978*). From the Middle Holocene, chamois became largely extirpated in the region.

At Pešterija, chamois remains primarily originated from geological layer 3 (eight specimens), and only one specimen was found in layer 5. The specimens include deciduous teeth (a left incisor and a left lower second premolar), a permanent right lower second molar, mandible fragments, and fragments of a left radius, metatarsal bone, and three first phalanxes, originating from a minimum of two individuals. The metatarsal fragment from layer 3 (square N19/a) bore transverse scraping marks and an overlying long cut mark, inflicted by a chipped stone tool. As previously mentioned, one of the phalanxes (from layer 5, square L19/c) was gnawed by a carnivore, and the other (from layer 3, square M21/a) shows digestive etching.

Red deer was also represented by a minimum of two individuals, and all skeletal elements attributed to this species (n = 13) originated from layer 3. These include an antler fragment, a deciduous upper right third premolar, a fragment of an upper right molar bud, a right and left first incisor, a molar fragment, a hyoid bone, two mandible fragments, a lumbar vertebra, a left radius fragment, a metapodial bone fragment, and a fragmented first phalanx. In addition, an upper right canine originated from layer 3/4. Based on the heavily worn deciduous premolar (from square M19/a), it can be suggested that the animal was killed at the age of 27 months, *i.e.* between the end of September and the beginning of October. The same age at death and ultimately the same hunting season were determin-

	TAXON	NISP	MNI
Mammals (large, medium-sized and small)	hare (*Lepus europaeus*)	2	1
	fox (*Vulpes vulpes*)	1	1
	marten (*Martes* sp.)	2	1
	indeterminate carnivores (Carnivora indet.)	1	/
	red deer (*Cervus elaphus*)	14	2
	roe deer (*Capreolus capreolus*)	2	1
	chamois (*Rupicapra rupicapra*)	9	2
	indeterminate ruminants (Ruminantia indet.)	9	/
	indeterminate mammals (Mammalia indet.)	1207	/
	TOTAL	**1249**	**8**
Micromammals	mole (*Talpa europaea*)	1	1
	wood mouse (*Apodemus* cf. *sylvaticus*)	1	1
	indeterminate murids (Muridae indet.)	1	1
	indeterminate squirrels (Sciuridae indet.)	1	1
	indeterminate micromammals (Micromammalia indet.)	24	/
	TOTAL	**28**	**4**
Birds	bird of prey	2	1
	indeterminate birds (Aves indet.)	27	/
	TOTAL	**29**	**1**
Amphibians	fire salamander (*Salamandra salamandra*)	1	1
	marsh frog (*Pelophylax* cf. *ridibundus*)	2	1
	indeterminate frog (Anura indet.)	2	1
	TOTAL	**5**	**4**
Fish	vyrezub (*Rutilus frisii*)	1	1
	TOTAL	**1**	**1**
Vertebrates	indeterminate vertebrates (Vertebrata indet.)	19	/
	TOTAL	**19**	**/**
Molluscs	Roman snail (*Helix pomatia*)	4	1
	indeterminate gastropods (Gastropoda indet.)	20	8
	freshwater mussel (*Unio* sp.)	2	1
	indeterminate molluscs (Mollusca indet.)	1	1
	TOTAL	**27**	**11**

Tab. 2. The taxonomic composition of the faunal assemblage from Pešterija Cave.

ed in the case of a red deer skull deposited on the floor of Building 28 at the site of Lepenski Vir (*Dimitrijević 2000; 2008; Dimitrijević* et al. *2016; cf. Brown, Chapman 1991*).

Apart from red deer and chamois, the remains of another ruminant species – roe deer (*Capreolus capreolus*) – were also present in the faunal sample, albeit in modest numbers. Two elements were attributed to roe deer – an antler tip and a longitudinally split first phalanx and an antler tip, found in geological layers 3 and 3/4, respectively. A total of 11 specimens from layers 3 and 4 were identified only to the order level, categorized as ruminants (Ruminantia indet.).

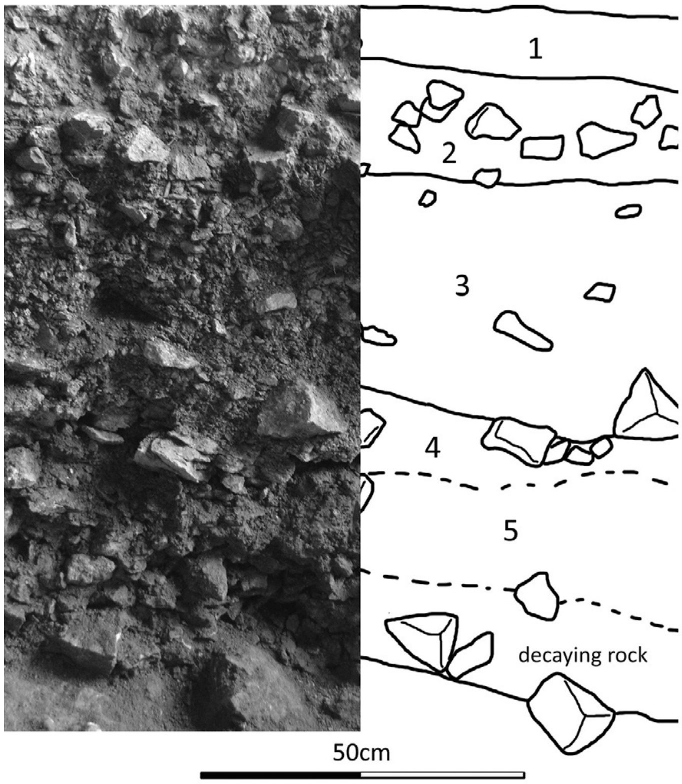

Fig. 7. A part of the western profile within Pešterija Cave (photo and drawing Sofija Dragosavac).

The sample contained remains of at least two species of carnivore – fox (*Vulpes vulpes*) and marten (*Martes* sp.) – all of which were discovered in layer 3. The fox was represented by a calcaneus fragment, and the marten by a fragment of the right mandible and a gnawed fragment of the right humerus. In addition, one carnivore left ulna fragment from layer 3 most likely belonged to a canid larger than a fox, which allows the possibility that it originated from a dog (*Canis familiaris*). As previously mentioned, certain bone fragments bore gnawing marks, with punctures corresponding to fox or dog teeth. While there is ample evidence of local dog domestication in the Iron Gates Mesolithic (*Bökönyi 1975; 1978; Dimitrijević, Vuković 2012*) and long histories of human-canid coexistence in this area (*Radovanović 1999; Dimitrijević 2008; Živaljević 2015*), in other parts of the Balkans this phenomenon is still poorly understood. There is certainly a possibility that dogs were companion species to the Mesolithic communities in the Ponišavlje region as well, but this hypothesis remains to be tested with future excavations retrieving skeletal elements that can be identified with more certainty.

The faunal sample from Pešterija also yielded small mammal remains, represented by an upper right third premolar fragment and a right fourth metatarsal of a hare (*Lepus europaeus*). The majority of micromammal remains (n = 24) consisted of long bones that did not allow for precise taxonomic identification. Only twospecimens could be identified at the species level – the left humerus of a mole (*Talpa europaea*), and the left mandible of a wood mouse (*Apodemus* cf. *sylvaticus*). In addition, two more specimens could be identified to the family level – a left humerus, most likely of a murid (Muridae indet.), and a right humerus belonging to a member of the squirrel family (Sciuridae indet.). The wood mouse and mole are species which typically inhabit deciduous forests, woodland edges, wet meadows and shrublands. Consequently, the occurrence of their remains at Pešterija is indicative of a relatively humid and moderately warm climate during the time of their accumulation (*cf. Popov 2000*).

The bird bone assemblage from Pešterija mainly consisted of skeletal elements – coracoid, ribs, vertebrae, long bones, tarsometatarsi, and phalanges (n = 27) – that did not allow for more precise taxonomic identification. They mainly derive from small birds, except for a second phalanx found in layer 4 (square L19/c) and an ungual phalanx (talon) found in layer 3 (square M19/a) (Fig. 9.a) which belonged to larger birds of prey. At the Mesolithic site of Vlasac in the Iron Gates, the occurrence of metatarsi and phalanxes of white-tailed eagle (*Haliaeetus albicilla*) has been associated with a possible trophy collection of claws (*Bökönyi 1978.49*). While not identifiable at the species level, the ungual phalanx from Pešterija potentially belonged to a large falcon and may have held similar symbolic significance.

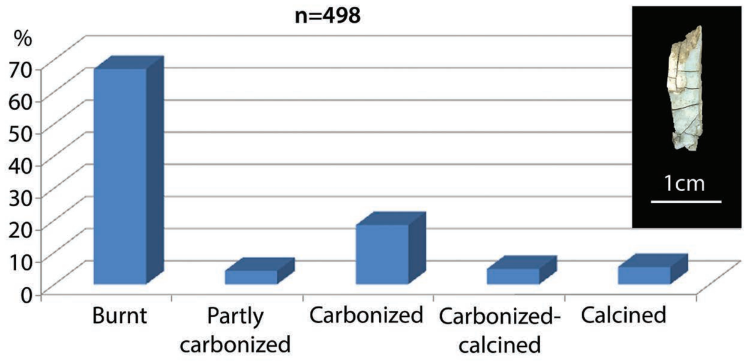

Fig. 8. The distribution of mammal bones based on the degree of burning. Top right: a calcined bone fragment from geological layer 3 of Pešterija Cave (square N/19a).

The faunal assemblage from Pešterija also included five amphibian bone specimens: a humerus of fire salamander (*Salamandra salamandra*), a right ilium bone and a humerus of marsh frog (*Pelophylax* cf. *ridibundus*), and two indeterminate bone fragments which most likely originated from a member of the frog order (Anura indet.).

A particularly notable find, and the sole fish skeletal element in the sample, was unearthed in geological layer 3 (square M20/c). The element in question is a fragmented pharyngeal tooth of vyrezub or pearlfish (*Rutilus frisii*) (Fig. 9.b), one of the largest representatives of the Cyprinidae family. At present, this fish species inhabits the estuaries and the coastal areas of the Black, Azov, and Caspian Seas, and undertakes seasonal spawning migrations to their tributaries (*Kottelat, Freyhof 2007; Boldyrev 2022*). However, its migration to the Danube, the largest tributary of the Black Sea, has never been documented in the historical record. The only currently extant Danubian populations are landlocked, inhabiting several subalpine lakes and a short river flowing through Austria (*Zauner, Ratschan 2005; Schmall 2007; Schmall, Ratschan 2010*). However, ancient DNA analysis of cyprinid pharyngeal teeth from several Mesolithic sites in the Iron Gates has confirmed that they originated from vyrezub (*Živaljević* et al. *2017a*). In the Iron Gates Late Mesolithic, pharyngeal teeth of this species were commonly modified and worn as garment appliqués, which makes the occurrence of the tooth from Pešterija Cave even more significant (discussed in more detail below). In addition, unmodified vyrezub pharyngeal bones and teeth have also been identified in the faunal assemblage from the Mesolithic layer at Bukovac Cave, in the Resava River valley (a tributary of the Velika Morava, which flows into the Danube) (*Živaljević* et al. *2018*). This suggests that the Black Sea vyrezub populations were entering the whole stretch of the Danube (including some of its tributaries) during their spawning migrations, at least up to the Middle Holocene.

The molluscan assemblage from Pešterija also includes species known from other Mesolithic sites, as shell fragments of the Roman snail (*Helix pomatia*) were retrieved from geological layers 3 and 4. *Helix* gastropods have been documented at several final Pleistocene and Early Holocene sites throughout the circum-Mediterranean region, and were most likely used in the inhabitants' diet as part of the 'broad spectrum revolution' (*Lubell 2004a; 2004b*). Other local gastropods (Gastropoda indet.) were also identified in the sample, but they were too small to be used as a dietary source. In addition, two fragments of freshwater mussel (*Unio* sp.) were found in layer 3. At several Mesolithic sites in the Iron Gates region (Padina, Schela Cladovei, Kula), the damage observed on the anterior part of recovered *Unio* shells suggests they were cracked open using some form of tool, indicating their use as a dietary source (*Clason 1980; Pickard* et al. *2017; Živaljević* et al. *2017b*). Due to their fragmentary condition, this kind of damage could not be identified on the specimens from Pešterija; however, it is noteworthy that one of them revealed traces of use, as discussed in further detail below.

Butchery marks

Traces potentially associated with butchering were observed on the previously mentioned chamois metatarsal fragment from geological layer 3 (square N19/a). This bone bore transverse scraping marks

Fig. 9. **a** ***An ungual phalanx (talon) of a bird of prey from geological layer 3 of Pešterija Cave (square M19/a).*** **b** ***vyrezub pharyngeal tooth from the zone with lighter sediments in geological layer 3 (square M20/c) (photo Ivana Živaljević).***

and an overlying long cut mark. In addition, two first phalanxes – of a red deer from layer 3 (square N19/b), and an unidentified ruminant from layer 4 (square L19/c) – were most likely cracked with the intent of extracting marrow.

Lithic artefacts

Technological analysis

In geological layer 3, a total of 78 stone artefacts were collected. Among these, two cores (one yielding blades and one yielding blades and flakes), 19 unretouched flakes, 18 blades and bladelets, 10 retouched tools (nine of which were made on bladelets), and 29 chips and small flake fragments were identified. The majority of artefacts (excluding flakes and small fragments) were crafted from chert (26 pieces) among which are six pieces which, based on macroscopic characteristics, can be classified as 'Balkan flint' (Tab. 3). At least one of them is typical (yellowish-brown, white spotted), while the others match the colour and structure of the 'Balkan flint' varieties confirmed in neighbouring Bulgaria (*Gurova* et al. *2022*). Nineteen artefacts were made from chalcedony, and three of undetermined raw material due to burning effects. Furthermore, one artefact was made from low-quality siliceous rock. The presence of pebble cortex was noted solely on one flake fragment, one blade and one core, suggesting that primary cortex removal occurred off-site for the cores.

The technological composition of the collection indicates that both laminar and non-laminar components are equally represented. The orientation of negatives on the dorsal face of the artefacts, as well as the striking platforms, indicates that both blades and bladelets, as well as retouched flakes, were obtained from cores with unprepared platforms (Tab. 4). This reduction scheme has been confirmed on two cores from the assemblage. One core was formed from a piece of raw material resembling 'Balkan flint' and contains two striking surfaces (Fig. 10.a). The second core, featuring a worn platform edge, was utilized to produce microblades and was struck around its entire perimeter (Fig. 10.b). Different core reduction patterns are also evidenced by several pieces with prepared platform types, as well as by the multidirectional orientation of negatives – more common in flakes than in blades and bladelets. Furthermore, the absence of cortex on the artefacts suggests that primary decortication, and likely core shaping, was conducted off-site.

The reconstruction of the knapping technique was conducted by analyzing multiple attributes, including interior platform angle, lip formation, platform thickness, bulb morphology, bulbar scar, conus formation, and the regularity of blades (*Pelcin 1997; Magnani* et al. *2014; Hege 2015*). Flakes, blades, and bladelets were detached using a soft hammer (Tab. 5). Some of the artefacts were knapped via direct percussion, as indicated by the pronounced bulb and lip formation, and by the presence of bulbar scars. Pieces that exhibit an interior platform angle (IPA) of 90°, a diffuse bulb, and distinct lip formation likely suggest the use of indirect percussion. With regard to blades and bladelets, it has been found that there are no examples with both straight edges and dorsal ridges, which could indicate knapping by pressure technique. The same conclusion arises when it comes to cores – since weakly expressed negative bulbs can be observed on the scars of the detached bladelets, directly below the core platform.

The differences observed between blades and bladelets on one hand, and flakes on the other, relate mainly to the choice of raw materials. Both chert and chalcedony were equally used for blades and bladelets, while flakes were primarily made from chert. Additionally, differences can be noted in the prevalence of 'Balkan flint', which was exclusively used for crafting blades and bladelets (Figs. 11,12). The discovery of a core made of 'Balkan flint' at Pešterija, along with several small fragments and chips, indicates that

		Blanks			Retouched tools			
Raw material	Cores	Flakes	Blades	Bladelets	Flakes	Blades	Bladelets	**TOTAL** (%)
Flint	0	11	1	4	1	1	2	**20** (40.8%)
Balkan flint	1	0	2	2	0	0	1	**6** (12.2%)
Chalcedony	0	6	2	6	0	1	4	**19** (38.8%)
Silicious rocks	0	1	0	0	0	0	0	**1** (2.1%)
UND	1	1	1	0	0	0	0	**3** (6.1%)
TOTAL (%)	**2** (4.1%)	**19** (38.8%)	**6** (12.2%)	**12** (24.5%)	**1** (2.1%)	**2** (4.1%)	**7** (14.3%)	**49**

Tab. 3. General structure and raw material composition of the lithic assemblage from layer 3 of Pešterija Cave.

some artefacts made of this raw material were likely manufactured on-site rather than being transported to the site as finished products. One medial fragment of a blade, likely employed as a sickle insert (see the use-wear analysis results), stands as a potential exception. This artefact could have been made and used as part of a composite tool even before the community inhabited the cave.

		Flakes	Blades	Bladelets	**Total**
Dorsal scar negatives	Unidirectional	7	1	4	**12**
	Multidirectional	4	0	2	**5**
	Diagonal	0	1	0	**1**
Platform type	Flat	8	1	1	**10**
	Dihedral	1	0	0	**1**
	Faceted	2	1	1	**4**
	Linear	2	0	3	**5**
	Punctiform	0	1	3	**4**
	Cortical	1	0	1	**2**
	Undetermined	1	0	2	**3**

Tab. 4. Dorsal scar negatives and platform type on artefacts from layer 3 of Pešterija Cave.

The relatively regular fractures on both ends of one distal and two medial fragments of blades made of 'Balkan flint' prompted us to conduct analyses to determine whether the blade fractures were intentional. The analysis utilized criteria proposed by Vyacheslav S. Slavinsky *et al*. (*2019*) and Hugo Anderson-Whymark (*2011*). Applying those criteria revealed that traces of intentional fracturing can only be observed on a single blade fragment (specifically the one used as an insert), at one fracture point. This is especially evident because this piece displays the point of percussion on the dorsal ridge, enabling a more predictable outcome of fracturing (*Slavynski* et al. *2019*). The absence of the Hertzian cone on this fracture may be attributed to the characteristics of the raw material. Additionally, the other two blade fragments do not display any discernible traces of percussion or flexing fracturing.

Among the retouched tools, abruptly retouched pieces represent the predominant type ($n = 6$). Furthermore, one retouched blade, a tool with an oblique-convex truncation, one retouched flake, and one denticulated tool were also discovered. Within the category of backed implements, the following were identified: three backed bladelets – two fragments with straight backs and one bladelet with a curved back – and two atypical geometric microliths including one segment (Fig. 12.q).

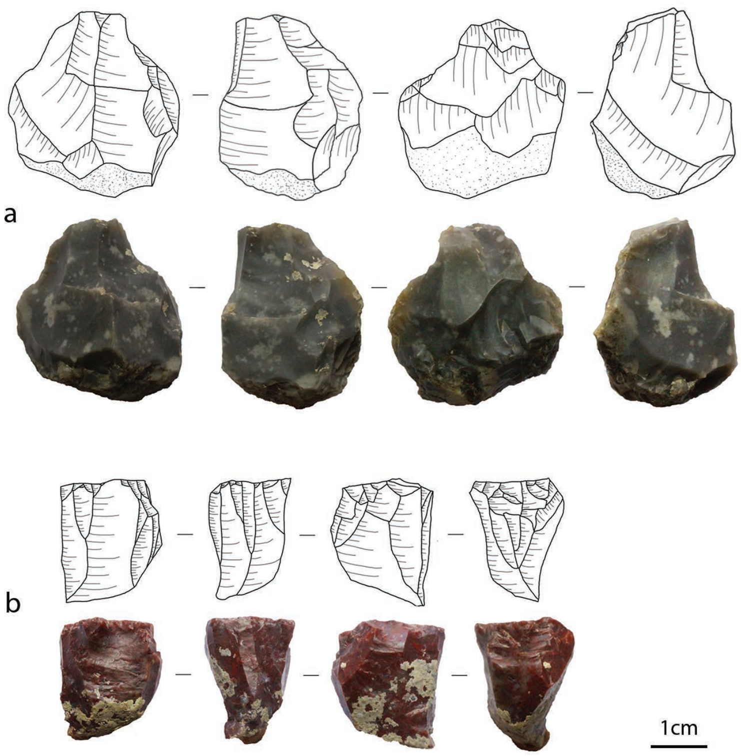

Fig. 10. Cores from layer 3 of Pešterija Cave (photo Danilo Pajović; drawing Sofija Dragosavac).

Use-wear analysis

Fifty-two knapped stone artefacts (Tab. 6) and one blade-like tool made from a fragment of a freshwater mussel shell (*Unio* sp.) – originating from geological layers 3 and 3/4 – were examined for traces of use (Fig. 13.a). The artefacts were analysed via low and high-power approaches (*Semenov 1964; Keeley 1980; Vaughan 1985; Jensen 1988; van Gijn 1989; Odell 2001*), using Nikon SMZ-U and Leica S9D stereomicroscopes, Olympus BX 51M and Nikon Eclipse ME 600 metallographic microscopes, and a Hirox RH 2000 digital microscope. The knapped stone artefacts were cleaned using detergent and demineralized water in an ultrasonic tank for 15 minutes, followed by rinsing for an additional 10 minutes. During the analyses, samples were further cleaned with ethanol as necessary.

The majority of the analysed artefacts (86%) had been affected by post-deposi-

	Platform thick.	IPA	Bulb morphology			Lip formation			Bulb scar		Conus formation
	(mean)	(mean)	absent	diffuse	pron.	absent	diffuse	pron.	absent	present	
Blades	2.77	/	0	3	0	0	1	2	3	0	0
Bladelets	2	92	2	3	2	1	4	2	7	0	0
Flakes	3.23	93.3	3	7	6	0	6	10	9	7	0

Tab. 5. The presence of attributes for characterizing the knapping technique on artefacts from layer 3 of Pešterija Cave (after* Pelcin 1997; Magnani *et al.* 2014; Hege 2015*)

tional surface modifications (PDSM), such as soil sheen (Fig. 13.b.1), glossy appearance, various mechanical alterations, bright spots, patina, general weathering, or a combination of two or more of these (Fig. 13.b.2). The most frequent PDSM is glossy appearance which damages the artefacts by creating a surface that mimics the polish generated by use. Thermal stress was found on 13% of the artefacts and it is distinguished by a colour change and potlid fractures (Fig. 13.b.3), usually associated with low to medium firing temperatures (*e.g., Purdy 1975; Patterson 1995; Petrović 2021*).

Unfortunately, post-depositional modifications have affected the preservation of the use-wear traces, and a large number of samples are interpreted as undiagnostic (56%), while 25% of the artefacts bear no traces of use. The non-diagnostic samples are interpreted as probably used, but the micro traces have been concealed or removed by physical and chemical alterations and the exact worked material could not be determined. Traces characteristic of processing animal matter are detected on 6% of the artefacts examined, vegetal materials on 2%, while 11% of the artefacts have only macro traces suggesting the use of medium-hard, medium or soft materials. The micro traces of hard animal materials such as bone or antler are represented by flat and melting topography, and covered linkage of polish. Topography characterizes the morphology of the polish, while linkage describes the connectivity of diverse polish features and levels of polish development more clearly, indicating the material, activity and time spent to modify a certain item. The texture can be smooth, or smooth and greasy/matt, and rough, or rough and greasy/matt, while topography can be domed, flat, pitted, granular, melting, cratered, or similar (*e.g., van Gijn 1989*). Linkage categories include open, tight, half-tight, compact, and indeterminable. The processing of hide/like materials is evidenced by step and halfmoon terminations (Fig. 13.c.1), rough texture (Fig. 13.c.2), granular topography and open linkage, suggesting a short period of use.

The evidence for working of vegetal matter at Pešterija is noted on one blade fragment used as an insert, from geological layer 3 (square N20/a). Macroscopic analysis showed snap and step scar terminations and developed edge rounding (Fig. 13.c.3). The oblique bidirectional trend testifies that the insert was used in a cutting motion. Microscopic observation revealed a smooth texture, flat topography and covered linkage identifying the micro polish as resulting from processing of vegetal matter, further implying a siliceous-rich plant (Fig. 13.c.4).

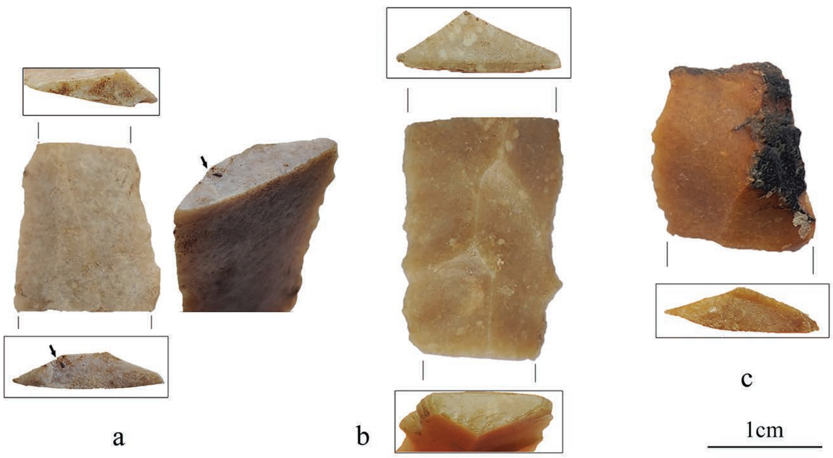

Fig. 11. Fragments of the 'Balkan flint' blades from layer 3 of Pešterija Cave (photo Sofija Dragosavac).

A techno-functional study of the artefacts from Mesolithic layer 5b at Rouffignac displayed similar traces that were also attributed to plant working, in particular, cutting reeds (*Visentin* et al. *2015.Fig. 65.2*). The absence of striations, noted on the insert from Pešterija, indicates the possibility of cutting wild siliceous species (*van Gijn 2010*). On another part of the used edge, there are random step and feather traces, which suggest that the blade fragment was embedded in a haft or handle. In addition to the traces of hafting, there are several areas of dark residues. The micro polish is evenly distributed suggesting that the blade was broken before it was used. The observed traces indicate that the insert was indeed hafted and used as a sickle. The nearest analogies are to be found in Bulgaria, where sickle inserts are considered as an

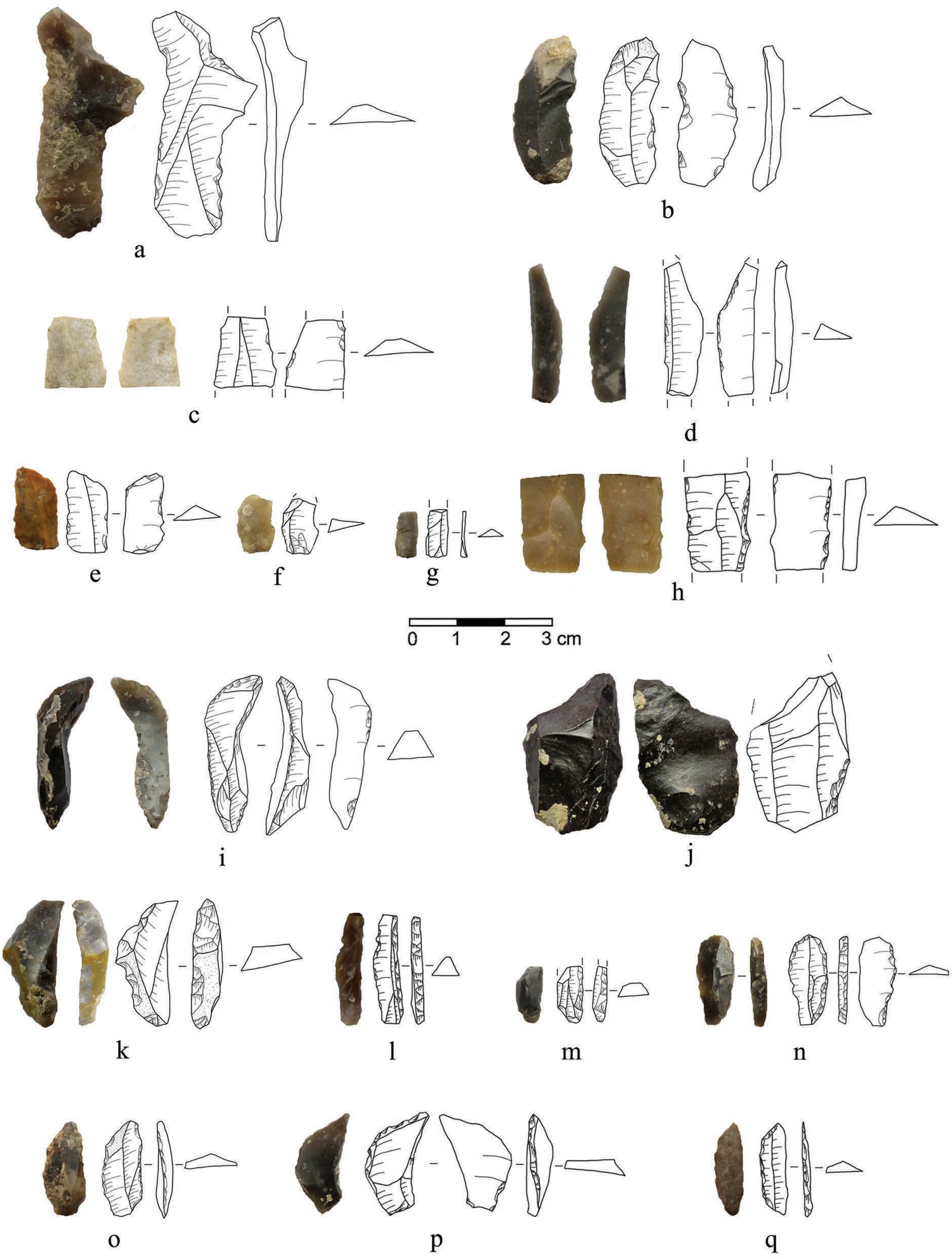

*Fig. 12. Unretouched blades and bladelets (*a–g*) and retouched tools (*h–q*) from layer 3 of Pešterija Cave (photo Danilo Pajović; drawing Sofija Dragosavac).*

Sample	Layer	Square	PDSM	Thermal stress	Activity	Worked material
1	3,4	M19/b	high glossy appearance			non-diagnostic
2	3,4	M19/b	glossy appearance			not used
3	3,4	M19/b				not used
4	3,4	L19/b	glossy appearance			non-diagnostic
5	3,4	M19/a	glossy appearance			not used
6	3,4	M19/b		yes, potlid fracture		non-diagnostic
7	3	M19/a	glossy appearance			non-diagnostic
8	3	M19/a	glossy appearance			medium material
9	3	M19/a	glossy appearance		cutting	hide-like traces
10	3	M20/d	glossy appearance			non-diagnostic
11	3	M20/d	high glossy appearance, soil sheen			non-diagnostic
12	3	M20/d	glossy appearance			non-diagnostic
13	3	M20/d	glossy appearance			non-diagnostic
14	3	M20/d	glossy appearance			non diagnostic
15	3	M19/d				not used
16	3	L19/c	high glossy appearance, traces of metal	yes, potlid fractures		non-diagnostic
17	3	M20/b	glossy appearance			non-diagnostic
18	3	M20/b	glossy appearance			not used
19	3	N19/b	patina			not used
20	3	N20/a	glossy appearance	yes, potlid fractures		not used
21	3	N20/a			cutting	plant
22	3	M19/b	light glossy appearance, white/ blue patina			not used
23	3	M21/a	soil sheen, glossy appearance, bright spot			non-diagnostic
24	3	N20/a	glossy appearance			not used
25	3	N20/a				not used
26	3	N20/a	glossy appearance, soil sheen			non-diagnostic
27	3	L19, M19, N19/a,b, H20/a,b	soil sheen, glossy appearance			not used
28	3	M20/b	glossy appearance, soil sheen			non-diagnostic
29	3	M19/b	glossy appearance, soil sheen			not used
30	3	N19/a	glossy appearance, soil sheen			hard animal material
31	3	N19/a	patinated			hide-like
32	3	N19/a	glossy appearance, metal			non-diagnostic
33	3	L19/a	glossy appearance, patina			non-diagnostic
34	3	N20/b	glossy appearance, soil sheen			soft, soft-medium material
35	3	N20/b				non-diagnostic
36	3	L19/d	glossy appearance			non diagnostic
37	3	L19/c	patina	yes		non-diagnostic
38	3	M19/b	light glossy appearance	yes, potlid fracture	cutting	soft-medium material
39	3	M19/b	glossy appearance		cutting	medium, medium-hard material
40	3	M19/b	high glossy appearance	yes		non-diagnostic
41	3	M20/b	light glossy appearance			medium
42	3	L20/d	glossy appearance			medium-hard material

Tab. 6. Use-wear analysis results.

Tab. 6 continued

43	3	L20/d	altered			non-diagnostic
44	3	M21/a	altered	yes		non-diagnostic
45	3	L20	bright spots, patina			non-diagnostic
46	3	L20	high glossy appearance			non-diagnostic
47	3	L20/a	high glossy appearance			non diagnostic
48	3	L20/a				non-diagnostic
49	3	L20/d	glossy appearance			non-diagnostic
50	3	L20/d	glossy appearance			non-diagnostic
51	3	L20/c	light glossy appearance			non-diagnostic
52	3	L20/c	light glossy appearance			not used

indicator of agricultural practices in the Early Neolithic as they were found in abundant quantities (*Gurova 2012*; *2014*).

Osseous tools and possible ornaments

Osseous tools

Manufacturing and usage traces were detected on several specimens, such as a red deer mandible (Fig. 15.a) from geological layer 3 (square M21/d), a fragment of a large mammal bone (potentially nasal) with a retouched edge, found in layer 3 (square M20/2), and the aforementioned *Unio* shell fragment (Fig. 14) retrieved from layer 3 (square N20/b).

The basal fragment of the red deer mandible discovered in square M21/d exhibited multiple sets of diagonal cut marks at varying angles, indicative of butchering (*cf. Binford 1981*), but it also displays evidence of additional manipulation and use. Specifically, it appears to have been intentionally fractured to create a 'point', with the surface of the break howing traces of polishing. Moreover, the traces on the 'pointed' portion suggest that the object was used in some manner (Fig. 15.a).

Two specimens (both from layer 3, square M19/c) could be associated with tool types already known from other Mesolithic sites in the wider region. The first one is an artefact made from a longitudinally split long bone diaphysis of a large mammal (Fig. 15.b). It was longitudinally broken but remained in use even after this. The preserved working edge is trimmed and concave, which is reminiscent of tools from the site of Vlasac which have been interpreted as chisels. At Vlasac, chisels were made from aurochs (*Bos primigenius*) metatarsals, by cutting off a part of the proximal end to produce a handle, and the work-

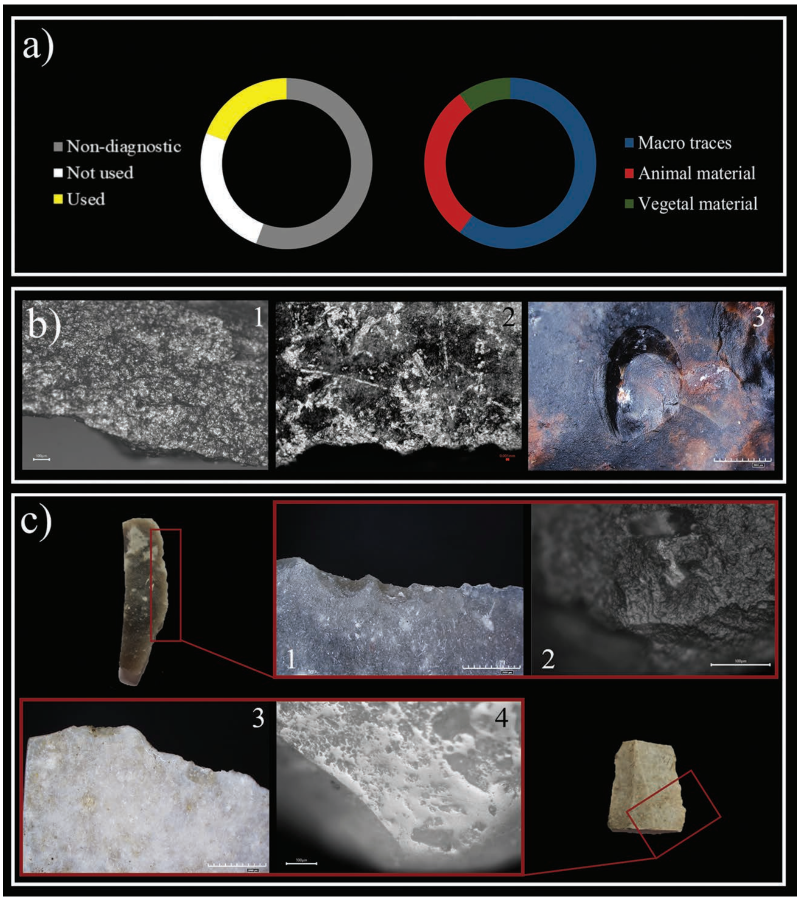

Fig. 13. **a** ***Use-wear results of the Pešterija Cave sample.*** **b** ***post-depositional surface modifications (PDSM):*** **1** ***soil sheen;*** **2** ***combination of soil sheen and glossy appearance;*** **3** ***potlid fracture as a result of thermal stress.*** **c** ***worked materials:*** **1** ***step and halfmoon macro terminations, hide processing;*** **2** ***rough texture, hide processing;*** **3** ***snap and step macro terminations with edge rounding, plant working;*** **4** ***flat topography and smooth texture, plant working (photo A. Petrović).***

ing part was trimmed into a fan-shaped or semi-circular edge. The length of such tools was usually between 8–10cm, and they were most likely used in woodworking. In addition, chisel-like artefacts with a similar trimmed fan-shaped, flat, or circular working edge, were also made from red deer antler and wild boar (*Sus scrofa*) tusks (*Srejović, Letica 1978; Borić* et al. *2014; Cristiani, Borić 2021*). The fragmented artefact from Pešterija was made from different raw material (*i.e.* from a long bone of a ruminant smaller than aurochs), but the similarity in the manufacture and the shape of the working edge suggests that it could have also been used as some sort of chisel.

The second specimen, a small antler tine fragment with a partially preserved working edge, also has analogies with the osseous industry from the Iron Gates sites. It is reminiscent of a fairly ubiquitous group of cylindrical and semi-cylindrical bevelled tools from Vlasac, made from red deer antler beams or tines, where the active part had been produced by percussion, oblique cutting and scraping to form a wide, usually fan-shaped edge (*Srejović, Letica 1978*). Based on their morphology and presumed function, such tools have been interpreted as hoes, axes, and axe-hammers (*Srejović, Letica 1978*), *i.e.* as chisels, axes or blades (*Cristiani, Borić 2021*), and were most likely used in tree-felling and/or woodworking. Apart from Vlasac, such tools have been found at many Iron Gates sites – Alibeg, Lepenski Vir, Răzvrata, Hajdučka Vodenica, Icoana, Ostrovul Banului, Schela Cladovei, Ostrovul Corbului, Velesnica and Kula (*Vitezović 2011; 2017; 2021; Boroneanț, Mărgărit 2017; Mărgărit, Boroneanț 2017; Mărgărit* et al. *2017a; 2017b; 2018a; 2023; Živaljević* et al. *2017b; Boroneanț* et al. *2018*). Given that the antler artefact from Pešterija was only partially preserved, the exact type could not be determined, but it was most likely some sort of cylindrical or semi-cylindrical bevelled edge tool.

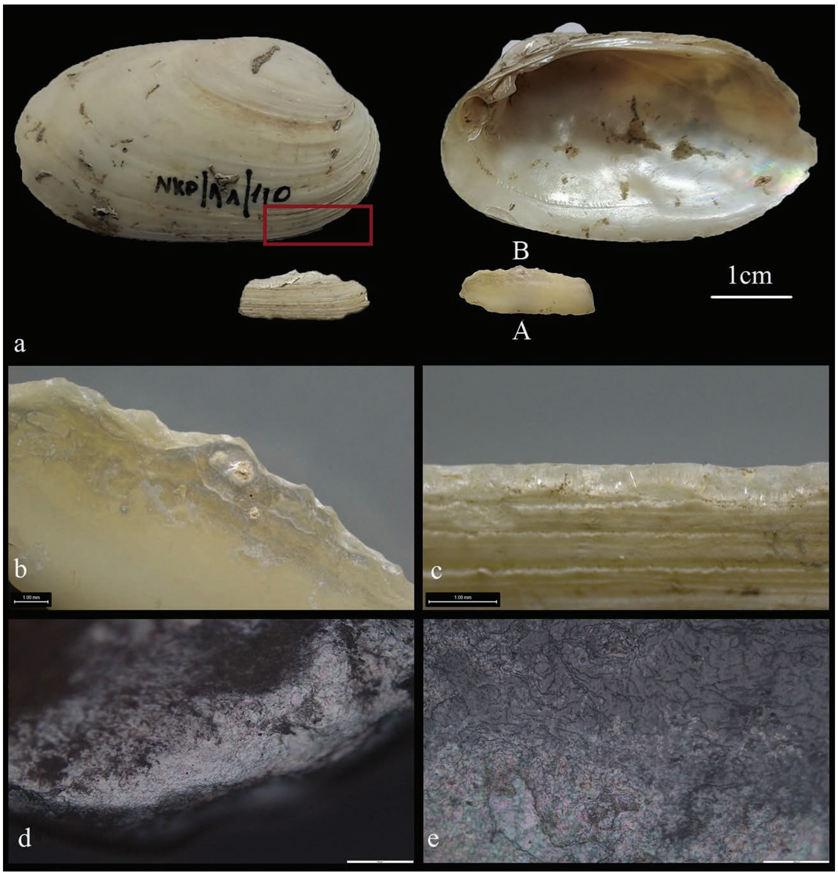

Fig. 14.* a *outer and inner sides of the valve of a mussel (*Unio crassus*) from the reference collection (Laboratory for Bioarchaeology, Department of Archaeology, University of Belgrade), Viminacium (NKP-11/110,131) and a blade-like tool made on the shell fragment found at Pešterija Cave.* b *macro trace, snap terminations and overlapping distribution, B side.* c *macro traces, short transitional striations, A side.* d *micro traces, smooth to rough texture, B side.* e *micro traces, granular topography and polish distribution, B side (photo A. Petrović).

A blade-like tool made from freshwater *Unio* mussel shell fragment was recovered from geological layer 3 (square N20/b). It was manufactured by shaping the fragment of the shell ventral marginal edge (Fig. 14.a). The most pronounced area of use is on the B side, where step scarring occurred with an overlapping distribution (Fig. 14.b). The trend of the traces is unidirectional oblique towards transitional, which is associated with a mixed motion of cutting and scraping. Macro traces are indicative of the working of hard to medium-hard material, possibly of mineral origin. On the opposite, A side, less developed traces with snap terminations are present, presumably from handling. Short striations directed transitionally are noted inside the macro scars (Fig. 14.c). Similar traces are observed when working the mineral materials, such as clay (*Mărgărit* et al. *2021. Fig. 3*).

The diagnostic micro traces with smooth to rough texture, granular to flat topography and covered linkage are found on the B side (Fig. 14.d-e). Based on both macro and micro traces, it is possible that this zone was used to process hard animal matter, either bone or antler. The micro traces on the A side show no visible striations, which is to be expected when processing clay, as previously shown by the experiments (*Mărgărit* et al. *2021.Figs. 3,4*). A more probable interpretation of the mentioned traces is the use of the A side for prehension, as the small, snap traces could have been made to support the grip of the hand. Another possibility is that this area was indeed used briefly to process a mineral matter, and then subsequently became the handle. Brief usage would explain the absence of the micro striations.

Possible ornaments

In addition to the two bone artefacts, another fragmented bone item was discovered in layer 3 (square L19/d), its specific function remaining somewhat ambiguous. It is a small fragment of a diaphysis of a large mammal long bone, with a partially preserved circular perforation (Fig. 15.c). This artefact could have been a bone pendant, similar to the perforated objects known from Vlasac (*Srejović, Letica 1978*) and Cuina Turcului (*Mărgărit* et al. *2020*). Other potential pendants or clothing appliqués include animal teeth specimens – an upper right canine and a lower left first incisor of red deer, and the aforementioned vyrezub pharyngeal tooth.

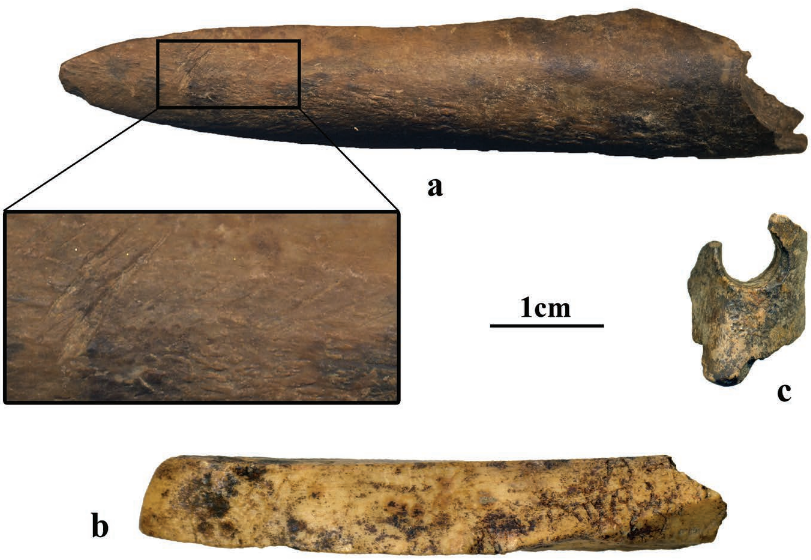

Fig. 15. **a** ***a fragment of a red deer mandible from geological layer 3 of Pešterija Cave (square M21/d), exhibiting traces of butchery and possible use.*** **b** ***a longitudinally broken bone tool, possibly a chisel (from geological layer 3, square M19/c).*** **c** ***a fragment of a bone object with a partially preserved circular perforation (from geological layer 3, square L19/d) (photo Ivana Živaljević).***

The red deer upper right canine (Fig. 16) was found in the zone of ashy sediment in geological layer 3/4 (square L19/a). Based on the size, morphology, closed root and heavy wear (*cf. d'Errico, Vanhaeren 2002*), it was determined that it originated from an older male, probably aged between six and 10 years. The canine was manipulated to a great degree, but the exact purpose of these modifications remains unclear. The occlusal surface of the crown wear is quite long and is completely covered with traces of polishing, and there are numerous, short overlying cut marks in several directions, inflicted by a very thin knapped stone tool. They were mainly oriented diagonally to the tooth-long axis, with a smaller number of transversal cut marks. Furthermore, the lingual surface of the crown exhibited three or four deep oblique cut marks, likely inflicted during the extraction of the tooth from the alveolus.

Throughout the Upper Palaeolithic and the Mesolithic, red deer canines were widely used as personal adornments, as demonstrated by numerous discoveries from burial and occupational sites across Europe (*e.g., Vanhaeren, d'Errico 2001; d'Errico, Vanhaeren 2002; Rigaud 2011; Grünberg 2013; Macāne 2022*). In the Balkans, they have been documented in Epipalaeolithic contexts in the Iron Gates (Cuina Turcului and Climente II), Bosnia and Herzegovina (Badanj), Croatia (Vela Spila and Vlakno) and Greece (Kastritsa and Klithi), whereas their use during the Mesolithic was primarily restricted to the Adriatic coast (Nugljanska peć, Pupićina peć, Vlakno and Lim 001) (*Cristiani* et al. *2014a; Borić, Cristiani 2016; 2019; Cârciumaru, Nițu 2018; Cvitkušić* et al. *2018; Mărgărit* et al. *2020; Cvitkušić, Vujević 2021*). Typically, such ornaments were made by drilling or carving a perforation into the root; however, the specimen from Pešterija lacked such perforation. Nevertheless, given the numerous traces of polishing and cut marks, as well as the presence of dark brown-blackish matter (possibly adhesive?) on the apex of the root and the tip of the crown, it can be assumed that the tooth was manipulated with a similar intention.

According to Francesco d'Errico and Marian Vanhaeren (*2002*) and Solange Rigaud (*2011. 79,139*), the presence of unpaired canines could suggest that these ornaments circulated in gift exchange networks. This interpretation seems particularly plausible in cases when a large number of unpaired canines occur in an assemblage, especially if they exhibit different manufacturing traces and techniques. The specimen from Pešterija is the only red deer canine in the assemblage, so it remains unclear whether it originated from an animal caught locally or was obtained through exchange. Nevertheless, it is worth mentioning that other red deer teeth were also present in the faunal sample from the site. One of them – a left first incisor – bore a small dent and several dark specks on the root, which could be indicative of ornament fastening and suspension.

The vyrezub tooth from Pešterija was fragmented (Fig. 9.b), so it was not possible to determine whether it bore a perforation or binding compound residues on the neck, which was a common suspension technique of vyrezub teeth ornaments in the Iron Gates (*Cristiani, Borić 2012; Cristiani* et al. *2014b; Mărgărit* et al. *2018b*). However, the absence of visible traces of modification or use does not exclude the possibility of its non-local origin. The Pešterija Cave is located about 100m above the small Zvonačka River, which flows into the Jerma (a tributary of Nišava), thereby placing it within the Danube drainage basin. Nevertheless, the site remains distant from known migratory routes of vyrezub, at least based on available data. For instance, current populations in the Dnipro and Don basins primarily spawn in larger rivers, typically those spanning at least 20–30 meters in width (*Boldyrev 2022*), and they do not migrate to smaller tributaries. The isolated populations in Austria do undertake short migrations from smaller Danube tributaries to lakes, but this is probably a consequence of habitat fragmentation and dam building in more recent times (*Schmall, Ratschan 2010*). It is also worth noting that no other fish remains were recovered from Pešterija, save for this particular tooth. Consequently, it seems plausible that it was acquired through exchange, possibly with Mesolithic communities in the Iron Gates, or perhaps that it was a part of the clothing of a traveller from afar.

Discussion

As will be evident from the preceding discussion, there is no doubt that the artefacts unearthed from layer 3 of the Pešterija Cave should be attributed to the Mesolithic. In terms of chronology, the site either dates back to the period before the emergence of the Neolithic in the central and eastern Balkans (*c.* 6300/6200 cal BC) or is contemporary with it. Moreover, the settlement patterns, dietary practices, and technological behaviours recorded at Pešterija closely resemble those observed at Mesolithic sites within the Iron Gates region and throughout the Balkan interior, such as Trebački Krš near Berane (*Đuričić 1996*), Vrbička Cave near Nikšić (*Borić* et al*. 2019*), Neziri Cave in Albania (*Hauck* et al. *2017*), and Hoţilor Cave situated north of the Iron Gates (*Boroneant 2011*). Most of these sites in the interior of the peninsula exhibit low numbers of finds, with forest species (primarily deer) dominating the faunal assemblages, while among the artefacts,

Fig. 16. An upper right red deer canine found in the zone of ashy sediment in geological layer 3/4 of Pešterija Cave (square L19/a), exhibiting numerous modifications (polishing and cut marks) (photo Ivana Živaljević).

tools crafted from irregular flakes are common, alongside sporadic instances of backed tools and geometric microliths.

Nevertheless, it is important to consider that most of the sites comparable to Pešterija belong to the Early Mesolithic rather than the Late Mesolithic. Focusing solely on the Late Mesolithic sites (*i.e.* those dating later than *c.* 7500 cal BC), the potential for comparison diminishes substantially as this period in the central Balkans has only been documented in the Iron Gates region. There are similarities between Pešterija and the Late Mesolithic lithic assemblages in the Iron Gates region (Vlasac, Ostrovul Banului, *etc.*), particularly evident in the knapping technology, characterized by the co-occurrence of bladelets and relatively wide blades, tools on irregular flakes, and backed tools (*Kozłowski, Kozłowski 1982; Radovanović 1996a; Boroneanț 2000*). All this indicates that there was a technological uniformity of Late Mesolithic industries in the interior of the Balkans, which is somewhat different from coeval industries in the hinterland of the coastal zone (*e.g.,* Crvena Stijena, Odmut), which exhibit a strong Castelnovian component (*Kozłowski* et al. *1994; Mihailović 2007a; Kačar 2019*).

The discovery of the vyrezub pharyngeal tooth in Pešterija, possibly used as an ornament, provides evidence of the social connectivity among the communities dwelling in Pešterija and those in adjacent regions. The utilization of such teeth as personal ornaments has been documented across Central, Southeastern, and Eastern Europe during the late 8th and throughout the 7th millennium cal BC (extending even longer in the latter region). The production of ornaments (most likely garment appliqués) included the extraction of teeth from the pharyngeal bone, drilling through or grooving at the tooth neck to enable fastening and suspension by sinew threads and binding organic compounds (*Rigaud 2011; Cristiani, Borić 2012; Cristiani* et al. *2014b; Rigaud* et al. *2014; Mărgărit* et al. *2018b*). Vyrezub teeth modified in such a manner have been discovered in Late Mesolithic burial and occupational contexts in the Upper Danube region in Germany (Probstfels, Falkensteinhöhle, Burghöhle von Dietfurt, Hohlenstein-Stadel) (*Rigaud 2011*; *Grünberg 2013*), in the Iron Gates (Lepenski Vir, Vlasac, Icoana, Schela Cladovei, Kula) (*Srejović, Letica 1978; Radovanović 1996b; Borić 2003; Borić* et al. *2014; Borić, Cristiani 2016; 2019; Živaljević 2017; Živaljević* et al. *2017b; Mărgărit* et al. *2018a*), in the Crimea (Shan-Koba, Zamil-Koba I) (*Kraynov 1938; Bibikov* et al. *1994*) and the Dnipro Rapids region in Ukraine (Mar'ivka, Vasylivka II, Skelia-Kamenolomnia) (*Telegin 1991; Lillie* et al. *2020; Haskevych 2022*).

Mesolithic communities residing along the Danube, Dnipro, and Crimean rivers certainly had first-hand knowledge of schools of vyrezub during their seasonal migration to these waterways, especially during spawning (between April and May, *cf. Kottelat, Freyhof 2007; Schmall, Ratschan 2010*). Although these fish were caught locally in all mentioned regions, the utilization of the same element from the same species underscores a notable level of connectivity and shared concepts regarding bodily adornment and meanings attributed to the fish across a broad geographical area. The occurrence of a vyrezub tooth at Pešterija Cave indicates that such concepts and practices also spread beyond the natural habitats of the species, *i.e.* through exchange networks.

The differences between Pešterija Cave and the coeval sites in the Iron Gates largely stem from the fact that Pešterija, unlike the settlements in the Iron Gates, represented a temporary hunting camp where various activities were carried out. Opportunities to utilize diverse resources, including the forest fauna found on the slopes of Asenovo Kale Hill, were available close to the cave. Since there are no indications that Mesolithic communities stayed in the cave for extended periods or that the cave was inhabited by a large group, it is logical to assume that a larger settlement – which could have served as a base camp – probably existed in the proximity of Pešterija.

At this point, the question arises of how to explain the presence of Mesolithic groups in the mountainous regions of southeastern Serbia, some 20km away from the Nišava River valley, which could have served as a centre of aggregation for the Mesolithic population. Although this issue can only be discussed hypothetically for now, we will provide some possible explanations (which are not mutually exclusive):

- The most logical explanation is that Mesolithic sites in the Nišava Basin have not yet been discovered. However, several caves have been excavated in the Ponišavlje region so far, including those ideally positioned relative to the river, but no Mesolithic remains have beendocumented (except in Pešterija). For example, no Mesolithic finds were detected in Pešturina Cave (located near the Nišava River on relatively low terrain), at the Pećina kod stene site (situated just a few meters above the Studena River bed in Jelašnica Gorge), or in the Potpeč Cave on the banks of the Visočica River – which provides evidence of fishing at the beginning of the Last Glacial Maximum (the results of research are yet to be published).

- The settlement of hilly-mountainous areas in the interior of the Balkans may have been uneven, influenced by geographic, ecological, and social factors (such as the need to maintain exchange and information networks, *etc*., *Whallon 2007; 2011*). In this context, the question arises whether the Upper Ponišavlje region provided favourable conditions for seasonal exploitation of the mountainous zone – as in Istria (*Komšo 2006*) and northern Montenegro (*Mihailović 2007a; Borić* et al. *2019*) – or if the settlement of this part of the peninsula occurred for other reasons.

- Regarding the previously mentioned points, it is worth noting that two out of three radiocarbon dates obtained suggest that the occupation of Pešterija Cave aligns chronologically with the emergence of the Neolithic in the central and eastern Balkans, dated *c.* 6300/6200 cal BC. If there was territorial competition between Mesolithic and Neolithic groups, it could have led to the retreat of Mesolithic communities into suboptimal ecological zones on the fringes of areas best suited to agriculture (*Forenbaher, Miracle 2006; Radovanović 2006; Mihailović 2021*).

The notion of contemporaneity and the role of social factors is supported not only by the homogeneity of Mesolithic technology and the evidence of the transportation of the vyrezub tooth, but also by the presence of artefacts made from 'Balkan flint' and (likely) sickle inserts in Pešterija. Similar findings were already documented in the Early Neolithic of the Iron Gates and northwestern Bulgaria (*Borić 2011; Gurova 2012; 2014; Gurova* et al*. 2022*). Artefacts made from 'Balkan flint' have been previously documented in Late Mesolithic layers at Vlasac, Padina, and Lepenski Vir (*Kozłowski, Kozłowski 1982; 1984; Gurova* et al. *2022*) and may represent the earliest evidence of contacts between Mesolithic and Neolithic groups (*Mihailović 2007b*). Of course, it remains to be seen whether the raw material from Pešterija indeed belongs to the typical 'Balkan flint' category. However, even if this is not the case, it is worth noting that Mesolithic and Neolithic communities utilized various types of this raw material (*Gurova* et al. *2022*). The use of this material carried not only economic significance, but also social importance, indicating social openness (*Mihailović 2007b*).

Conclusions

After decades of searching (albeit not systematically) for Mesolithic sites in the interior of the Balkans, one such site has indeed been discovered: Pešterija Cave. Nevertheless, this site was not in proximity to the Iron Gates, significant rivers, or any easily accessible terrain. Instead, it was found in an unexpected location – distant from the Mesolithic group aggregation hubs, *c.* 20km away from the Nišava valley, situated in a relatively remote area in southeastern Serbia. Nevertheless, Pešterija Cave represents a more or less typical Mesolithic temporary settlement with characteristic tools and faunal remains. This goes against (perhaps unrealistic) expectations that larger, archaeologically visible semi-sedentary Mesolithic settlements near the Danube would be discovered first.

Pešterija Cave testifies to the fact that Mesolithic populations (apart from the Danubian region) did inhabit the interior of the Balkans, which had long been assumed but lacked confirmation. It remains to be determined in which geographic areas and under what circumstances the aggregations of Mesolithic groups took place, what settlement patterns these communities practiced, what was their social connectivity like, and what kinds of interactions these populations had with Neolithic ones.

The presence of 'Balkan flint' and sickle inserts suggests contact of Mesolithic groups that inhabited Pešterija with Neolithic communities in neighbouring areas – most likely from northwestern Bulgaria. This would imply that interactions between Mesolithic and Neolithic groups, previously documented only in the Iron Gates region (*Borić, Price 2013*), were probably not an isolated but a widespread phenomenon. In any case, the discovery of the Mesolithic at Pešterija Cave opens up a completely new perspective in the Mesolithic and Neolithic research of eastern Serbia and northwestern Bulgaria. This applies particularly to the Ponišavlje region, where recent research has unveiled evidence of human settlement spanning from the Last Glacial Maximum to the advent of the Neolithic.

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Late Upper Palaeolithic ornaments from Vlakno cave, Croatia

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ABSTRACT - *This paper presents the richest prehistoric assemblage of ornaments in the Eastern Adriatic discovered to date, found in the Late Upper Palaeolithic layers of Vlakno cave, Croatia. The abundance and multiform of bead types indicate that the site was likely used as a workshop for ornaments,* i.e. *that production was performed on site. Technological and use-wear analysis of each taxon used for beads allowed us to elaborate on its mode of production, use, and overall position of the Vlakno cave site and its role in the regional context during the Late Pleistocene.*

KEY WORDS – *ornaments; use-wear analysis; Late Upper Palaeolithic; Eastern Adriatic; Vlakno cave*

Poznomlajšepaleolitski nakit v jami Vlakno, Hrvaška

IZVLEČEK – *V članku predstavljamo najbogatejšo doslej odkrito prazgodovinsko zbirko nakita na vzhodnem Jadranu, ki je bila najdena v poznomlajšepaleolitskih plasteh v jami Vlakno na Hrvaškem. Številčnost in raznolikost jagod nakazujeta, da je bilo najdišče verjetno uporabljano kot delavnica za nakit in da je proizvodnja potekala na kraju samem. Tehnološka analiza in analiza obrabe vsakega taksona, ki je bil uporabljen za izdelavo jagod, nam omogočata določiti način izdelave in uporabe ter mesto in vlogo jamskega najdišča Vlakno v regionalnem kontekstu v poznem pleistocenu.*

KLJUČNE BESEDE – *ornamenti; analiza sledov uporabe; pozni mlajši paleolitik; vzhodni Jadran; jama Vlakno*

Introduction

During the Upper Palaeolithic period, craft specialization reflects the increasing complexity of human culture and behaviour. The development of sophisticated tools, artistic expression, and symbolic artefacts suggests that our ancestors possessed advanced cognitive abilities, social structures, and cultural practices. These crafts served practical purposes but also were crucial in expressing identity, spirituality, and social cohesion within Upper Palaeolithic societies. One of the recognized prehistoric crafts is the production of ornaments (*Rigaud* et al. *2019*). Personal ornaments have been, and continue to be, elements that embody and signify social and individual identity. Since the Upper Palaeolithic, our ancestors have crafted beads and pendants from various materials (*e.g.*, *Vanhaeren, d'Ericco 2006; Bar-Yosef 2015; Radovčić* et al. *2015; Sehasseh* et al. *2021*). However, the only ones preserved are those made of inorganic and animal hard tissues like stone, clay, bone, ivory, teeth, and mollusc shells. In contrast, organic materials such as wood, leather, and

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feathers that were likely used for ornamentation have decomposed and disappeared (*Hurcombe 2014*). Since Randall White (*1992*) highlighted the social and symbolic roots of ornaments' origin, prehistoric body adornment has been studied widely. However, there is still much to understand and learn about the symbolic behaviour of our ancestors. What were the modes of acquiring raw materials for ornamentation or the modalities of bead production, use, and finally discard? Obtaining information on these specific issues is not an easy task because of the archaeological contexts of their discovery. Prehistoric beads are rarely found *in situ* as a part of the preserved ornamental composition, *i.e.* as a part of burials (*e.g., Orschiedt 2016; Gravel-Miguel* et al. *2022*). Mostly, they are discovered scattered throughout the deposits or during the subsequent sieving of the sediment. Despite the challenging circumstances of their found state, detailed analysis of these mainly small-sized artefacts can provide important information about our ancestors' lifestyles and symbolic behaviour. In that sense, the Vlakno cave stands out as an important site for activities related to prehistoric ornaments in the wider Adriatic region during the Late Peniglacial and beginning of the Holocene. Integrated analysis of the most numerous collection of *Columbella rustica* shells from Vlakno cave gave us solid arguments for how this prehistoric site was used as a specialized workshop for ornaments, especially during the Holocene (*Cvitkušić* et al. *2024*). To strengthen the hypothesis of the site's role as a workshop for ornaments and to extend it to the Upper Palaeolithic period, here we present a detailed analysis of the ornaments discovered in the Epigravettian layers of Vlakno cave, which is to date the richest discovered assemblage of ornaments in the Eastern Adriatic. Moreover, a thorough analysis of each taxon used for beads during the Pleistocene in Vlakno cave allowed us to elaborate on its mode of production and use in the regional context spanning a period of almost 10 000 years.

Site background

The Vlakno cave is situated on the island of Dugi Otok on the Eastern Adriatic coast of present-day Croatia (Fig. 1). The cave is positioned on the eastern slopes of the central part of the island, 150m away from today's seashore (Fig. 2.a). A wide opening oriented towards south/south-east and the small inner cave space of about 40m^2 made it ideal for small groups of foragers during the Upper Palaeolithic and the Early Mesolithic (*Vujević, Parica 2011; Vujević, Bodružić 2014; 2021; Vukosavljević* et al. *2014; Vujević 2016; 2021; Cvitkušić* et al. *2018*). The potential of the cave for such use is additionally emphasized by a spring in the immediate vicinity, next to today's beach (*Brusić 2004.198; Vujević 2018.41; 2021.35*).

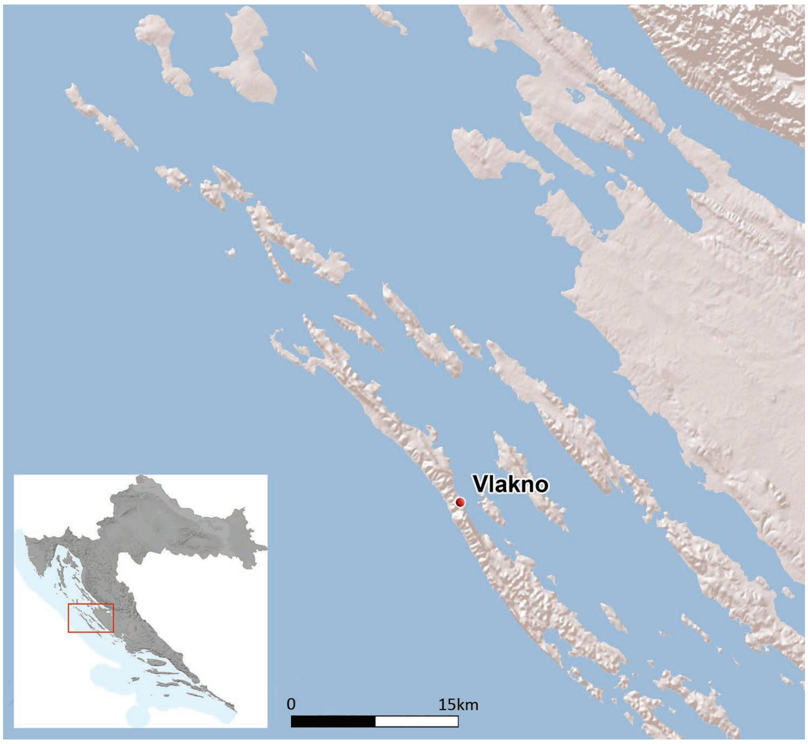


Fig. 1. Position of Vlakno cave on Dugi otok, Croatia.

Research in the cave started with a small test trench (2m^2) in 2004 (*Brusić 2004*). Research was continued in 2007 (*Brusić 2007.400–401*), and systematic excavations began in 2011. They covered an area of 12m^2 east of the test trench.[1] The five-meter-deep test trench revealed numerous cultural layers which can be monitored with relative continuity to 19550–19400 cal BP (Beta-302247:

1 The research was carried out as part of two scientific research projects of the Croatian Science Foundation: Epigravettian communities of Northern Dalmatia (IP-2019-04-6115) and Transition and tradition in the Vlakno cave: Model of the transition from the Palaeolithic to the Mesolithic in the area of Northern Dalmatia (UIP-2014-09- 1545).

16 330±70 BP). However, the bedrock has not been reached, so this depth regarding the archaeological stratigraphy is probably not final. Ongoing systematic excavations reached a 4 m depth from the surface (Fig. 2.b).

The stratigraphy reflects the potential of the site. The preliminary results of the geoarchaeological analysis show strong anthropogenic processes in almost all layers (Boschian pers. comm.). The stratigraphic sequence is intersected at a depth of approximately 2m by a 10–15cm thick layer of tephra (Neapolitan Yellow Tuff) from the eruption on the Phlegraean fields near Naples that happened 14.9±0.4 ka cal BP (*Deino* et al. *2004; Vujević 2021*). The thick cultural layer and stratigraphy without visible hiatus (beside tephra) places Vlakno cave among the few sites in the wider Adriatic region that makes it possible to explore the last phases of the Pleistocene after the Last Glacial Maximum (LGM) and adaptation of communities to the new climatic period of the Holocene (*Vujević, Parica 2011; Vujević, Bodružić 2014; Vukosavljević* et al. *2014; Vujević 2016; 2018; 2021; Cvitkušić* et al. *2018*).

To date the stratigraphy of the Vlakno cave is divided into ten strata, five of which form the upper part of the stratigraphic sequence, the one above the tephra, while the other strata are in layers below it (Figure 3). Stratum 1 represents the surface layer. It is characterized by dominant Mesolithic finds mixed with a smaller amount of cultural material from other periods, from the Neolithic to the Modern Age. Strata 2 and 3 are associated with the very beginning of the Holocene. Chronologically, the Holocene occupation started ca. 11 300 cal BP (Beta327417 9860±40 BP, (94.2%) 9370–9260 cal BC; 11 320–11 210 cal BP) and lasted until *c.* 10 000 cal BP (Beta677951 9300±30 BP, (95.4%) 8179–7773 cal BC; 10 128–9722 cal BP; *Vujević, Cvitkušić 2024*).

Fig. 2. **A** ***The position of Vlakno cave on the eastern slopes of the central part of the Dugi otok;*** **B** ***Inner place during systematic excavations.***

Stratum 4 ends the Pleistocene, while Stratum 5 represents the first phase of the cave settlement after the eruption in the Phlegraean fields. The tephra layer served as a stratigraphic boundary between Stratum 5 and Stratum 6 (*Vujević, Parica 2011.26; Vujević, Bodružić 2021*). Strata 6–10 below the tephra layer represent various Late Upper Palaeolithic (LUP) phases. The dates cover the chronological period from about 15 000 to 19 500 cal BP. Stratum 10 includes the lowest layers from the test trench, although since these layers have not yet been reached through systematic excavations, the phasing could be some what different in the future.

In cultural terms, Strata 2 and 3 belong to the Early Mesolithic period. Although it corresponds temporally to the *Sauveterrian* (see *Visentin 2017*), the characteristics of the lithic assemblage show little similarity with it, showing one more time that the use of the term Mesolithic in the Northern Adriatic context is primarily a chronological determinant (*Miracle* et al. *2000; Vukosavljević* et al. *2014*). Basically, almost the entire stratigraphic sequence of Vlakno cave is so far characterized by the

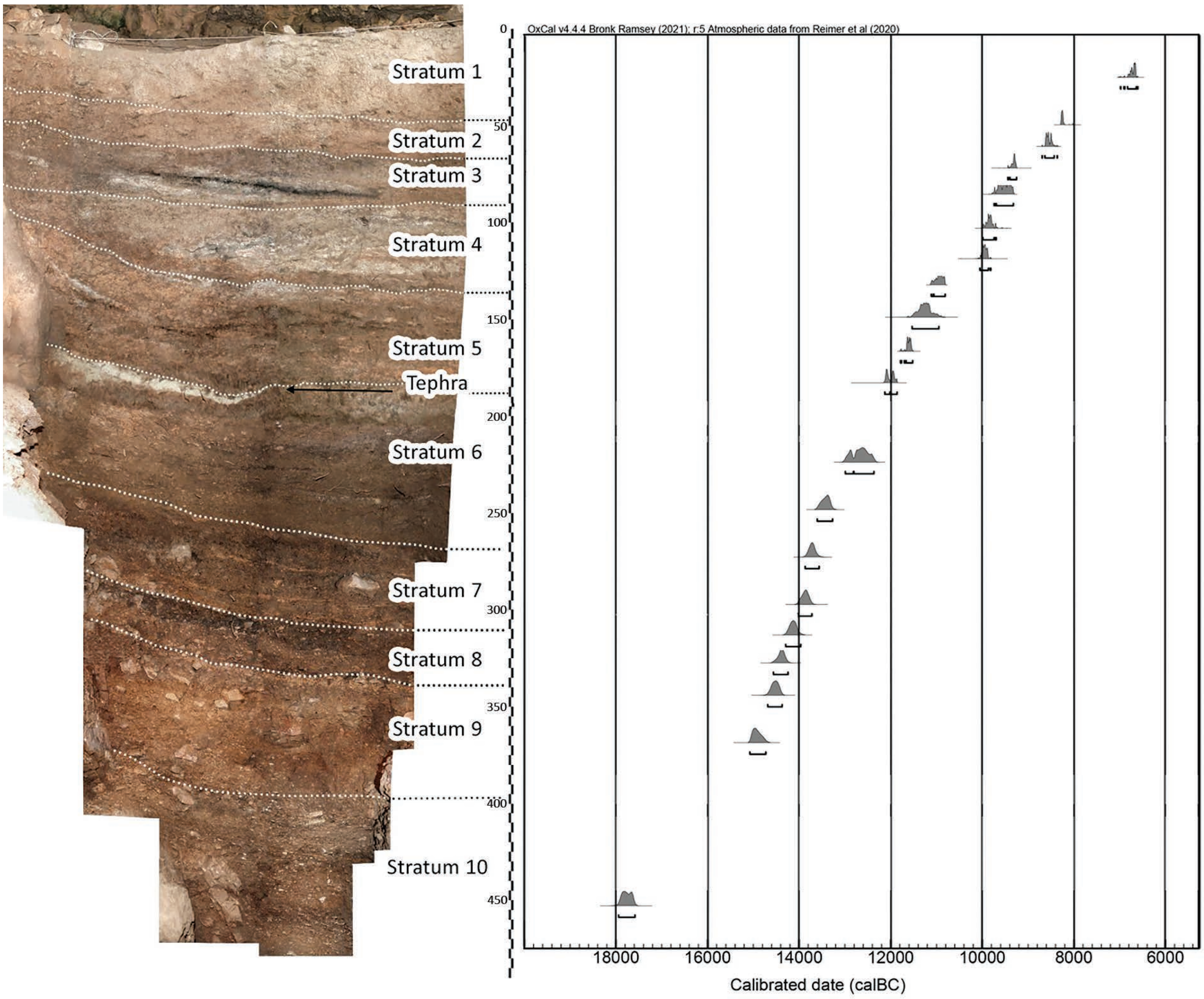


Fig. 3. The stratigraphic sequence of Vlakno cave (D. Vujević).

Epigravettian cultural assemblage. Some differences can be noticed in the lithic assemblage of Stratum 2, but they relate to the frequency of different tool types without the emergence of new ones. There is a decrease in the number of endscrapers and backed tools, as well as in bladelets and blades usage for tool production (*Vujević, Bodružić 2021*). Faunal records show similar patterns, although with more pronounced changes during the transitional and especially Holocene period in which big game hunting (mostly red deer) continued to be practised but groups also made use of other available mammalian species, in particular small game and small to medium-sized carnivores such as foxes. Holocene groups also adapted and diversified their diets by including land snails, marine molluscs and fish (*Radović* et al. *2021*). Lithic analyses by Vukosavljević (*2012.127*) and Dario Vujević and Mario Bodružić (*2021*) have shown that the occupation at Vlakno in all phases had a strong residential character. However, the question is whether it has always been the primary reason for choosing Vlakno. Nikola Vukosavljević (*2012.128*) has questioned the residential character of the site during the formation of Stratum 2 due to the presence of a Mesolithic burial in the small cave area. Other categories of finds, especially ornaments, could also indicate different functions of the place, at least in certain periods. A rich assemblage of personal ornaments in the form of beads and pendants is represented throughout the sequences. Besides ornaments made from modified shells and animal teeth, in Late Upper Palaeolithic deposits artefacts decorated with geometric incisions have also been discovered, such as an anthropomorphic bone pendant, two deer canines, an animal bone rib, and two fragments of chert nodules. As this paper focuses on the ornaments, such decorated artefacts will not be presented here.

Material and methods

Throughout the Late Upper Palaeolithic deposits, 897 pieces of ornamental assemblage were discovered, of which 413 are beads, 36 are unmodified specimens (Fig. 3; Tab. 1, see below), together with 448 fragments and debris. The ornamental assemblage is classified according to taxonomic and ecological/environmental attributes (see Methods), as follows: Class 1 – marine gastropods, bivalves, and scaphopods; Class 2 – freshwater gastropods; and Class 3 – terrestrial mammals. Table 1 presents the distribution of beads and unmodified specimens for each taxon throughout LUP layers. In particular, Class 1 is represented by gastropods *Columbella rustica*, *Tritia neritea*, *Luria lurida* and *Tritia nitida*; bivalves *Glycymeris* sp. and *Acanthocardia tuberculate*; scaphopods *Antalis* sp. In Class 2 are *Theodoxsus danubialis* and *Lythoglyphus naticoides*, while in Class 3 are *Cervus elaphus* teeth. Out of 448 fragments and debris in the assemblage, 29 fragments belong to the *Glycymeris* shells and 419 to the posterior ends of *Antalis* sp., determined as production waste.

Taxonomical determination of marine species is done by the Atlas of the Mediterranean Seashells (*Giannuzzi-Savelli* et al. *2001; 2002; 2003*), while the nomenclature follows the World Register of Marine Species (https://www.marinespecies.org/index.php – accessed on February 2019 and April 2020). The poor state of preservation and surface exfoliation made it impossible to taxonomically determine two marine species belonging to the *Glycymerididae* and *Dentaliidae* families. According to the literature, several similar scaphopod species were present along the Mediterranean shores during the Pleistocene (*Poppe, Goto 1991*). Formerly in the generic genus *Dentalium*, species from the Mediterranean are now attributed to the genus *Antalis* (*H. Adams, A. Adams 1854*). Vlakno specimens are likely a mix of more than one species *e.g.*, *Antalis vulgaris, Antalis dentalis,* and *Antalis inaequicostata* that we group under the taxon *Antalis* sp. Regarding the *Glycymerididae* family, there are three determined species in the Adriatic Sea: *Glycymeris bimaculata* (*Poli 1795*), *Glycymeris glycymeris* (*Linnaeus 1758*) and *Glycymeris nummaria* (*Lamarck 1758*) (*Legač, Hrs-Brenko 1999; Crnčević 2014*). In earlier studies, *Glycymeris pilosa* (*Linnaeus 1767*) and *G. glycymeris* were mistakenly identified as *G. glycymeris* (*e.g.*, *Poppe, Goto 1991; Legač, Hrs-Brenko 1999; Peharda* et al. *2010*). Recently *G. pilosa* and *G. glycymeris* have been identified as two different species (*Purroy* et al. *2016*). While *G. glycymeris* is well documented in the North Atlantic, its presence is poorly documented in the Mediterranean, compared to *G. pilosa* and *G. bimaculata,* which are well documented in the Adriatic Sea (*Purroy* et al. *2016; Legač, Hrs-Brenko 1999*). Overall, the complex determination of bivalves is the reason for different data on the distribution of species of this genus (*Legač, Hrs-Brenko 1999*). Concerning the Vlakno case, characterized by poor preservation and surface exfoliation on a significant share of *Glycymeris* specimens, we have decided to group them under the taxon *Glycymeris* sp. *Tritia neritea* (*Linnaeus 1758*) is a species of marine gastropods that belongs to the *Nassariidae* family and is widespread in shallow waters of the Mediterranean, sandy shores of the Atlantic coast (*e.g.*, in Portugal, Spain and France) as well as in coastal lagoons, saltmarshes and close to river mouths (*Southward* et al. *1997*). Its distribution is also well recorded in the Adriatic region. All the marine species used for bead production in Vlakno cave can be found in the Adriatic Sea.

The taxonomy of freshwater gastropods is determined according to the literature (*Mastitsky, Samilenko 2006; Komšo, Vukosavljević 2011; Cristiani 2012*). *Theodoxus danubialis* is a common species of river snail present in the area of the Danube River, which can also be found in rivers and lakes from northern Italy to Slovakia, Ukraine, and Croatia (*Hartzhauser* et al. *2007*). *Lithoglyphus naticoides* are present in the shallow waters of rivers and lakes in central and eastern Europe (*Hartzhauser* et al. *2007*) as well as in the Balkans, in the rivers of the Black Sea drainage basin (*Radoman 1983*). Both species can be considered autochthonous.

Siniša Radović (Department of Palaeontology and Quaternary Geology, Croatian Academy of Sciences and Arts) determined the attribution of mammal teeth, while the sex determination of red deer canines was carried out according to the criteria in Francesco d'Errico and Marian Vanhaeren (*2002*).

The complete ornamental assemblage has undergone technological, use-wear, and residue analysis to reconstruct its production and use modalities. Our methodology integrates metric, technological, use-wear, and residue studies supported by taphonomical examination. Taxonomic identification was carried out on all specimens, including fragments. Morphometric measurements were taken to determine variability and frequencies. After visual inspection, the specimens were sorted according to their integrity into three groups: Group 1 – whole specimens with perforation; Group 2 – whole specimens without perforation; and Group

3 – broken specimens, fragments, and debris. Group 1 includes whole, undamaged perforated specimens and specimens with missing small parts, *e.g.*, the apexes of the gastropods, small parts of the roots, or crowns of the teeth.

Metrical variables are recorded with a digital calliper in two general categories: (1) the dimensions of maximum length and width (in mm) for all specimens (Groups 1, 2 and 3), and (2) the dimensions of maximum length and width (in mm) of hole for all perforated specimens (Group 1). For *Antalis* sp., additional dimensions were taken, in particular, the radius of the anterior and posterior extremities. Specimens with a radius of dorsal aperture ranging from 0.64 to 1.98mm are selected as waste, and those with an aperture equal or larger to 1.99mm as beads (*Lindberg 2013; Arrighi* et al. *2020*). Concerning the length, *Antalis* beads are divided into three categories: Category 1 – beads smaller than 10.00mm; Category 2 – beads between 10.01 and 19.99mm; and Category 3 – beads longer than 20.00mm.

The taphonomic study was carried out on marine and freshwater shells' beads with a focus on pre-depositional alterations (predator drilling, bioerosion), anthropogenic modifications (perforations, ochre residues, thermic alterations), and post-depositional alterations (fragmentations, decalcifications) (*Driscoll, Weltin 1973; Claassen 1998; Crothers 2004; d'Errico* et al. *2005*).

All specimens were analysed by low and high magnification using a Zeiss Axio Zoom V16 stereo microscope with progressive magnifications ranging between ×10 and ×112 and equipped with a Zeiss Axiocam 305/506 colour camera in the DANTE – Diet and Ancient Technology Laboratory, Sapienza University of Rome, Italy. The use-wear and technological analysis of beads aimed to identify functional modifications such as the rounding of the perforation, faceting of the profile, changes of colour, striations, and residues to discern patterns of acquisition, manufacturing, wear, use, and deposition/discard. The type and distribution of use-wear traces and residues on well-preserved perforated shells related to the perforation hole, the lip, and dorsal and ventral surfaces have been recorded. Use-wear traces and residues related to the root, crown, and perforation were recorded for teeth pendants. Interpretative criteria for the technological and functional study are established by previously conducted studies on the production and use of prehistoric ornaments (*Taborin 1993; Vanaheren, d'Errico 2001; 2003; 2005; d'Errico, Vanhaeren 2002; Bonnardin 2007; 2009*).

Results

The LUP ornamental assemblage from Vlakno cave is rich and diverse (Fig. 4). Analysis showed that beads (N=413) were produced from ten different raw materials (Tab. 1 and Fig. 4), *i.e. Columbella rustica* (N= 23), *Tritia neritea* (N=132), *Luria lurida* (N=1), *Tritia nitida* (N=7), *Glycymeris* sp. (N=29), *Acanthocardia tuberculate* (N=1), *Dentalium* sp. (N=183), *Theodoxsus danubialis* (N=6), *Lythoglyphus naticoides* (N=2), and *Cervus elaphus* teeth (N=29). Throughout the LUP layers, 36 unmodified specimens of marine shells (N=18) and red deer canines (N=18) were discovered. Most of the LUP ornamental assemblage is well preserved.

Marine molluscs

Of the marine species, ***Columbella rustica*** shells are the best preserved (Fig. 4.a). Most of the *C. rustica* shells are complete, while ~20% of specimens are missing lip or apex parts. Pitting and root damage are observed on two specimens. Almost 20% of perforated *C. rustica* shells are black, characterized by the even dark colour of the surface and core, likely resulting from controlled exposition to the fire (*Perlès, Vanhaeren 2010*). The natural pattern of the shell's surface is lost in most LUP *C. rustica* due to the various chemical and mineralogical changes that occur during the long-term residence in the sediment (*Claassen 1998*). The use-wear is detected on ~60% of the LUP *C. rustica* beads. The perforations are mostly round in shape. The integrated analysis determined that *C. rustica* beads from Vlakno cave were produced with a simple technique involving direct percussion with pebbles (*Cvitkušić* et al. *2024*). Spots of red residues have been identified inside one LUP specimen.

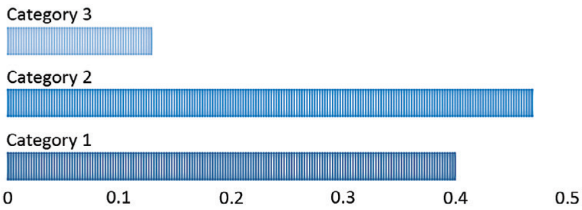
Of the 134 ***Tritia neritea*** shells, 93 are whole and perforated, 25 are missing half of the perforation and outer lip area, and 14 are fragmented (Fig. 4.b). Almost 80% of the *T. neritea* shells are poorly preserved, with significant post-depositional alterations, such as exfoliated surfaces and concretions from the sediment. Analysis of less than 20% of well-preserved *T. neritea* beads showed they were used (Fig. 6.d,e). In a few specimens, the suspension mode is indicated by rounding in the lip area (Fig. 6.d,e). The perforations on *T. neritea* beads are oval in shape. A small share (~14%) of

Fig. 4. Selection of LUP ornaments from Vlakno cave. **A** ***Columbella rustica;*** **B** ***Tritia neritea;*** **C** ***Antalis sp.;*** **D** ***Lithoglyphus naticoides;*** **E** ***Tritia nitida;*** **F** ***Cervus elaphus teeth;*** **G** ***Luria lurida;*** **H** ***Acanthocardia tuberculate;*** **I** ***Glycymeris sp.***

the *T. neritea* beads are black, with an even colour and high surface polish, likely indicating deliberate burning (*Perlès, Vanhaeren 2010; Perlès 2018*). Ochre residues in the form of small stains and spots are detected on a dozen *T. nerita* located along the perforation hole, in the lip area, and on the two specimens all over the upper surface of the shell.

Significant surface exfoliation prevented the exact species determination of ***Antalis*** shells, as well as their processing and use modes (Fig. 4.c). Out of the total number of *Antalis* specimens (N=602), only 30% are beads, while the rest are waste with a dorsal aperture too narrow to be strung (*Arrighi* et al. *2020*). *Antalis* sp**.** is the most represented taxa in the Vlakno LUP ornaments, but compared to the others its accumulation is mainly restricted to a single stratum with 95% of finds discovered in Stratum 6.1., *i.e.* layer 98 (Tab. 2, see below). The length of *Antalis* beads ranges from 1.93 to 30.09mm, with a mean of 12.31mm. The length distribution shows that most of the beads fall into two categories: smaller than 10.00mm or between 10.01 and 19.99mm, respectively (Graph 1). Beads longer than 20.00mm are the least represented. *Antalis* shells were likely collected from thanatocoenoses as a significant share of specimens have surface abrasions, typical small holes drilled by predators, and sponge marks (*Arrighi* et al. *2020; Bar-Yosef Mayer 2008*). Use-wear analysis of a small share of well-preserved beads (~20%) showed that most beads have polished extremities, most often with rounded rims and grooves, indicating that the beads were suspended and used (Fig. 5.h,i). Most used beads have ochre spots dispersed along the body's surface (Fig. 5.i). Identifying the production techniques for *Antalis* shell in Vlakno will remain a matter for future research.

Most ***Tritia nitida*** discovered in the layers above the tephra are poorly preserved with heavy surface exfoliation (Fig. 4.e). Of seven perforated *T. nitida* beads,



Graph1. Length frequencies of* Antalis *sp. beads: Category 1 >10.00mm; Category 2 10.01 – 19.99mm; Category 3 <20.00mm.

use-wear with developed rounding along the perforation hole is observed on one specimen, but it cannot be distinguished if it is from the use or taphonomy.

Glycymeris sp. shells are present throughout the LUP deposits and are characterized by various states of integrity and size range, and notably there are 29 perforated whole valves, three unmodified whole valves, and fragments (N=38) (Fig. 4.i). Modified *Glycymeris* valves are perforated in the umbo area on the beak. Developed use-wear traces of the hole rim and polished hinge teeth with ochre residues are observed on a few large and better-preserved specimens, suggesting that these were likely suspended as ornaments (Fig. 5.f,g). Moreover, we have detected rounding of the edges, striation and ochre residues on a few randomly analysed fragments, which directed us to a more detailed study of the use of *Glycymeris* sp. in Vlakno cave in the future. In Stratum 9, a small perforated *Glcycmeris* shell was discovered together with a perforated ***Luria lurida*** gastropod. Microscopic analyses of *Luria lurida* showed horizontal incisions and striation in the perforation area, indicating that the hole was made by horizontal sawing movements using a sharp tool (Fig. 4.G). One fragment conditionally attributed to *Luria lurida* from Stratum 6 was perforated using the same technique, with ochre residues all over the inner part and less on the external surface (Fig. 4.g).

One perforated and one whole unmodified valve of ***Acanthocardia tuberculate*** was discovered in the LUP layers above the tephra. A polished beak and elongated irregular perforation with rounded edges at the top of the umbo area with clear use-wear traces indicate extended use of perforated A. *tuberculate* specimen (Fig. 4.h).

Freshwater molluscs
Eight perforated freshwater gastropods were discovered in LUP deposits: six ***Theodoxus danubialis*** and two ***Lithoglyphus naticoides*** (Fig. 4.d). Poor preservation and surface alteration affected the observation of possible use-wear traces on most specimens, while clear use is detected on one *Theodoxus danubialis* and one *Lythoglyphus naticoides* (Fig. 5.c). Perforations on all freshwater gastropods are oval. One *Theodoxus danubialis* is black, likely due to intentional heating.

Mammal teeth
Taxonomical analysis showed that all 47 mammal teeth from LUP deposits belong to ***Cervus elaphus*** (Figs. 4.f and 6). Specifically, there are 29 modified teeth: 26 whole perforated canines, two whole perforated incisors, and one canine with traces related to the initial stage of production (Fig. 6). There are 18 whole canines without traces of modification. Half of the unmodified teeth have flint traces in the ventral/labial bottom of the crown area, which results from the extraction activity, indicating the collection mode. Small parts of the root or crown are missing on almost half of the teeth. Female and male canines are almost equally represented. Use-wear analysis showed that all perforated teeth are used. Technological analysis of the perforation mode revealed two main production techniques. The first and most frequent one is characterized by bilaterally thinning, followed by scraping and grooving of the root surface (Fig. 6.c-k,n-p). The second, less represented technique is characterized by bilateral drilling of roots (Fig. 6.l,m). A significant share of teeth pendants have rounding on the lateral sides of the roots, indicating the suspension mode. One canine demonstrates unfinished perforation with the initial stage of the most represented production technique in Vlakno – bilateral grooving and thinning of the root (Fig. 6.q). The fracture encompassing the scraped surface of the root area indicates that this specimen may have been discarded during processing, as the tooth would break in the case of ongoing production activity. Few perforated teeth have lateral fractures in the perforation area or the broken tip of the hole in the root area. The asymmetric profile of the perforation holes, accompanied by a specific arrangement of inside striations, demonstrates that perforations were made manually. Moreover, anthropic production is supported by two canines with incised decorative notches on the lobe surface (Fig. 6a,b).

Discussion and conclusion

Our study emphasizes the significance of the Vlakno cave as a vital LUP site for understanding the production and use of ornaments in the Adriatic region. Additionally, it complements previous research on Holocene ornaments (*Cvitkusić* et al. *2024*) extending the

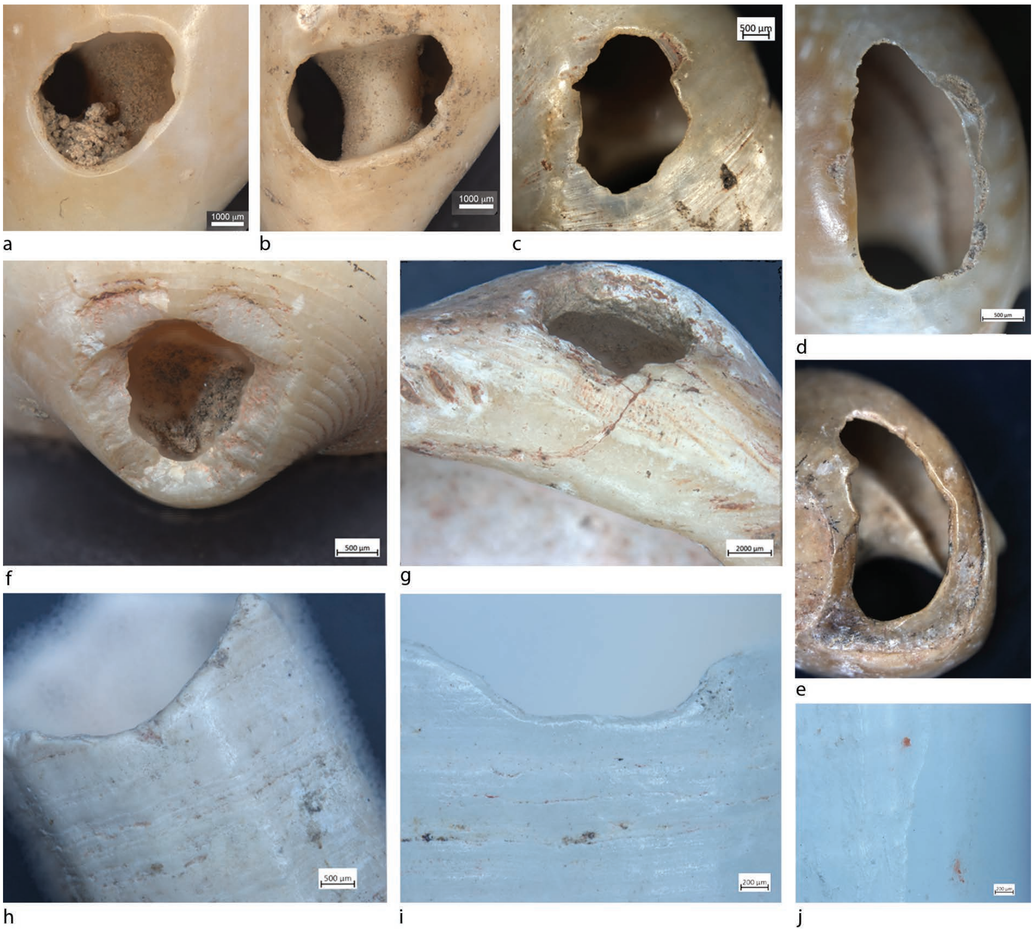


Fig. 5. Selection of use-wear and ocher traces on LUP shell ornaments from Vlakno cave presented by sample numbers: **a Columbella rustica *VL/O/78.4;* b Columbella rustica *VL/O/56.6;* c Lithoglyphus naticoides *VL/O/58.34;* d Tritia neritea *VL/O/58.22;* e Tritia neritea *VL/O/67.6;* f Glycymeris *sp. VL/O/58.18;* g Glycymeris *sp. VL/O/89.1;* h Antalis *sp. VL/O/101.9;* i Antalis *sp. VL/O/98.40;* j *Antalis sp. VL/O/97.99.***

role of Vlakno cave as a production site for ornaments in the broader regional context to the Late Upper Palaeolithic.

From the LGM to the early Holocene, dramatic climate change profoundly affected the geography of this area, and the transformation of the Adriatic Plain into the Adriatic Sea, as we know it today, fundamentally altered the lifestyle of prehistoric people (*Sikora* et al. *2014; Peresani* et al. *2021*). Numerous prehistoric sites with rich archaeological assemblages, including ornaments, faunal remains, and stone and bone artefacts, have been revealed on the present-day margins of the prehistoric Adriatic Plain, such as Šandalja II (*Karavanić 1999*), Kopačina (*Vukosavljević, Perhoč 2017*), Vela Spila (*Čečuk, Radić 2002; Cristiani* et al. *2014*), Badanj (*Borić* et al. *2023*). However, these sites provide partial insight into the subsistence strategies and lifeways of people inhabiting the submerged Adriatic area during the Upper Palaeolithic (*Rossi Radić* et al. *2020*). In this context, the Vlakno cave, serving as both an inland and later island site, gives us vital information about the adaptations of prehistoric people who repeatedly occupied it for more than 10 000 years. During LUP, a significant number of discovered sites with ornaments in the Eastern Adriatic (*Cvitkušić 2017; Borić* et al. *2023; Vukosavljević 2023; Cristiani* et al. *2014*) suggest their important role in the lives of prehistoric peoples of this region. In Eastern Adriatic LUP contexts, beads are primarily discovered in small amounts, likely lost while being used (*Cvitkušić, Komšo 2015; Cvitkušić 2017*). Vlakno cave is an exception, boasting the most extensive and varied ornaments yet discovered in the Eastern Adriatic region, strongly implying *in situ* production. The nearest site to Vlakno cave with a rich LUP ornamental assemblage is Badanj cave, situated in present day Bosnia and Herzegovina (~330km away from Vlakno cave) (*Borić* et al. *2023*). Compared to Vlakno, there are no traces of *in situ* production in Badanj, although we cannot completely exclude this activity because of the old excavation methods. Heterogeneous materials for ornaments in the

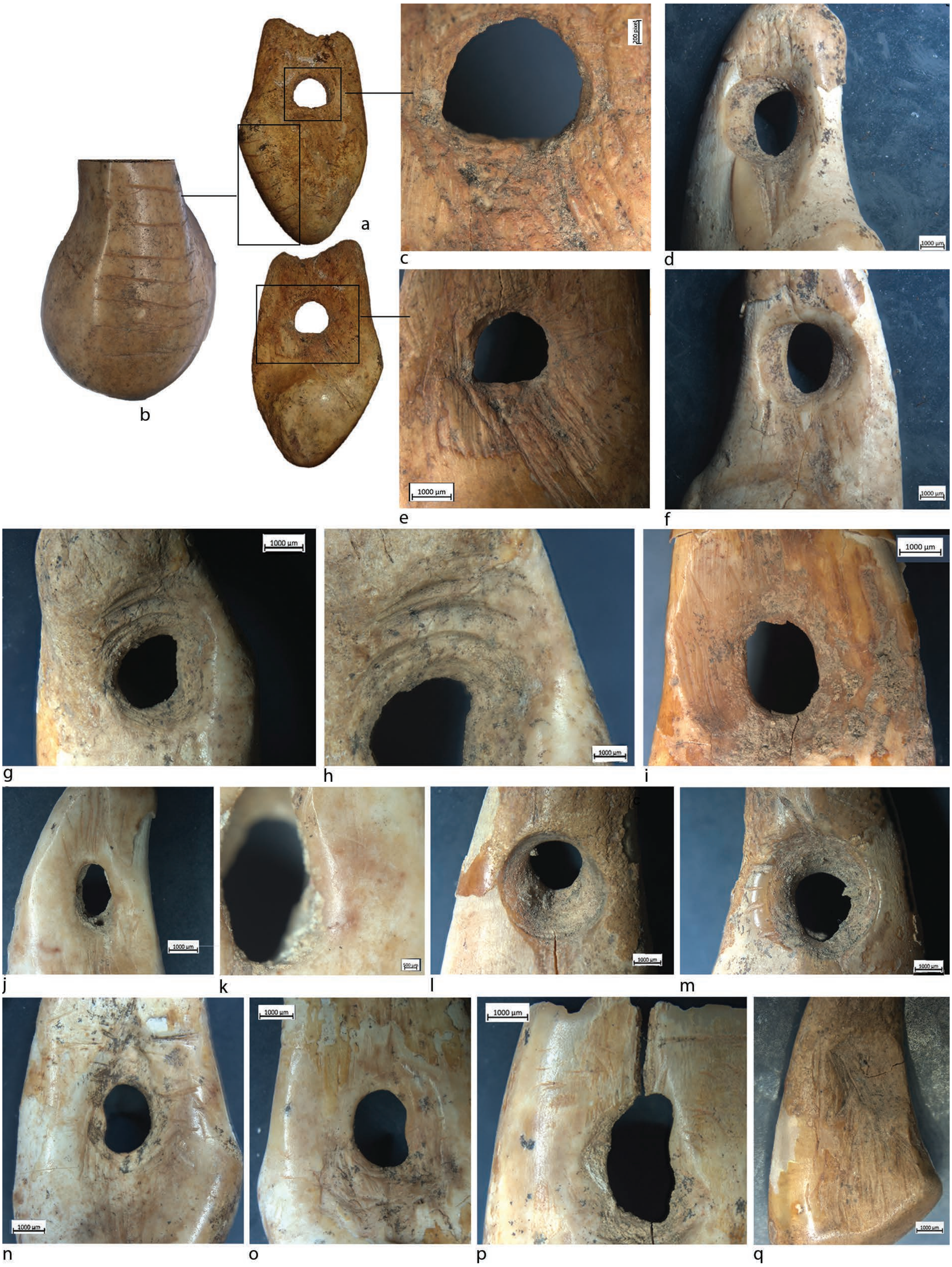


Fig. 6. Selection of LUP deer canines from Vlakno cave presented by sample numbers: a ***VL/O/60.23;*** b ***detail of VL/O/60.23 with decorative notches;*** c, e ***details of production traces with grooving and scraping of VL/O/60.23 in hole area;*** d, f ***VL/O/16.1;*** g ***VL/O/11.1;*** h ***detail of drilling in hole area together with use-wear of VL/O/11.1;*** i ***detail of scraping and grooving of surface of VL/O/60a.8;*** j, k ***VL/O/101.2 detail of production and use-wear;*** l ***VL/O/3.1 drilling mode of production;*** m ***detail of decorative notches of hole of VL/O/3.1;*** n, o ***VL/O/102.1;*** p ***VL/O/6.3;*** q ***VL/O/66.30 initial production stage with scraping and grooving traces.***

LUP layers of Vlakno cave are locally outsourced. The selection of specific raw materials for ornamental purposes in Vlakno Cave, along with the used beads and ochre residues, reflects their symbolic role.

Our detailed analysis of each taxon from the Vlakno cave allowed us to elaborate on *in situ* production and discuss specific ornaments in the wider regional context (Fig. 7). During LUP, the beads made of marine species are the most represented in Vlakno cave, mainly corresponding to regional trends (Tab. 2, see below). Regarding marine species, the most numerous are scaphopods, *i.e. Antalis* sp., but compared to the second most frequent type, gastropods *Tritia neritea*, their appearance is limited almost exclusively to Stratum 6. *Antalis* sp. is almost equally represented by beads and posterior pieces, *i.e.* production waste. In archaeological contexts, a narrow posterior end (<1mm) is rare, and the reason is likely the impossibility of suspending such beads (*Arrighi* et al. *2020*). In Vlakno cave, 41% of *Antalis* posterior ends, *i.e.* production waste, suggest *in situ* production. Like the *C. rustica* (*Cvitkušić* et al. *2024*), *Antalis* shells indicate that raw material was brought to the site for *in situ* production. *Antalis* beads are discovered in the LUP horizons of Badanj cave (*Borić* et al. *2023)* and, in the broader region, in Franchthi cave (*Perlès 2018; 2019*). Besides *Antalis* sp., the *in situ* production during the LUP in Vlakno cave is supported by red deer teeth (*Cervus elaphus*). Half of the sample exhibits use-wear traces, while the other half consists of whole, unmodified teeth with flint extraction marks. Additionally, one canine shows the initial production stage, *i.e.* traces of grooving. A preliminary analysis of the LUP faunal assemblage of Vlakno cave shows red deer is the prevailing species, while lithic artefacts indicate that hunting was the dominant economic activity (*Cvitkušić* et al. *2018*). Significant symbolic finds are two decorated deer canines with transversal incisions over lobe surfaces. An analogous example of decorated notches on the red deer canine is known from Badanj cave and Riparo Tagliente (*Leonardi 1983; Borić, Cristiani 2023*). This ornament type is relatively common during LUP in the Adriatic basin. Vlakno and Badanj are the sites with large numbers of finds of red deer teeth, while a smaller quantity was retrieved at Biarzo (*Bertolini* et al. *2016)*, Šandalja II, Romualdova cave (*Cvitkušić 2017),* and Vela spila *(Cristiani* et al. *2014*).

T. neritea beads, the second most numerous LUP bead type in Vlakno, are almost uniformly represented throughout the layers. Due to its naturally thin and fragile shell, it can be easily perforated but also damaged, which could be a possible cause of a significant share of broken and unpreserved specimens in the sample. A similar distribution of *T. neritea* in the ornamental assemblage is recorded in Badanj cave, while in Franchthi cave and Riparo Tagliente, *T. neritea* is the dominant taxa during LUP (*Fontana* et al. *2009; Perlès 2019; Borić* et al. *2023*). The presence of *T. neritea* beads in the hinterland site of Zala cave likely suggests the existence of contacts and exchanging routes in the Eastern Adriatic region during LUP (*Cvitkušić 2015*). Moreover, a regional exchange system in this area during the Holocene is suggested by Darko Komšo *et al*. (*2019*) based on the distribution of beads made from marine and freshwater shells, a hypothesis supported by Vukosavljević and Ivor Karavanić (*2015*), who provide evidence of similar patterns in

Fig. 7. Map with the sites in the broader Late Upper Palaeolithic context discussed in the text:* 1 *Romualdova cave;* 2 *Šandalja II;* 3 *Ljubićeva cave;* 4 *Pupićina cave;* 5 *Zala cave;* 6 *Vlakno cave;* 7 *Vela spila;* 8 *Badanj;* 9 *Crvena stijena;* 10 *Franchti cave;* 11 *Grotta Palicci;* 12 *Riparo Tagliente;* 13 *Riparo Biarzo.

lithic raw material distribution. Marine bivalves, predominantly *Glycymeris* sp. shells, are exclusively found in the LUP deposits of Vlakno cave. Its use is ambiguous due to the detected use-wear traces and ochre residues on a few perforated specimens and fragments, suggesting that *Glycymeris* shells in the Vlakno cave may have had a functional purpose. In the broader LUP regional context, the same situation is recorded in Franchthi cave (*Perlès 2019*). The most extensive number of *Glycymeris* sp. is discovered in Badanj (*Borić* et al. *2023)*, and to a small extent in Vela Spila (*Cristiani* et al. *2014*), Šandalja II (*Cvitkušić 2017)*, Crvena stijena (*Borić, Cristiani 2019*), and Riparo Tagliente (*Fontana* et al. *2009*). In the regional LUP context, besides Vlakno, only one unmodified specimen of *Acanthocardia tuberculate* is discovered in Šandalja II (*Cvitkušić 2015*). Regarding *Luria lurida,* its presence is recorded in the Gravettian burial of Grotta Palicci in Puglia, situated across the Vlakno cave, slightly to the south (*Ronchitelli* et al. *2015*).

Freshwater gastropods are sporadically represented in the Vlakno ornamental assemblage. Out of two species, *Theodoxus danubialis* is more numerous compared to *Lithoglyphus naticoides*. In the regional context, both species' use as an ornament is recorded in the Riparo Biarzo (*Cristiani 2012*), Badanj (*Borić* et al. *2023*) and Vlakno cave. In general, in the spatiotemporal and chrono-cultural distribution, *L. naticoides* is more frequent in archaeological records of hunter-gatherers (*Boroneanț 1999; Eriksen 2002; Nițu* et al. *2019*). Freshwater sources likely had a significant role in hunter-gatherer lifeways. The importance of fishing is suggested by the results of stable isotope analyses showing high protein intake from freshwater fish in the Adriatic during Epigravettian (*Vukosavljević 2023*), which finds of harpoons and freshwater gastropods from Badanj and Vlakno caves can additionally support. Moreover, the presence of marine gastropods *T. neritea* in the hinterland site of Zala cave points to the existence of long-distance contacts from hinterland sites to those closer to the Late Glacial shore.

The variety of carefully chosen LUP ornament types in Vlakno cave in general corresponds to the broader regional trends spanning present-day Italy and Slovenia, the Adriatic littoral zone and its hinterland of the Dinaric Alps including present-day Croatia, Bosnia and Herzegovina and Montenegro (*Cristiani* et al. *2014; Cvitkušić 2015; 2017; Cvitkušić, Komšo 2015; Borić, Cristiani 2016; Borić* et al. *2023; Vukosavljević 2023*). Considering this observation alongside the well-documented LUP sites with ornaments in the northeastern Mediterranean, the Vlakno cave stands out as a prominent place for activities related to ornament production in this vast region. The Danube Gorges Epipalaeolithic sites and various contemporaneous Late Epigravettian sites in Italy share common features such as specific lithic artefacts, geometric motifs, and particular bead types (*Mussi 2002; Borić, Cristiani 2016*), such as the sites of Grotta Paglicci (*Mezzena, Palma di Cesnola 1967*), Riparo Tagliente (*Fontana* et al. *2009*), Riparo Biarzo (*Cristiani 2012*), S. Maria di Agnano (*Giacobini 2006*), Grotta di Fumane (*Fiocchi* 1997), Grotta dei Fanciulli (*Vanhaeren, d'Errico 2003*), Ovčja jama (*Osole 1962/63*), Vela spila (*Cristiani* et al. *2014*), Vrbička cave (*Borić, Cristiani 2016*), Crvena Stijena (*Mihailović* et al. *2017*), Badanj (*Borić* et al. *2023*), Franchthi cave (*Perlès 2018*), Cuina Turcului (*Cârciumaru, Nițu 2018*) and Climente II (*Mărgărit 2008*). Vlakno cave, with its *in situ* activities, rich symbolic assemblage, and central geographical location in the aforementioned area, perfectly fits in this broader LUP context, complementing our knowledge of how symbolic behaviour influenced movements of Late Upper Palaeolithic hunter-gatherers.

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Tab. 1. Ornament assemblage from the Late Upper Paleolithic layers of Vlakno cave. *Numbers indicated in the parenthesis indicate unmodified specimens.

Period	Stratum	Divison of Stratum / Layers	Marine gastropods, bivalve and scaphopods							Freshwater gastropods		Mammal teeth
			Columbella rustica	*Tritia neritea*	*Tritia nitida*	*Luria lurida*	*Glycymeris sp.*	*Acanthocardia tuberculata*	*Antalis sp.*	*Theodoxus danubialis*	*Lythoglyphus naticoides*	*Cervus elaphus*
Late Upper Palaeolithic	4	4.1.	1	9 (1)	1 (1)		1	1				
		4.2.	2	12	2		(1)		1			2
		4.3.	2	6			1			1		
		4.4.	4 (1)	15	1 (4)				1	1		1
	5	5.1.	9	20	2 (6)		12			1		1
		5.2.		3			2 (1)				1	1(1)
		5.3.					1		1			(1)
		5.4.	1	6				(1)	1			
		5.5.		3					4			
		5.6.	1	5					1			(1)
		5.7.	2				4 (1)					
	TEPHRA ~ 14.9±0.4 ka cal BP											
	6	6.1.		38			2		169		1	6(2)
		6.2.		1	1		2		1			2(1)
		6.3.	1	2			1			1		3(2)
		6.4.		2 (1)						1		3(1)
		6.5.										
		6.6.		1			1		3			3(6)
		6.7.		1			1		1			1
	7	7.1.										3(2)
		7.2.										
		7.3.		1								
		7.4.										1
		7.5.		6						1		(1)
	8	8.1.		1								
		8.2.										
		8.3.										2
		8.4.										
	9					1	1					

Tab. 2. The ornamental assemblage from the LUP contexts in the Eastern Adriatic region.

Period	General classification	Species	EASTERN ADRIATIC REGION								
			Šandalja II	Pupićina cave	Ljubićeva cave	Romualdova cave	Vlakno	Vela spila	Zala	Crvena Stijena	Badanj
Late Upper Palaeolithic	Terrestrial mammal	*Bos/bison* tooth	1								
		Lynx lynx tooth	1								
		Cervus elaphus tooth	5			1	29 (18)	7			30
		Alces alces tooth		1							
		Unidentified sp. bone	2								
	Marine gastropods, bivalves and scaphopoda	*Tritia neritea*			1		132 (2)	2	14		269
		Columbella rustica		1			23 (1)	2			38
		Dentalium/Antalis sp.					183				371
		Tritia nitida					7 (11)				
		Nassarius (Tritia) gibbosulus						7			22
		Acanthocardia tuberculata	(1)				1(1)				
		Luria lurida					1				
		Gylcymeris sp.	1	(1)			29 (3)	5		3	53
	Freshwater gastropods	*Teodoxus danubialis*					6				1
		Lithoglyphus naticoides					2				8
	TOTAL		**10 (1)**	**2 (1)**	**1**	**1**	**414 (36)**	**23**	**14**	**3**	**792**

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The process of neolithization and consequent changes in the region of Istanbul

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ABSTRACT - *During the last few decades, our knowledge of processes leading to the establishment of food-producing communities in regions peripheral or exterior to that of the core areas of primary neolithization has increased considerably, making it possible to better understand the interaction of migrant farmers with local indigenous communities and how they adapted to environmental conditions that were much different from the places they came from. The paper will limit its focus to discussing the process of neolithization in the region around Istanbul, where the emigrant farmers merged with the Mesolithic community of the Ağaçlı culture and developed a new socio-economic model forming the Fikirtepe culture.*

KEY WORDS – *Ağaçlı; Fikirtepe; Marmara region; neolithization; cultural adaptation*

Proces neolitizacije in spremembe v regiji Istanbul

IZVLEČEK – *V zadnjih nekaj desetletjih se je znanje o procesih, ki so vodili k oblikovanju skupnosti pridelovalcev hrane v obrobnih regijah ali zunaj osrednjih območij primarne neolitizacije, zelo povečalo. To omogoča boljše razumevanje interakcij migrantskih kmetov z lokalnimi domorodnimi skupnostmi in njihove prilagoditve okolju, ki je bilo precej drugačno od tistega, iz katerega so prišli. Članek se osredotoča na razpravo o procesu neolitizacije v regiji okoli Istanbula, v kateri so se priseljeni kmetje združili z mezolitsko skupnostjo kulture Ağaçlı in vzpostavili nov družbeno-ekonomski model kulture Fikirtepe.*

KLJUČNE BESEDE – *Ağaçlı; Fikirtepe; regija Marmara; neolitizacija; kulturna prilagoditev*

Introduction

The process of neolithization in the Balkans has been one of the most debated topics of European archaeology due to its significance in laying the foundations of the socio-economic settings of later stages, not only in the eastern parts of Europe but almost all over the continent. The onset of a new way of living based on farming in Europe, after being discussed for several decades in terms of extremes, ranging from colonization by Near Eastern farmers to actions of sporadic diffusionists to anti-diffusionist autochthonous models, finally came to be explained by the massive endemic movement of Anatolian farmers. Thus, particularly with the flow of new information from archaeogenetic studies, a consensus has been reached on placing the origin of farmers introducing Neolithic way of life to Europe to be from the core areas of primary neolithization in the East. Even if the prime question seems to have been answered by hardcore evidence, it is now understood that the processes that led to the neolithization in the regions beyond its primary formative zone are far more complex and multifaceted than our earlier, simplistic presumptions. The increased pace of research

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now makes it possible to ask several new questions that were not possible even to consider a few decades previously. Among the challenging issues now becoming apparent are the adaptability of emigrant farmers to new habitats, the pace of migratory movements, trajectories followed by the migrating groups, contacts with local Mesolithic communities, defining the impact of social memories, changing spheres of interaction, and the Neolithic package or packages, among others, all of which necessitate revising our way of looking at Neolithic expansion. In this respect, the emergence of different Neolithics consequential to Neolithic expansion has become more evident than before, and this requires new definitions of factors ranging from simple agricultural villages to stately urbanization, nomadic herding, semi-nomadism, seasonal pastoralism, and small farmsteads. Here, with this paper, we shall restrict our investigation to a particular case, the onset of the Fikirtepe culture in the region around Istanbul, not because it is the most interesting case but because it is probably the best documented and exemplified. During the last decade or so, several excavations in and around Istanbul have made it possible to picture the adaptive processes of migrant farmers coming from semi-arid regions of Anatolia to live in the rainy forested marine habitat of the Istanbul area. Moreover, the earliest stages of the Fikirtepe culture are, at the same time, the peaceful cohesion of migrant farmers with local Mesolithic Ağaçlı communities. We shall try to present this significant encounter.

An overview in retrospect

Interest on the onset of Neolithic cultures of Anatolia came to the forefront only after the start of excavations at Nevalı Çori, then followed by those at Göbeklitepe. In earlier years, in spite of the work done at sites such as Çayönü or Caferhöyük, the early Neolithic of Anatolia was considered as the 'secondary Neolithic', a delayed reflection of developments that took place in the southern Levant. The increased pace of field work during in recent years has revealed many unexpected results that have led to changes in the way we look at the onset and spread of the Neolithic way of life, almost forcing us to reconsider what is implied by the term Neolithic itself. Most of the revolutionary developments in recent decades have been extensively published, several of them in *Documenta Praehistorica* (*Budja 2009*; *Çilingiroğlu, Çakırlar 2013; Güler* et al. *2013; Karul 2020; Özdoğan 2014a*). However, during the last few years the flow of new information has accelerated, presenting hitherto overlooked aspects of primary neolithization.

In this context, so much has changed from what we wrote in our paper on the expansion of Neolithic culture to Southeast Europe published only ten years ago in *Documenta Praehistorica* that it can now be considered partially out of date on some critical issues. Therefore, to prevent misunderstandings, an overview of recent advances will first be presented along an updated picture.

One of the prime questions that have been occasionally answered without much thought is the timing of the migratory movement. It has been almost conventional to place the expansion of farming from the core areas to other regions in the early years of the Pottery Neolithic, to a time frame from 6600–6400 BC, which signifies the time of massive movements covering Western Anatolia, the Aegean, Thrace and parts of Eastern Greece, marked by the foundation of hundreds of new settlements. However, it is clear that before these massive migratory movements sporadic ones were going to and fro, bringing back information on the lands further away. It is possible to surmise that such journeys were undertaken by peddlers, wanderers, and herders moving in concert with Mesolithic groups. Even though there is no way to specify these early scouting movements, it is clear that the farmers in the core regions were well informed of the outer territories, and thus the social pull of looking for opportunities may have developed. When big groups began to move, they knew exactly where they were heading, as otherwise hundreds of new settlements could not have been placed in the best locations in a newly reached foreign territory. Though scanty, there are indications of such pioneering movements taking place as early as 7400 BC, at a time when pottery was scarce, as only a few sherds from this scouting stage are known from Bahçelievler, denominated as Proto-Fikirtepe, or from northern Bulgaria and classified as monochrome ware. Thus, distinguishing the remnants of early migrants from those of later ones is essential in understanding the neolithization process, but it is not always easy to do.

The other issue worth considering is migrant farmers' adaptation to a habitat different from that of their home region. The new way of living based on agriculture had originated in semiarid conditions, where springs as sources of drinking water were scarce and the green cover of the open forest environment lacked tall-growing trees. As such, the locations of the settlements were strictly determined by the specific locations of the springs or perennial rivers, inevitably necessitating clustering, since dispersed settlements or housing were almost impossible. Moreover, over time settlements, regardless of their cultural identities, had to be repeatedly established at the same location, giving rise to multi-layered mound formations. Likewise, mudbrick developed as the principal building material, most appropriate for the long, dry summers of semiarid conditions. The rare presence of tall-growing trees was also one of the factors in defining the construction techniques used for buildings. Emigrant farmers settling in the Marmara region quickly realized that mudbrick was unsuitable as a building material for the rainy conditions, and so transferred their knowledge of architectural systems to wooden-post constructions. Due to the extensive presence of fresh water almost everywhere in the region of Marmara, settlements did not need to cluster and occasionally shifted their location, and thus in contrast to the heights of the settlement mounds of Anatolia, single-period flat settlements dominated the cultural environment. Using easily perishable building materials such as wood also led to archaeological deposits of insubstantial thickness. For that reason, most of the sites are single-period flat sites, difficult to locate in surface surveys, and easily and unintentionally destroyed.

Encounters among the emigrant farmers and local Mesolithic communities have occasionally appeared in the literature, but hardly any discussions were supported by concrete evidence, except perhaps for that on Lepenski Vir (*Brami* et al. *2022*). In this respect, the Marmara region, now with over nine well-excavated and documented sites, has made it possible to visualize the interaction between the two communities, the local Mesolithic community of the Ağaçlı culture and emigrant farmers giving rise to the Fikirtepe culture, developing an assorted socio-economic model best suited for that region.

Eastern Thrace and the Marmara basin

The Sea of Marmara, the divide between Southeast Europe and the Near East, is an atypical inland sea being part of a chain of landlocked seas featuring volatile conditions. The Sea of Marmara, the westernmost component of this system, also provides its connectivity to the global oceanic system by the narrow and relatively shallow strait, the Dardanelles. The Bosporus, located on the other end of the Sea of Marmara, is the link to other inland marine bodies, such as the Black Sea, the Strait of Kerch, the Azov Sea, the Maynch Depression, the Caspian, Uzboy Channel and Aral Lake. The Bosporus, being much shallower than the Dardanelles in this system of landlocked seas, plays a critical role in defining marine conditions such as salinity and oxygen circulation. The entire system presents a unique, multifarious picture, the condition of each component being specific to that unit and affecting all others simultaneously. Even a simple overview of this system would be beyond the coverage of this paper (*Erinç 1954; Özdoğan 2007*). However, it is worth noting that when emigrant farmers reached the region, Marmara, still being cut off from the Black Sea, was a relatively shallow brackish lake just before the beginning of the salinization process through the Dardanelles (*Algan* et al. *2011*). Thus, in considering the process of neolithization, particularly in regions peripheral to Marmara and the Black Sea, the changing coastal topography and marine environment particular to each region needs to be considered. The change from brackish to saline conditions and the development of the vertical circulation of oxygen in the Marmara basin took place during the evolutionary stages of the Fikirtepe culture. Considering that Fikirtepe culture depended on fishing and collecting shells for subsistence, changes in marine conditions taking place during the lifetime of this culture must have been of critical importance (*Meriç, Algan 2007*)

Local Mesolithic culture of the East Marmara region – the Ağaçlı culture

In the Marmara region, as in most of Anatolia, the cultural stage preceding the Neolithic period, be it denominated as Epi-Palaeolithic or Mesolithic, is mainly confined to the coastal regions. In areas further inland, the evidence of Mesolithic occupation becomes very scanty or even absent (*Çalışkan Akgül* et al. *2023*). On the other hand, it seems justifiable to postulate that Mesolithic communities must have densely occupied all the coastal areas of Anatolia. However, it should be considered that global sea levels were considerably lower during the Mesolithic than today, and thus lowland sites have all been inundated, leaving those areas blank in surface surveys. In this respect, the coastal terraces along the Black Sea coast on either side of the Bosporus have revealed a rich assemblage of Mesolithic sites, termed the Ağaçlı culture after the most prolific site on the western part of the Bosporus (*Gatsov 2006; Gatsov, Özdoğan 1994; Kartal 2011*). During our surface surveys in the 1980s, we located over 100 localities with Mesolithic artefacts, mainly located on fossilized sand dunes along the Black Sea coastline, revealing a lithic assemblage somewhat reminiscent of the late circum-Pontic Epi-Gravette tradition characterized mainly by microlithic tools, geometrics being rather rare (*Cohen, Gorelik 1998; Biagi, Kiosak 2010; Gatsov 2013*). Sites of the Ağaçlı culture clustered mainly along the Black Sea, seemingly attracted by its rich marine resources, as it was then still connected to the Caspian. Nevertheless, sites of the Ağaçlı culture extended up to the southern coast of Marmara without penetrating further inland (*Sarı, Akyol 2019*).

The coming of the Neolithic farmers

As noted previously, the migratory movement of farmers should be considered under two distinct headings: the initial, sporadic movements, as early as the second half of the 8th millennium BC, at a time between 7400–6800 BC, and the more organized massive one from 6600 to 6400 BC. Even though we have limited information on the trajectories of the initial movement, after coming to the Lakes District people moved northwards following the valley of the Sakarya River, as attested by the early dates from Bademağacı, Keçiçayırı, Bahçelievler (*Fidan* et al. *2022*) and Barcın. Even if the Mesolithic communities of Ağaçlı had a notable cluster along the coastal areas, they must also have had a sparse presence in the interiors – hunting, looking for raw materials, or for some other reasons. Without the consent of the locals, the movement of farmers, at least in its initial stage, would have been near impossible. Farmers on the move must have travelled relatively quickly in the more or less sparsely populated zone. Nevertheless, migrant groups paused their movement before going into the territories densely inhabited by the Ağaçlı communities, as signified by numerous sites along the southern littorals of Marmara, such as Aktopraklık, Yenişehir, Ilıpınar, Menteşe, Barcın and several other as yet unexcavated ones.

The settlements established by the Neolithic farmers are villages, as in contemporary Anatolian Neolithic settlements, overwhelmingly dependent on farming, with hunting or fishing either absent or rarely implemented (*Roodenberg 2019*). Farmers brought the primary components of the Neolithic package, cultivated plants and domesticated animals (except for pigs), the know-how of essential commodities, architectural practices, and the social memory of village life. It is worth noting that in terms of lithics, pressure flaking and bullet core technology also came to the region with migrant farmers (*Gatsov, Nedelcheva 2016; 2018*). The earliest group had begun its move at the time of transition from the PPN to PN or at the time of the so-called PPNC when pottery was a scarce commodity. On the other hand, pottery had already become a common commodity by the time of the later arrivals. Still, contrary to the red-slipped, painted pottery of groups moving through the Aegean littoral into Thrace, the pottery of Eastern Marmara was mainly dark monochrome, lacking painted decoration. Likewise, there were several other notable differences in the Neolithic packages of the eastern and western groups. However, as these had been previously detailed in an earlier issue of this journal, we will avoid going into them here (*Özdoğan 2014a.Fig. 12*).

Coalescence of migrant farmers and local Mesolithic communities

The Lakes District, located at the southern end of the valley of the Sakarya River, developed as a secondary core area for migrant farmers moving west from the Central Anatolia plateau and for those arriving at the Gulf of Antalya through maritime routes. Once in the Lakes District, there were two possible courses to take, either moving northwards through the valley of the Sakarya or west to the Aegean littorals. The Sakarya route must have been preferred in the earlier stages of Neolithic expansion, as it was dotted by several sites that yielded early monochrome pottery. As there is no apparent Mesolithic habitation along the Sakarya valley, at least not worth considering, and migrant communities continued without encountering obstacles up to the southern shores of Marmara. However, when reaching the borders of areas densely occupied by the Mesolithic Ağaçlı groups, Neolithic farmers ended their movement. It seems that this obstacle must have led to a change in the preferred route for those arriving later in the Lakes District, as indicated by the intensity of newly established sites all around the Aegean. From the Lakes District, farmers must have followed the valley of the Büyük Menderes stream to reach the Aegean coast, and from there they had multiple choices: maritime crossing towards mainland Greece, particularly to Thessaly and Macedonia, or continuing northwards along the coast, establishing several settlements, some of which are on islands on the coastal shelf, or became islands with the rise in the sea level during the Neolithic era. Those reaching the Dardanelles poured into Thrace, going through almost vacant territories and establishing hundreds of new settlements. The apparent density of Neolithic communities in the Eastern Balkans indicates that this route must have continued to be used for a considerable time.

Even though the timing is impossible to set, the emigrant farmers that moved North through the Sakarya, establishing the settlements mentioned above, remained there for about 200 years without moving further.

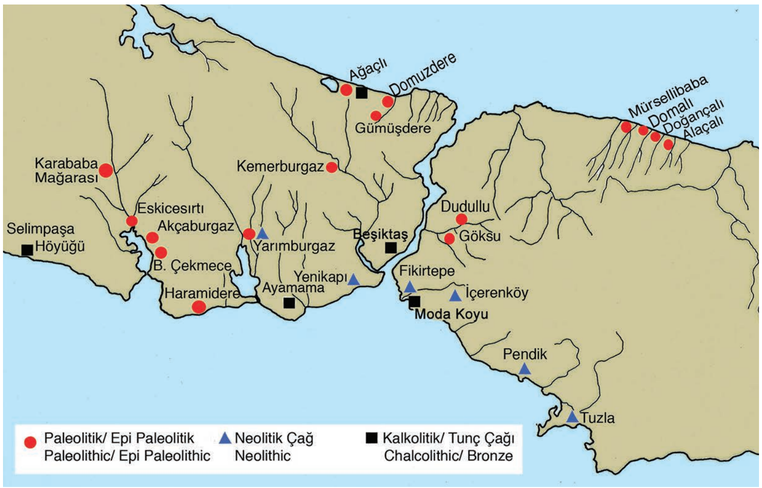

Fig. 1. Major prehistoric sites in and around Istanbul.

The two communities then merged, evidently peacefully with no sign of any conflict, developing a new socio-economic model, one that will become known as the Fikirtepe culture. Fikirtepe culture was considered to be founded by Neolithic communities, and we never wondered why the settlement organization and subsistence pattern of Fikirtepe was so different from all other Neolithic settlements. However, recent evidence has drawn a picture that is very different from what was accepted without much question for almost a century.

Changing picture of the Fikirtepe culture

Even though the site of Fikirtepe is one of the earliest excavated Neolithic sites, due to its location within the city of Istanbul, just at the crossroads between Anatolia and the Balkans, it has been customary to scrutinize its artefactual assemblage to look for cultural connections. For several decades, Fikirtepe remained the only excavated site in northwestern Turkey, but it did not yield what was expected, giving way to further biases. The increased pace of research in Bulgaria by the second half of the last century made it possible to view cultural assemblages of prehistoric periods, particularly those of earlier phases of the Neolithic that featured paint-decorated pottery vessels, as not being represented at Fikirtepe even by a single piece. Likewise, depictions of females, either as clay figurines or anthropomorphic vessels, despite their extensive presence in almost every Neolithic site, were conspicuously absent at Fikirtepe and other sites of this culture. Even though the excavations at Fikirtepe took place in the early 1950s, faunal remains had been meticulously collected and studied, revealing an extensive dependence on marine sources and hunting (*Boessneck, von den Driesch 1979*), both of which were almost totally absent in Neolithic sites south of the Marmara. The onset of several rescue excavations in and around Istanbul has finally made it possible to revise our view of the formative stage of the Fikirtepe culture.

Recent work in the environments of Istanbul

The commencement of large-scale infrastructure projects within the metropolitan area of Istanbul has made it possible to conduct extensive archaeological research, revealing hitherto unknown sites. One of the most prolific is the excavations at Yenikapı, the ancient Theodosius harbour of the Byzantine period, once the gulf of a stream that was filled in over time. Yenikapı excavations have been very prolific for almost all periods, and along with revealing outstanding finds, the fill in the harbour has yielded an amazing sequence of historical periods with indicators of environmental

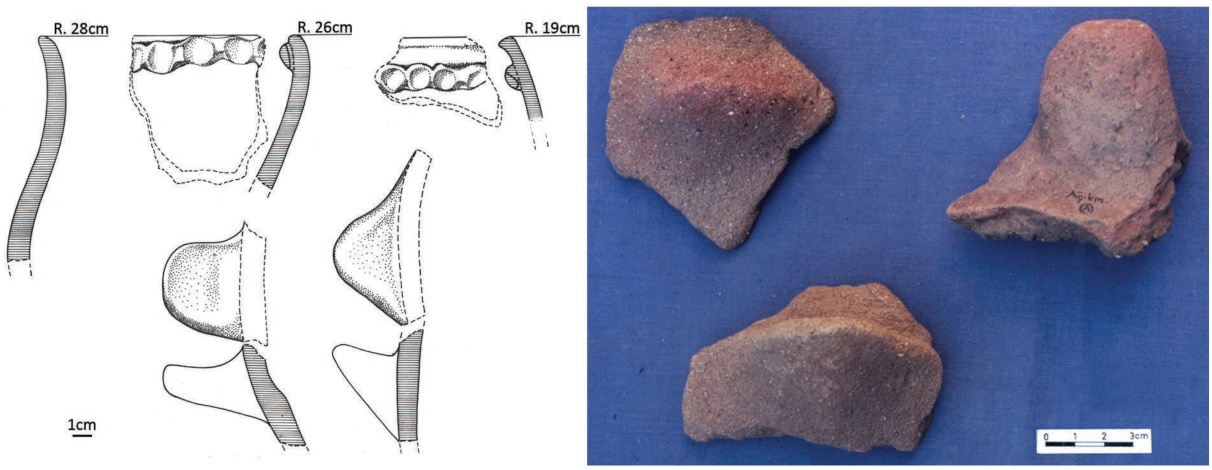

Fig. 2. Fikirtepe sherds recovered at Ağaçlı.

changes (*Algan* et al. *2011*; *Yalçın* et al. *2015*). However, a stony fill was encountered at the bottom of the ancient harbour, which turned out to have been laid during a transgression period of the Sea of Marmara, blanketing the remains of a Neolithic settlement located nine metres below the present-day level of Marmara. The site had developed along one of the deltaic channels of the ancient steam, which flowed to Marmara (*Yalçın* et al*. 2015*). By the early stages of the Neolithic, the present-day Sea of Marmara basin was still a brackish lake, somewhat smaller than when it was invaded by the saline waters of the Aegean coming from the Dardanelles. Only a segment of the Neolithic occupation had been exposed during the excavations, revealing cultural deposits of Early, Classic and Late Fikirtepe/Yarımburgaz 4 horizons, mainly consisting of the remains of some domestic structures, burials and wooden artefacts. Most significant is that due to anoxic conditions organic materials have been in an excellent state of preservation, not only the wood of houses and burials but also some objects and plant remains (*Kızıltan, Polat 2013*).

The Neolithic site of Pendik, a twin site of Fikirtepe, is located on the Asian side of Istanbul. Since the 1960s the site has been excavated on several occasions, revealing Early and Classical phases of the Fikirtepe culture (*Özdoğan 1983; 2014b; Gatsov 2003*). However, the most extensive work has been the 2011–2013 rescue operations of the Istanbul Archaeology Museums, exposing a trench of over 200 metres long extending from one end of the site to the other, for the first time making it possible to discern the settlement pattern on that scale (Fig. 4). Along with revealing several hut-like constructions, the excavations also uncovered a massive burnt structure and several inhumated burials.

Fig. 3. A selection of microlithic tool of the Ağaçlı culture.

Another major rescue excavation within the metropolitan area of Istanbul is the ongoing work at Beşiktaş, where 42 of the kurgan type of burials, dated to 3300 BC, have been recovered (*Özdoğan 2024*)*.* It is of interest to note that the kurgans are 60 metres away from the present-day coastline and at its level. Small pits revealing Early Fikirtepe pottery have been recovered about three metres under the kurgan cemetery, and the work on this is still continuing.

During 2022 and 2023 there were rescue excavations at the site of Fikirtepe, exposing the last remaining part, revealing material from the Classical phase of the Fikirtepe culture.

A new look at the Fikirtepe culture

Fikirtepe, both as a site and culture, has been extensively published on several occasions, covering the history of research, sequencing, faunal and cultural assemblages in full detail (*Özdoğan 2023*). Here, even as a summary of what has been detailed elsewhere, such information will not be repeated. Instead, the picture drawn by the recent work in Istanbul on the formative stage of the Fikirtepe culture will be briefly discussed.

Fig. 4. Pendik, a part of the section extending through the site.

As already noted, during the last few decades there have been several prehistoric excavations and surveys in the region around Istanbul, providing ample new evidence on the formation and develop-

Fig. 5. Pendik, huts with semi-sunken floors on the section.

of the settlement, almost forced us to reconsider the formative stage of the Fikirtepe culture. Through about 200 metres of exposed section (Fig. 4) there were medium-sized huts, storage pits, fireplaces and some simple burials (Figs. 5, 6). All the structures, either round or ovoid in plan, were wattle and daub construction, mainly of thin branches, having semi-sunken floorings and simple inhumations on the subfloor. On the easternmost end of the settlement, among round huts, there was a rectangular building with cellular divisions with mud-slab walls and a big cult

ment of the Fikirtepe culture (Fig. 1) The picture now drawn is a gradual and peaceful merger of two distinct cultures, the Mesolithic Ağaçlı and the Neolithic migrant farmers. Actually, the first sign of this came as early as 1980, during our survey in the region of Ağaçlı, recovering Early Fikirtepe sherds (Fig. 2) in one of the camp sites with some microlithic tools (Fig. 3) and the scattered remains of a wattle and daub structure which at that time was surmised to be intrusive. Istanbul Archaeology Museums rescue excavations at Pendik, excavating for the first time throughthe entire extent

table in one of the cells (Fig. 7) (*Özdoğan 2014a.Fig.6*). The construction was very unlike any of the round huts, not only in the plan but also in the construction technique, being highly reminiscent of PPN Anatolian tradition, which for the first time raised the possibility that the members of two communities lived together at the same site and maintained the particularities of their cultures.

At Yenikapı, the recovery of a Neolithic substratum at the bottom of a Byzantine harbour at nine metres be-

Fig. 6. Pendik, some of the burials and the flooring of a structure.

low the present level of Marmara, revealing various phases of the Fikirtepe culture, was beyond expectations. Likewise, among the architectural remains, as with the cellular building at Pendik, some structures were not in line with the simple round huts. One of these structures was constructed of curved timbers, surprisingly well preserved, suggestive of cruck-like construction systems (Fig. 8), and this particular building exemplifies how the migrant farmers who came with the knowhow of building substantial structures were able to apply their traditional knowledge to use the timber of tall growing trees. In the same layer, along with round huts, there was also a rectangular building of stone-lined walls (Fig. 9). As at Pendik, the presence of Anatolian type of structures together with simple huts again points to the two communities living together.

Fig. 7a. Pendik, the rectangular plan building with cellular divisions.

Fig. 7b. The same building with the cult table **in situ.**

Fig. 8. Yenikapı, preserved wooden timbers of a Neolithic building.

of two distinct traditions of burial customs in the same cultural layer, at least points presence of two communities living together with no sign of apparent hostility.

In featuring the new picture of the Fikirtepe culture, along with reconsidering what has been accounted above, the most concrete evidence has been of the faunal remains, which have been extensively studied and published (*Röhrs, Herre 1961; Boessneck, von den Driesch 1979; Çakırlar 2013; 2023*). It should be considered that the excavations at Fikirtepe took place in the 1950s, when collecting animal bones was not a widespread practice, sieves were hardly used, and in most cases, at least in the Near Eastern excavations, molluscs were not even considered. In this respect, Fikirtepe stands as an exceptional case, not only because faunal remains have been meticulously collected but also because they have been extensively studied and published. The Fikirtepe faunal assemblage, contrary to all other early sites south of Marmara, signifies the importance of marine sources in terms of diet, particularly in collecting molluscs and fishing. The diversity of fish species repre-

Yenikapı has revealed the earliest cremated burial of the Neolithic era, a practice unattested previously in Anatolia (*Kızıltan 2009*). There were several inhumations in a tightly contracted position, except for preserved wooden planks, and these were in the same tradition as Neolithic burials in the core area of the Neolithic. However, the recovery of a vessel, typical in shape for the Early or Proto Fikirtepe horizon, a jar with four lug handles, has revealed the fragmented remains of a cremated burial (Fig. 10). Here again, the togetherness

Fig. 9. Yenikapı, a rectangular plan Neolithic structure with walls lined with stones.

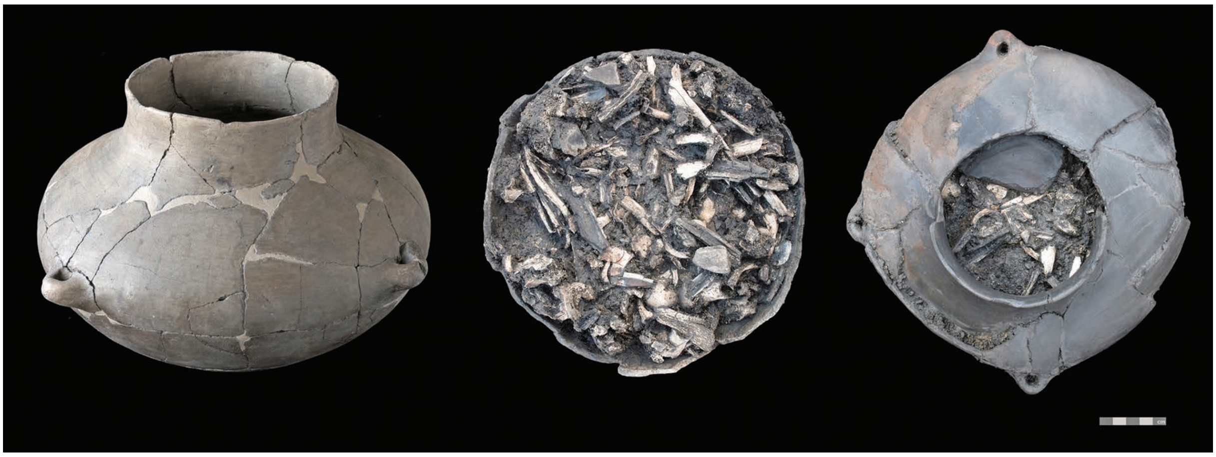

Fig. 10. Yenikapı, Fikirtepe type of jar with the remains of a cremated burial.

sented among the Fikirtepe faunal assemble has led to some controversy as to whether they employed open-sea fishing or simply made use of the lagoonal environment (*Çakırlar 2023*; *Yalçın 2023.286*).

On the other hand, no botanical remains were collected at Fikirtepe, and some wood and branch impressions left in the clayey daub of the huts are all there are. Due to the excavation systematics of the 1950s, it is no surprise that no botanical remains were collected, and thus in order to see the intensity and type of agricultural practices the only option is to look at the artefactual assemblage. In this respect, artefacts pointing to agricultural activities are present but relatively few compared to at other contemporaneous sites. Likewise, flint blades with silica-gloss are very rare, and grinding stones that can function effectively in processing grains are also scare, although some grinding activity took place on-site. In an overall assessment, Fikirtepe features a mixed economic model, some herding, low-level agriculture, hunting, fishing and mollusc collecting, a subsistence pattern notably different from that seen at any of the settlements founded by Anatolia farmers.

Some concluding remarks

For decades we have been writing and discussing the Fikirtepe culture, focusing on describing various components of the artefactual assemblages and considering the connectivity of this culture with its contemporaries. In this respect, the site of Fikirtepe is one of the hundreds of established sites consequential to Anatolian farmers' migration. As in several other cases, the contact with local autochthonous groups and their adaptation to new habitats were overlooked or passed over. It is the unprecedented recoveries of the recent rescue excavations in and around Istanbul that prompted us to look at the evidence and reconsider biases. In this respect, what has been concluded with this paper was evident since Neolithic expansion came to be discussed as a model, and the problem was the domination of fixed, oversimplified interpretations.

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Dating the Early Neolithic in Pelagonia: closing a chronological gap in Balkan prehistory

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ABSTRACT - *Since Gordon V. Childe first discussed the diffusion of culture from the Near East into Europe 100 years ago, various models for the advance of the Neolithic way of life have been proposed. Chronology has played an important role in this, but not all regions were included in the narratives due to a lack of data. Recent investigations in the border area between North Macedonia and Greece, namely in Pelagonia, have provided reliable new radiocarbon sequences, in total 42 new radiocarbon dates, that will contribute to the discussion on the Neolithic chronology of the Balkans.*

KEY WORDS – *Early Neolithic; Pelagonia, geographical region of Macedonia; absolute chronology; Neolithization process*

Datiranje zgodnjega neolitika Pelagonije: zapolnitev kronološke vrzeli v balkanski prazgodovini

IZVLEČEK – *Potem ko je Gordon V. Childe pred 100 leti prvič predstavil širjenje kulture z Bližnjega vzhoda v Evropo, so nastali različni modeli napredovanja neolitskega načina življenja. Kronologija je imela pri tem pomembno vlogo, vendar zaradi pomanjkljivih podatkov v zgodbe niso bile vključene vse regije. Nedavne raziskave v Pelagoniji, na mejnem območju med Severno Makedonijo in Grčijo, so prinesle nova in zanesljiva radiokarbonska zaporedja; skupaj 42 novih radiokarbonskih datumov, ki bodo vključeni v razprave o neolitski kronologiji Balkana.*

KLJUČNE BESEDE – *zgodnji neolitik; Pelagonija, geografska regija Makedonija; absolutna kronologija; proces neolitizacije*

Introduction

With the beginning of modern archaeological research, attempts were made to provide chronological frameworks for the different periods under investigation. As the discipline was evolving, a variety of methods were proposed for measuring time in the distant past. Before the mid-20th century most approaches were based on comparisons of stratigraphically secured finds that made it possible to elaborate on relative chronological schemes, but more exact determinations became possible with the development of radiocarbon dating in the late 1940s. Both approaches have been accepted and criticized, allowing archaeologists to favour the one that better supported their views on temporality.

Balkan archaeology is no exception in this regard, and numerous attempts have been made to determine both the beginning and end of the Neolithic Age, with the

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definition of the establishment of the first agricultural societies before their transformation into metallurgical communities remaining an ongoing process (*Childe 1929; Garašanin 1951; Gavela 1963; Benac 1979; Parzinger 1993; Todorova, Vaisov 1993; Sanev 1994; Korkuti 1995; Reingruber 2020*). Some authors have favoured relative chronologies based mainly on pottery and criticized the shortcomings of radiocarbon dating (*Milojčić 1949; Nikolov 1989*), while others, especially after the turn of the millennium, have emphasized the advantages of absolute dates and have been more cautious with direct material analogies (*Thissen 2000; Reingruber, Thissen 2005; Naumov 2009; Bulatović et al. 2018; Porčić 2023*). Nevertheless, nearly all archaeologists aiming to determine the timeframe of the Early Neolithic (EN) have attempted to provide elaborate perspectives on the dissemination of innovations from the Near East to Europe, reflecting in particular on the intermediary regions of the Aegean and the Balkans.

Given the influential relative chronology of the Balkans kans (*e.g., Milojčić 1949*), some archaeologists adjusted their own appraisals of the evidence based on this. Indeed, it has often seemed unthinkable to argue against such a chronology, leading to the situation in which authoritative *dicta* were followed and reinforced, as was the case with the so-called Preceramic Period in some countries (*Reingruber 2008.85–93*). On the other hand, language and national borders have often impeded productive communication among archaeologists, and the political situation of the 20th century, with Europe divided by an 'Iron Curtain', only exacerbated this.

These persistent, rigid approaches to archaeology were overcome not only with the political changes that occurred after 1989, but also with the broad acceptance of radiocarbon analysis. Although the first challenges to the relative chronological systems in the Balkans go back to the early 1970s when Colin Renfrew presented his new chronological insights based on the stratigraphy from Sitagroi with a sequence of 26 radiocarbon dates (*Renfrew 1971*), it took two decades until John Coleman gathered and analysed all the radiocarbon dates available at that time (*Coleman 1992*). The dissertation of Laurens Thissen (*2000*) set new standards with regard to the comprehension of the connectivity between Southeast Europe and Anatolia in light of the absolute chronology, and the online project CANeW (the precursor of 14SEA) in particular has led to the more widespread application of chronologies based on radiocarbon dates. As such, an absolute chronology has slowly been adopted and adapted, but even more than 20 years later some adjustments are still necessary (*Reingruber 2020.17*).

In the past, radiocarbon dates were either dismissed and ignored, or were accepted at face value with the expectation that they reflect a prehistoric 'reality'. Similarly, the quality of the dates is not sufficiently discussed, and one can observe a tendency to give credence to single dates, even with high standard deviations. This has led to a lopsided assessment of when and where the EN started in the Balkans. Sometimes, the properties of the calibration curve are not considered, especially the long-lasting plateaus resulting from the many wiggles (particularly that of the 7th millennium BC). This has led and still leads to a disproportionate emphasis on the oldest possible date instead of a more objective discussion of the dates in question. One must further acknowledge some inconsistencies in the interpretation of radiocarbon dates resulting from largely neglecting the origin of samples, natural effects on them, warnings by laboratories (*e.g.,* too little collagen in the samples, $\delta^{13}C$ effects, N:C-ratios, *etc.*). Moreover, the small number of dates inevitably cause biased interpretations. Despite some significant contributions to a better understanding of Neolithic chronology in the Balkans, regions with few and inconsistent radiocarbon dates were missing from broad chronological overviews. Such gaps in our knowledge have been detrimental to a better understanding of the advance of the Neolithic way of life.

Therefore, this paper will be an attempt to incorporate a missing region into the absolute chronological maps of the Neolithic Balkans. Our major focus will be on the new dates obtained from recent excavations and/or re-investigations of tell sites in Pelagonia (North Macedonia). We will provide more accurate information from the recent processing of the available data and present modelled sequences with the help of Bayesian statistics. As the research at some of the EN sites in this area is ongoing and the number of samples is still limited, we would like to stress that our models are provisional.

Neolithic in Pelagonia

Pelagonia is an elongated basin about 80km long and 20km wide that straddles the border area between North Macedonia and Greece (Fig. 1). Mountains with peaks as high as 2500m surround it, such as Dautica, Babuna, and Buševa in the north, Baba and Neredska in the west, Selečka and Niđe in the east, whereas the Varnoundas and Voras enclose the southern part. Surrounded by these mountains is a flatland at 600–700m above sea level. The fertile alluvial sediments of the flatlands are remnants of the Neogene lake that was naturally drained by the river Crna Reka and its tributaries that discharge into the river Vardar/Axios and from there into the Aegean Sea. As a result, a series of wetlands were created, particularly in the seasons of river floods, which were artificially drained during the melioration processes in the 1950s (*Arsovski 1997; Trifunovski 1998; Dumurdzanov* et al. *2004; Mirčovski* et al. *2015; Puteska* et al. *2015*). The existence of such wetlands in prehistory and particularly in the Neolithic period is confirmed by geoarchaeological research, while wetlands are also mentioned in some of the Medieval sources (*Kitanoski* et al. *1980; Chausidis 2003; Naumov 2020; Naumov* et al. *2021*).

The wetlands and alluvial soils of Pelagonia may have been an essential incentive for farming societies to settle here around 6000 BC. It was a wide-spread procedure in the Neolithic to establish and then continuously inhabit a site, resulting in tells several metres high. Besides Pelagonia, this practice is also present in other regions of the Balkan Peninsula, as well as in the Anatolian highlands and beyond (*Gallis 1992; Commenge 2009; Rosenstock 2009; Fouache* et al. *2010; Alexakis* et al. *2011; Ghilardi* et al. *2012; Lespez* et al. *2014; Ayala* et al. *2017; Naumov 2018*). Pelagonia can be considered an adequate setting for agricultural communities with access to a variety of resources around and in the wetlands (*e.g.,* fertile soils for cultivation, clay for constructions and pottery production, water animals and fruits) that enabled the ongoing occupation of tells for several hundred years.

This habitation pattern is reflected in the fact that houses were built and rebuilt on the same foundations for

Fig. 1. Map of south-eastern Europe with Neolithic sites mentioned in the text (Pelagonia highlighted in the red square): **1 *Vlaho,* 2 *Veluška Tumba,* 3 *Tumba Porodin,* 4 *Tumba Optičari,* 5 *Školska Tumba,* 6 *Čuka Topolčani,* 7 *Vrbjanska Čuka,* 8 *Markovi Kuli,* 9 *Mavropigi-Fillotsairi,* 10 *Revenia-Korinos,* 11 *Paliambela-Kolindros,* 12 *Nea Nikomedeia,* 13 *Vashtëmi,* 14 *Ploča,* 15 *Ohridati,* 16 *Lin 3,* 17 *Pogradec,* 18 *Cerje Govrlevo,* 19 *Tumba Madjari,* 20 *Amzabegovo,* 21 *Kovačevo.***

generations. Not only the use of the same plot over generations, but also large clay installations in their interiors, such as granaries, bins and ovens for storing and processing cereals, characterize this residential lifestyle (*Simoska, Sanev 1976; Kitanoski* et al. *1990; Naumov 2016*). Constant access to resources and a permanent residence manifested itself in flourishing societies that produced impressive painted pottery, human representations, house models, clay tablets, and stamps (*Simoska, Sanev 1976; Garašanin 1979; Sanev 1995; Naumov 2020*).

Despite these remarkable features of Pelagonian tells, they were not of particular research interest until the 1970s. Before that, only restricted fieldwork was carried out, for example by Vladimir Fewkes and Walter Heurtley in the 1930s or by Josip Korošec, Radoslav Galović and Miodrag Grbić in the 1950s at Grgur, Porodin, Karamani, and so on (*Fewkes 1934; Heurtley 1939; Grbić* et al. *1960; Galović 1964*). However, it was Dragica Simoska who had the greatest impact on the study of prehistoric sites in Pelagonia with a series of surveys and excavations in the 1970s, which contributed to a much better understanding of the first agricultural and metallurgical communities in the region (*Simoska, Sanev 1975; 1976; 1977; Simoska* et al. *1977; 1979*). This was followed by the more modest research in the northern parts of Pelagonia with limited fieldwork by Blagoja Kitanoski (*Kitanoski 1977; Kitanoski* et al*. 1978; 1980*). The archaeological boom of the 1970s turned out to be relatively short lived, as only a few sites were investigated in the next decade (*Todorović* et al. *1987; Kitanoski 1989; Simoska, Kuzman 1990*). What followed were two decades with a total absence of research in this region, until the 2010s when new and multidisciplinary explorations were initiated that are still ongoing (*Naumov 2022; Naumov* et al. *2014; 2018a; 2021; 2023a*). To better understand the prehistory of Pelagonia – particularly with regard to its neighbouring societies and wetland areas – further investigations were soon undertaken in the regions of Lake Ohrid and Lake Prespa (*Naumov* et al. *2018b; 2023b*).

These multidisciplinary projects and international collaborations were oriented towards newer methods, such as archaeobotany, dendrochronology, zooarchaeology, geoarchaeological and geophysical investigations, laser and LiDAR scanning, lipid and use-wear analysis, GIS and 3D modelling, most of which were implemented in Macedonian archaeology for the first time. One of the crucial aims was to obtain well-contextualized samples for radiocarbon dating providing an accurate chronological sequence of the sites. This way, a model could be created from the time of the initial inhabitation of first farming communities in Pelagonia until the social transformations occurring in the Late Neolithic and Early Chalcolithic. These chronological sequences and models can be used to include the Pelagonian chronology in the existing Balkan periodizations. In a first step, the proposition of a possible scenario related to the Neolithisation process in this region will be presented.

Pelagonia and the dating of Neolithic sites

After initial descriptions of the Neolithic in Pelagonia, attempts were made to better define its chronological framework. These were based on the relative chronology derived from analogies with other regions, as in the case of Tumba at Porodin (*Grbić* et al*. 1960*). Although belonging to the EN, the material from Porodin was first suggested to be from the Late Neolithic – yet it was an initial modest step to understand the chronological scope of this period in Pelagonia. Later, with the definition of the Velušina-Porodin cultural group, the earlier dating was highlighted once again, but still in terms of relative chronology (*Garašanin 1979*). This approach was also followed by the division into phases (*Sanev 1995*) that were adjusted to the existing ones from Amzabegovo, and as such contributed to its dating from 6100 until 4900 BC (*Gimbutas 1976*). Despite the small scale of this research, it was nevertheless a prolific time in Macedonian archaeology when the Neolithic period in this area was also starting to attract international interest.

As a result of the enthusiastic initiative and dynamic research in the 1970s, there were a number of radiocarbon samples obtained from the tells at Porodin, Trn, Mogila, and Topolčani, which were run at the laboratories in La Jolla, in the United States, and in Zagreb, Croatia (*Srdoć* et al*. 1977; Valastro* et al*. 1977*). Although they were available as published resources, it is surprising that they were hardly used in Yugoslavian and then later Macedonian studies dedicated to the Neolithic and the Neolithisation process (*Garašanin 1979; Sanev 1994; Mitrevski 2003*). It was not until the year 2000 that the dates were finally included in the larger Balkan chronology related to the appearance of first farming communities in Macedonia (*Thissen 2000*). Consequently, they were incorporated into the radiocarbon database of the CANeW project, and later later the 14SEA project, that provided the most comprehensive chronological outline of the Balkans and Anatolia (*Reingruber, Thissen 2005; 2017; Thissen, Reingruber 2017*). The radiocarbon dates from Pelagonia were not only set into broad chronological sequences but also used in overviews of the Neolithisation process in North Macedonia itself (*Naumov 2009; 2015*; *2023b; Fidanoski 2019*).

With the new initiative for more intensified and multidisciplinary research of the Neolithic tells in Pelagonia at the beginning of the 2010s, radiocarbon dating has been a regular practice and the major method to provide a firm chronology for particular sites and for the entire region. The Center for Prehistoric Research in Skopje launched several fieldwork projects in the Pelagonian basin in order to provide versatile data for understanding the timeframe, environmental setting and social dynamics of the Neolithic in this area, and consequently samples were taken from specific contexts to obtain well-founded sequences for each site (*Naumov 2023b*). Besides regional surveys and geomagnetic prospections, three particular sites in three different parts of the basin were focused on in order to determine the similarities and differences of communities that lived here: Vrbjanska Čuka at Slavej in the northern part of the valley, Veluška Tumba at Porodin in the central part and Vlaho at Živojno in the southern highlands. Systematic excavations at the three settlements provided the majority of samples for dating, and these will be used to establish the duration of specific building-phases at each site. In a second step, the sequences will be used to obtain a temporal perspective for the entire region of Pelagonia, particularly in relation to the Neolithic Balkans.

Samples from archaeobotanical, archaeozoological, and anthropological investigations were mainly used for the current dating of the investigated sites, *i.e.* the remains from seasonal plants, animal and human bones (*Antolín* et al. *2020; 2021; Naumov* et al. *2021; Sabanov* et al. *2022; 2023*). Short-lived seeds of cereals and legumes were preferred in this study, while the bones of pigs and humans, although dated, were generally excluded as they are susceptible to the reservoir effect. Similarly, the dating of charcoal was usually avoided due to the old wood effect. The datings were performed at the laboratories of the Universities of Seville (CNA), Bern (BE), Zurich (ETH) and Bristol (BRAMS), and have been published before as unmodelled dates on several occasions (*Stojanovski* et al. *2020; Naumov* et al. *2021; 2023b; Sabanov* et al. *2023*).

In this study, all 36 dates (Tab. 1, see below) were calibrated to the latest calibration curve[1] and Bayesian statistics were applied for modelling the sequences.[2] These results are subsequently rounded by 10 and interpreted in the 1σ range (at 68.3% probability). We then use their median values in order to reach the greatest limitations possible that are methodologically still acceptable (we are aware that new data will lead to more precise models).[3] This chronological study was executed at the Department for Prehistory in the Free University Berlin and at the Einstein Center Chronoi in Berlin. Besides the samples from Vlaho, Veluška Tumba and Vrbjanska Čuka, the recent ones from Tumba at Optičari, Školska Tumba at Mogila and Tumba at Porodin were also included in the study, while those from the 1970s are only mentioned in the general overview of the Neolithic chronology of Pelagonia.

Vlaho

Vlaho is situated on the lower slopes of the Nidje mountain, on a 6ha sandstone terrace created by two rivers (Fig. 2). Systematic research was started in 2020 and since then the site has been continuously excavated (*Naumov* et al. *2023a*). The geophysical prospections indicated the presence of a dozen of semicircular ditches, and their EN association has been verified by the excavation of three such features. Both geophysical coring and excavation confirm the existence of cultural layers 1.60m and 2.40m deep in which a number of unfired daub buildings have been detected, as well as structures made from laterally placed grinding stones. The unearthed pottery, models, and figurines form an apparent relationship with other EN sites in Pelagonia,

1 Radiocarbon dates used in this study that are not listed in Table 1 and 2 can be viewed in the Excel spreadsheet at www.14SEA.org (*Reingruber, Thissen 2017*).

2 Calibration and modelling were carried out using OxCal 4.4.4 (*Bronk Ramsey 2021*) and the IntCal20 atmospheric curve (*Reimer et al. 2020*).

3 Regarding the qualities of the dates we distinguish three levels of accuracy: single dates obtained on long-lived species (mainly charcoal) that were calibrated to the newest curve can be used only as a *Terminus post quem* (*TPQ*-cal), even when modelled statistically together with other such dates (*TPQ*-mod), although in this latter case the precision may be much better. Only dates stemming from a sequence that has been modelled according to short-lived species can be regarded as a *Terminus a Quo* (*TaQuo*) – not to be confused with *Terminus ante quem* (*TAQ*).

Fig. 2. Aerial photo from the site of Vlaho in the hilly area (©Center for Prehistoric Research).

but also with some in Central and Western Macedonia in Greece. In view of these features of the material culture, but also the geographical location and dating, Vlaho proves to be one of the settlements that played a significant role in the early Neolithisation processes in the Balkans.

The continuous excavation of Vlaho in the last few years has provided samples for archaeobotanical and archaeozoological analyses that were also used for its dating (*Antolín* et al. *2021; Naumov* et al. *2023a; Sabanov* et al. *2023*). There are only six dates available for the site so far, but many more are expected. The samples are related to stratigraphical units from the initial to the final stages of the EN occupation, so that a temporal overview of the general duration can be established. Most samples derive from cereals, but some were obtained from the bones of sheep and cattle.

The earliest date from Vlaho, ETH-132740, comes from a sheep bone found on the floor of Building 2. The sample ETH-132741, taken from cattle bone, strengthens the early dating of Building 2 since the calibrated and rounded by 10 the results are between *c.* 6420 and 6250 cal BC (compare Tab. 1 and Fig. 3). This building, one of the earliest at the site, is located above Building 1, for which there are no dates available yet. Two samples analysed in Seville (CNA-6151 and CNA-6152) place the activity within Building 3 at the same time of or a bit later than Building 2. It is followed in the stratigraphical record by Building 5, for which only a single date is available with a median of 6320 cal BC. The youngest date, CNA-6150, comes from a cereal sample in Building 7, which is situated in the top layers of the Vlaho stratigraphy. This date is much younger than the rest of the dates (6060–5990 cal BC).

These six dates were used for the Bayesian model (Fig. 4) based on their context within a particular building. At this stage of excavation, it is premature to define specific phases for the whole settlement. Nevertheless, the vertical disposition of buildings, one above the other, enables a stratigraphical succession from the earliest to latest buildings. This way the model can be used as a reference for either a continuous occupation and/or for the detection of cultural gaps. Judging by the median values of the model's boundaries, the EN community founded the settlement between 6400

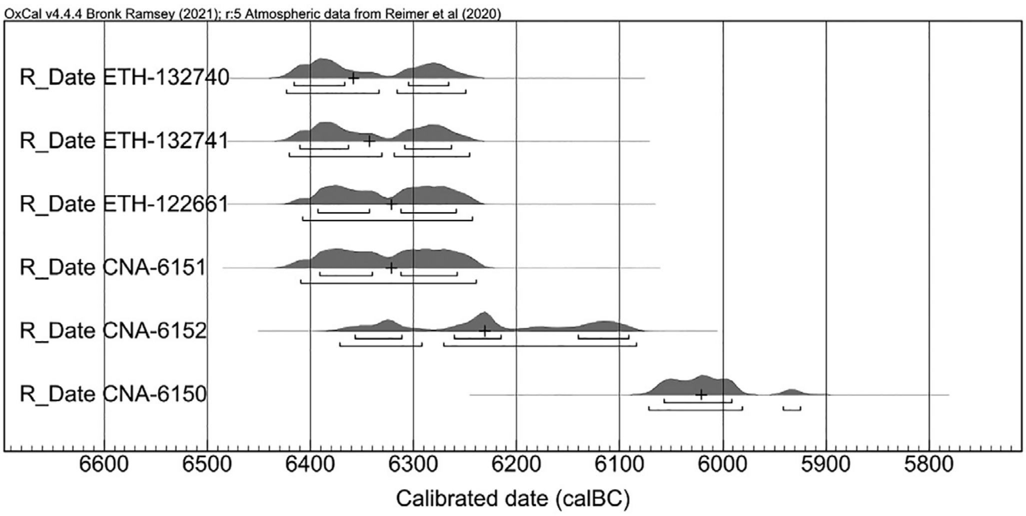

Fig. 3. Calibrated dates from Vlaho, sorted by age.

and 6360 cal BC; the activity within Building 3 may have occurred in the 2nd half of the 64th century BC, followed soon after around 6300 cal BC by Building 5. The next date, CNA-6150, is much younger, with a median of 6030 cal BC.

The provision of more dates for these contexts, but also for the site in general, will enable a more consistent chronological sequence. This significantly concerns the temporal gap between Buildings 5 and 7 of *c.* 150 years. This may indicate a lack of dates (including those from Building 6) or a brief inactivity in this part of the settlement or even in the entire site. Only intensified excavations of these levels in various parts of the site, together with more frequent sampling will resolve this question.

Nevertheless, we should not underestimate the importance of this high-quality data in our evaluation system. Despite the absence of dates from the earliest Building 1, a start of the sequence around 6400 cal BC (as *TaQuo,* see footnote 3) seems probable. It ends after *c.* 400 years of occupation latest at 5980 cal BC, according to the end of the model's boundary. This corresponds to the EN period in Aegean terminology and, as such, it is much earlier than any modelled sequence from Neolithic sites in the Balkans.

Veluška Tumba

The tell site of Veluška Tumba is positioned 400m south of Porodin on the lowest slopes of Baba Mountain next to the flatland plain of central Pelagonia (Fig. 5). It was largely excavated in the 1970s and 1980s, when its EN stratigraphical record of 4m height together with its distinct material culture were highlighted (*Simoska, Sanev 1975; 1976; Simoska 1986*). Novel multidisciplinary research was initiated in 2017, first with non-invasive investigations (archaeological and geophysical

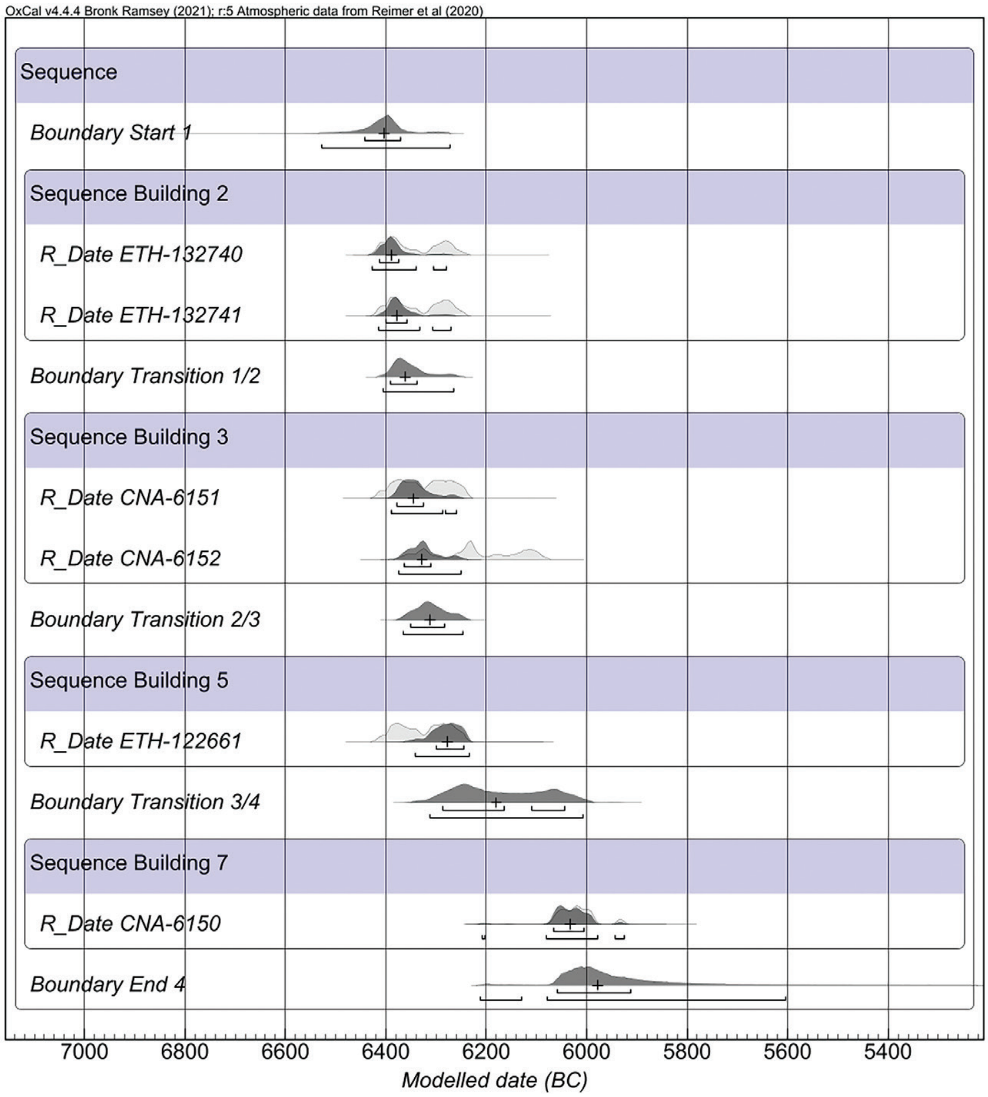

Fig. 4. Radiocarbon dates from Vlaho, modelled according to four building sequences.

prospections), followed by the still ongoing excavations (*Naumov 2022*). The recent research of Veluška Tumba provides detailed information on the spatial organization of this EN settlement, which is enclosed by two narrow ditches and daub buildings positioned in a northeast–southwest direction, often rebuilt in up to 13 architectural levels. The buildings contained several clay installations, such as ovens and bins, as well as dozens of large grinding stones.

Fig. 5. Photo from Veluška Tumba (©Center for Prehistoric Research).

The excavations and study of material culture were accompanied by archaeobotanical analysis which also provided samples for dating (*Antolín* et al*. 2021; Sabanov* et al*. 2023*). Besides these, samples of hazelnut and charcoal were also dated, but they are not included in this chronological study as they belong to the Mesolithic with results at 8846 BP (median at 8000 cal BC) and 7973 BP (median at 6900 cal BC). They also need additional revision and discussion, as at this stage it cannot be confirmed whether these samples are related to cultural activities or to natural events (*Naumov 2023b*). Similar to Vlaho, the Veluška Tumba samples derive from the stratigraphical units related to particular buildings, mainly concentrated in the earlier stages of the Neolithic settlement, some of which are synchronic, while others are erected one on top of another.

From the 18 samples from Veluška Tumba, two failed to be dated, two are from the Mesolithic, and one sample (BRAMS-4497), although from the EN layers, dates to the last century of the 6th millennium BC and may have been displaced by a rodent.[4] However, the 13 remaining samples provide a solid sequence ranging from 6020 to 5760 cal BC according to their medians (Fig. 6). The earliest Neolithic date is provided by the cereal sample BRAMS-4499 (6060–5990 cal BC: see Tab. 1) and it marks the foundation period of the settlement. The youngest date in the EN-sequence is ETH-122645 at 5760 cal BC according to its median. However, the sample, a pulse, was found in Building 1, one of the earliest in the sequence. Note that the date shows a high standard deviation and thus, if it has not been displaced by rodents or other agents, it may even be in line with the earliest occupation phase shortly after 6000 cal BC. Therefore, the cereal sample ETH-122646, dated to 5890–5720 cal BC (median of 5800 cal BC), provides the latest date from a secure unit. Still, this date is also not from the final stages of the settlement as there is stratigraphical evidence for at least nine more buildings erected above it.

The Bayesian model for the dates from Veluška Tumba provide a reliable dating of several buildings, as all the samples were taken from their interiors. Since the chronological modelling corresponds to the stratigraphical position of the buildings, it can be used for a better determination of phases along with the observed changes in the material culture in the future. Given the medians in the Bayesian model (Fig. 7), the chronological frame is set in the period between 6000 (as *TaQuo*) and 5820 cal BC, according to the boundary medians. Thus, the four consecutive building phases correspond well with the EN in Pelagonia.

It should be noted that the earliest date from Veluška Tumba is related to the level of protosoil in which the remains of material culture and cultivated plants were found. This could be a result of intensive building and rebuilding of houses for which the foundations were often dug deeper into the soil, as proven not only for this site but also at Vrbjanska Čuka (*Naumov 2020*). That this activity is related to the founding phase of the settlement is also indicated by the Bayesian model with a median of *c.* 5990 cal BC for this early date. The earliest detected architectural unit at Veluška Tumba so far is Building 16, with two dates (according to their medians) of 5970 and 5940 cal BC, respectively. Stratigraphically, it is followed by Building 1, which

4 In terms of Balkan chronology this would correspond to the Late Neolithic, but so far, no finds of this period were made. However, there is possibility that the upper part of the tell has been destroyed by constant ploughing in the last two centuries.

held most of the samples. Inclusive of the date ETH-122645 they narrow down the activity within this building to the time around 5920/5890 cal BC. Building 14, just above it, has a median of *c.* 5870 cal BC, and is in its turn succeeded by the last dated unit, Building 2, dated around 5850/5840 cal BC. Of course, these medians only represent a general chronological range for each of these buildings. They nevertheless indicate a gradual temporal perspective of the building intensity in the EN stages of Veluška Tumba. They should be regarded as approximate dates for the occupational period of these four buildings between 40 and 60 years each. With the future provision of more dates for each building phase, their time span will be determined more precisely.

The model from Veluška Tumba shows no temporal gaps, unlike the aforementioned model for Vlaho. This appears to be largely due to the higher number of samples, but also the stratigraphical records with no indications of geological events related to shorter or longer phases of abandonment. The dense succession of buildings in the stratigraphy also demonstrates an intensive occupation on this tell, which most likely was continuously inhabited (*Naumov* et al. *2020*). According to the boundaries of the model the duration of single sequences is between 70 and 20 years. Nevertheless, future dating of the phases following Building 2 is necessary to understand whether or not there was an uninterrupted occupation at this site.

For Veluška Tumba, the dates from the 1970s should also be mentioned. We did not include them in the discussion so far, due to the nature of their origin (charcoal samples from poorly defined layers). Despite their broad standard deviations, the calibrations reveal results around 5800 cal BC (as *TPQ*-cal). Thus, they overlap mainly with the younger part of the newly obtained sequence, and they substantiate this period as one of the most intensive occupations in the tell's stratigraphy. These findings will be discussed below in relation to the general chronology of Pelagonia.

Vrbjanska Čuka
The site of Vrbjanska Čuka is positioned in the northern part of Pelagonia, between the cities of Prilep and

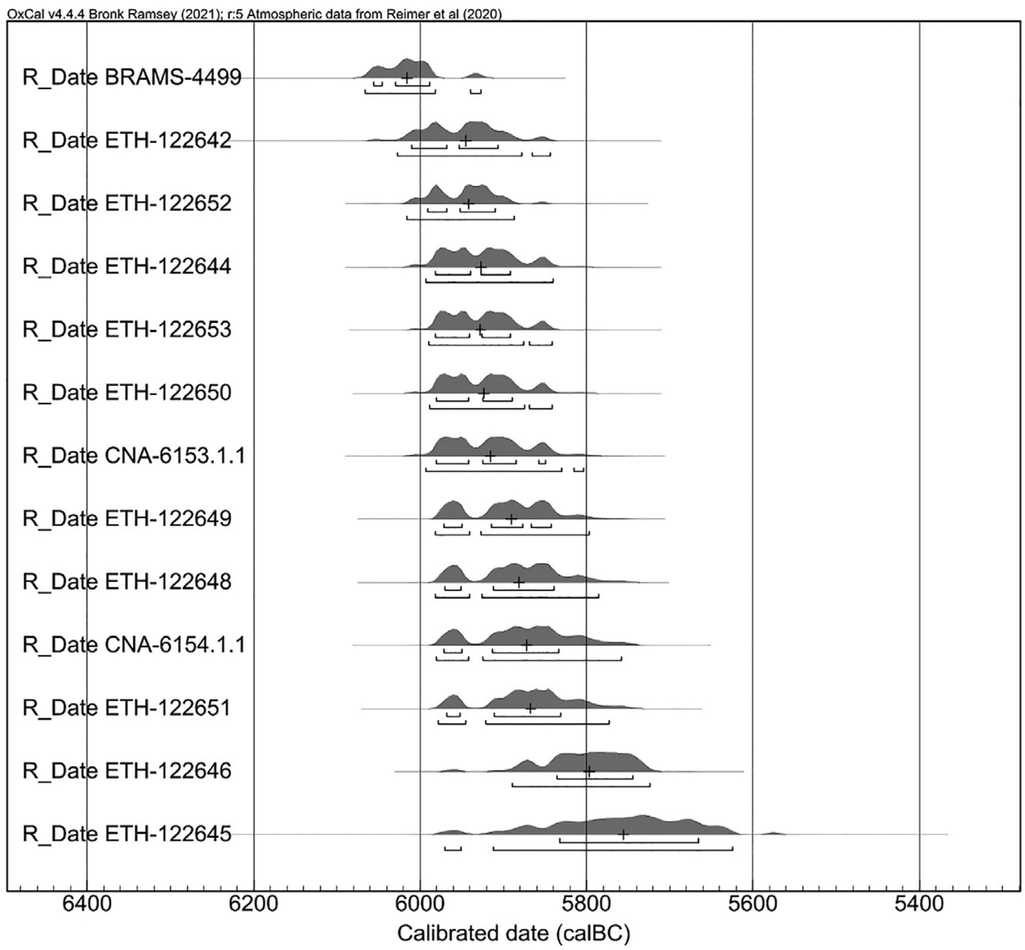

Fig. 6. Calibrated dates from Veluška Tumba, sorted by age.

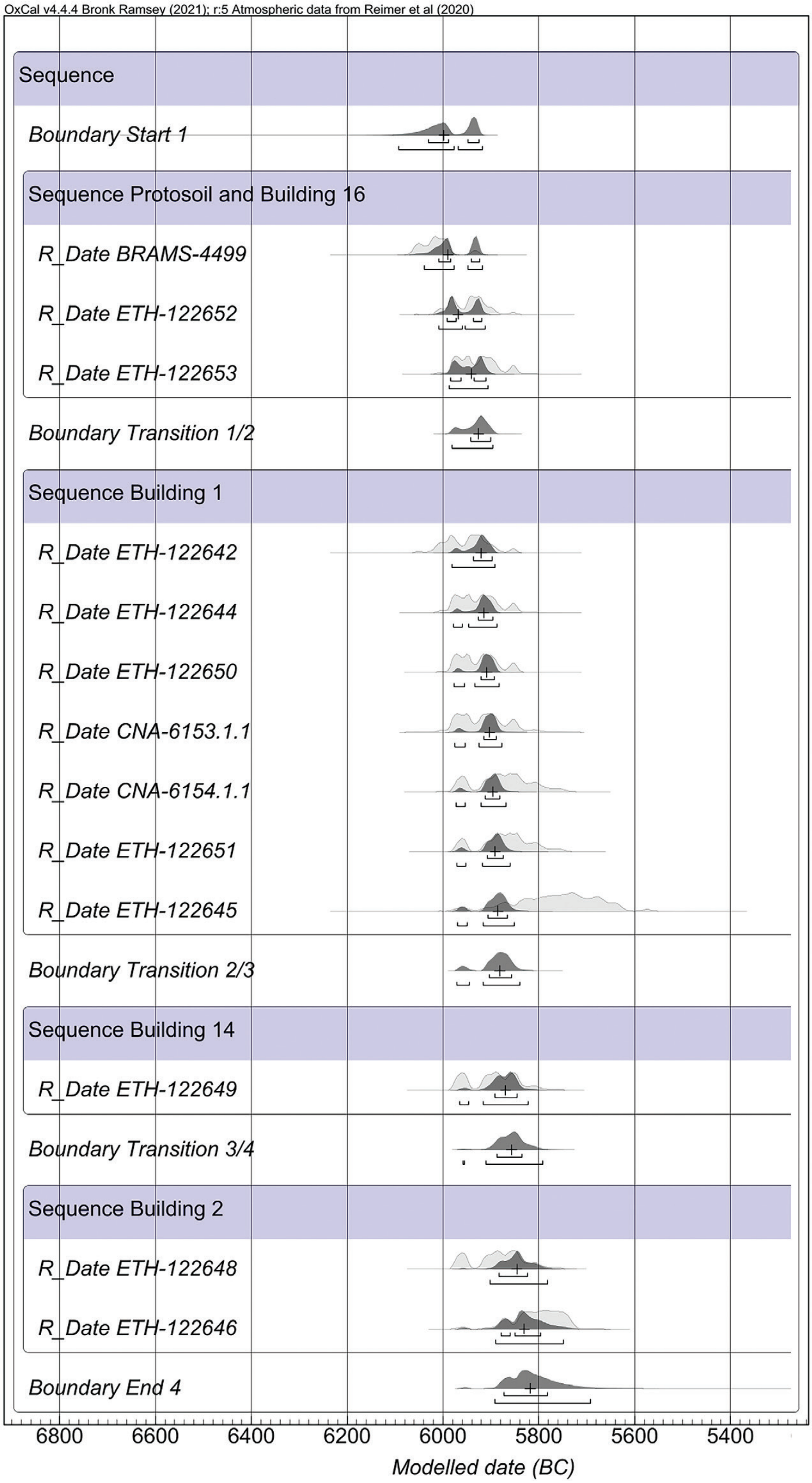

Fig. 7. Radiocarbon dates from Veluška Tumba, modelled according to four building sequences.

Kruševo, *i.e.* in the flatlands, 1.3km south of the village of Slavej (Fig. 8). The initial excavation was performed in the 1980s when its Neolithic character was determined through its impressive material culture and architecture (*Kitanoski 1989; Mitkoski 2005*). New multidisciplinary research started in 2016 and is still ongoing (*Naumov* et al. *2021; Naumov* et al. *2023c*). Other than the aforementioned sites, Vrbjanska Čuka ends with a Late Roman *villa rustica* and depositional pits, which were further used in the Medieval period, when this tell served as a necropolis. Only 1.30m of its height consists of EN layers, but these demonstrate a dynamic settlement with seven building layers enclosed by a broad ditch. The buildings, positioned in the NW–SE direction, contained a large number of massive clay installations (ovens, granaries and bins) as well as grinding stones. Like the cases of Veluška Tumba and Vlaho, the painted pottery, figurines, house models and tablets indicate distinct craftsmanship with complex symbolic and social features. An infant burial was discovered in the wall foundation of a house (Building 16).

Fig. 8. Vrbjanska Čuka as seen from the south (©Center for Prehistoric Research).

The archaeobotanical research provided the majority of radiocarbon samples, but also samples from lipid analyses and the above-mentioned infant burial were dated (*Beneš* et al. *2018; Antolín* et al. *2020; Stojanovski* et al. *2020; Sabanov* et al. *2022; 2023; Naumov* et al. *2023c*). Altogether 20 samples were sent to different laboratories, of which two belong to the Medieval period and another four were of poor precision. The remaining 14 samples are related to indoor stratigraphic units, *i.e.* particular buildings from different levels of the settlement. Not only the quantity but also the quality of the samples thus provide a reliable chronological sequence that demonstrates the temporal span of this EN settlement from its beginnings until its abandonment.

The earliest date is related to the cereal sample ETH-122658 from Building 11 (Tab. 1 and Fig. 9). It is calibrated to 6100–6000 cal BC, with the median of 6050 cal BC. The latest date, CNA-4705, was obtained from a lentil (5730–5670 cal BC, median of 5700 cal BC) and it overlaps with the lipid sample BRAMS-2838. The chronological frame of the medians suggests a temporal range of the EN settlement between 6050 and 5700 cal BC. It must be stressed that sample ETH-138166 from Building 16 belongs to an infant buried in the foundation for this structure (*Naumov* et al. *2023c*). The calibrated date has a median at 5900 cal BC and is as such *c.* 200 years older than expected on behalf of the stratigraphical position of the building between Buildings 5 and 14. We did not include it into the model as it is susceptible to the reservoir effect.

Given the reliable set of dates, we created a model with five sequences according to the excavated building units (Fig. 10). The building sequences represent three different architectural horizons that were dated on behalf of their stratigraphic disposition (*Naumov* et al. *2021*): The earliest is Building 11, which is in the same layer as Building 2 and next to it. Therefore, it is not surprising that their temporal ranges overlap, although sample ETH-122658 implies a possible earlier establishment of Building 11 at the end of the 7th millennium BC (5990 cal BC as *TaQuo*). On the other hand, the large number of dates from Building 2 determine its occupation between 5900 and 5860 cal BC. Given its stratigraphic position, Building 5 may also belong to this initial phase of Vrbjanska Čuka and can be chronologically attributed to the 59th century with its modelled median of 5830 cal BC.

As for the second architectural horizon, there are no dates available so far, but samples from interiors of Building 4 and Building 21, which are from this horizon, are ready for dating, so they will be incorporated in the updated version of the model.

The third architectural horizon consists of two subphases, each represented by a building unit. From Building 14 sample CNA-4705 was dated to *c.* 5790 cal BC. Building 8, which was founded above the previous one, largely corresponds to this dating with one median of 5760 (BRAMS-4542) and 5750 cal BC (BRAMS-2838).

Therefore, the model limits the duration of occupation at this site according to the boundaries between 6030–5740 cal BC. Nevertheless, despite the large number of samples and the thorough sequencing of Vrbjanska Čuka, more dating is still necessary in order to develop a better chronology of this site. Intensive dating of Building 4 would end in a more precise chronological understanding of the 2nd architectural horizon, while more dates from structures of the last occupational stage of this tell are also needed. Dating of the newly discovered Building 19 and Building 21 in the northern part of the trench will provide additional information on the settlement expansion and its temporality.

Dating other Pelagonian tells

Besides the sequences and models elaborated above for Vlaho, Veluška Tumba, and Vrbjanska Čuka, and next to the few dates obtained in the 1970s, there are also some newer dates available from other sites, yet only one to three per site. These are not sufficient for detailed observations, but they do contribute to a better understanding of the temporal determination of the tells and the dispersion of the Neolithic in Pelagonia, and will therefore be included in this chronological overview.

There are three samples from the EN site of Tumba at Optičari, taken from seed and animal bones unearthed in the 1980s when this tell was excavated (*Simoska, Kuzman 1990*). They were recently dated as part of the current projects (*Naumov 2023b*). The seed sample BE-5280 was dated to 5980–5850 cal BC (median of 5910 cal BC) (Tab. 2, see below). The two bone samples are almost a century younger with a median of *c.* 5800 cal BC. In this respect, the Optičari dates overlap with those from Veluška Tumba and Vrbjanska Čuka, indicating a synchronic occupation of these tells.

There is another tell in the same central part of Pelagonia that has been recently dated. Školska Tumba was excavated in the 1970s and again in 2014, providing more information on the complexity of Neolithic tells (*Simoska* et al. *1979; Naumov, Tomaž 2015*). Five sam-

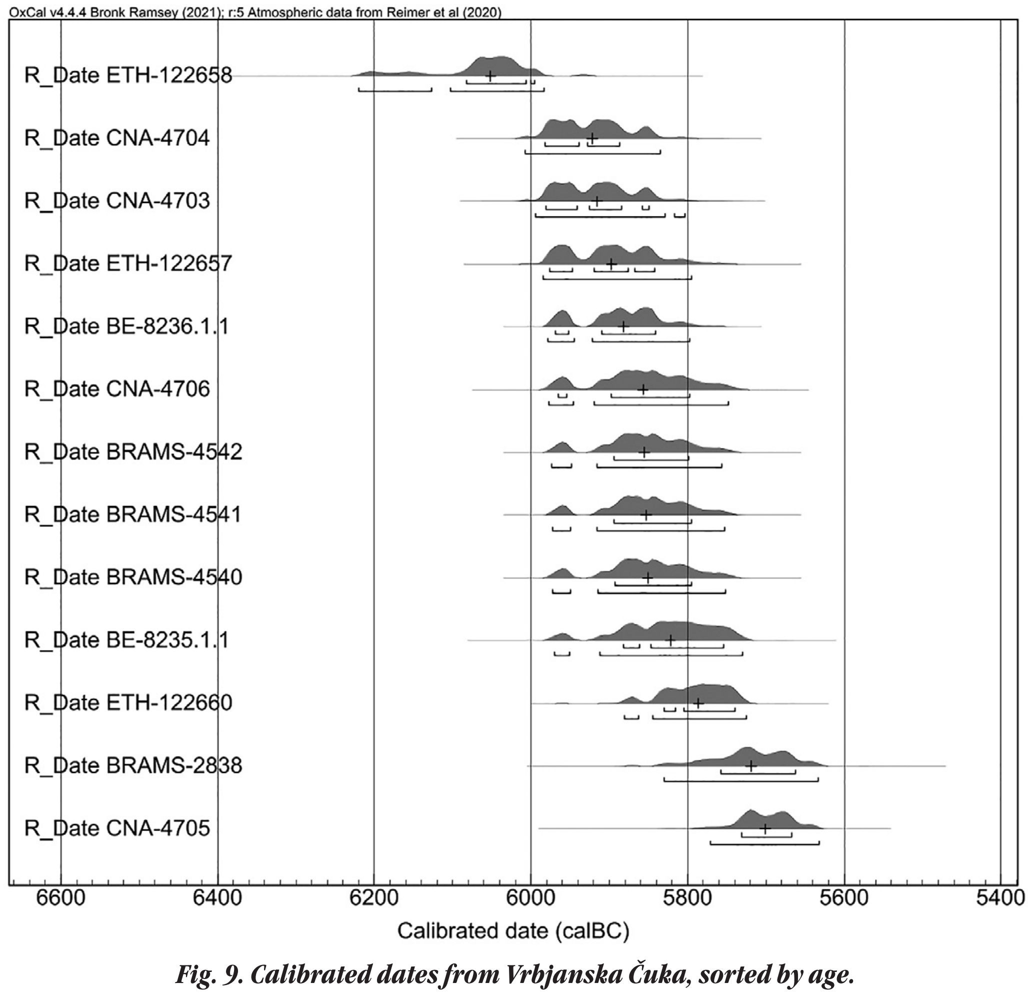

Fig. 9. Calibrated dates from Vrbjanska Čuka, sorted by age.

ples were taken from this site, yet only the two bone samples related to the earliest layers gave good results, whereas the seeds were dated to the Middle Ages (6th to 9th centuries AD), a period that was recorded in the excavations of both teams. The bone samples were recently dated to 5700–5600 cal BC, thus indicating the most probable period for the establishment of the tell (see Tab. 2). In this case, it is noteworthy that the ini-

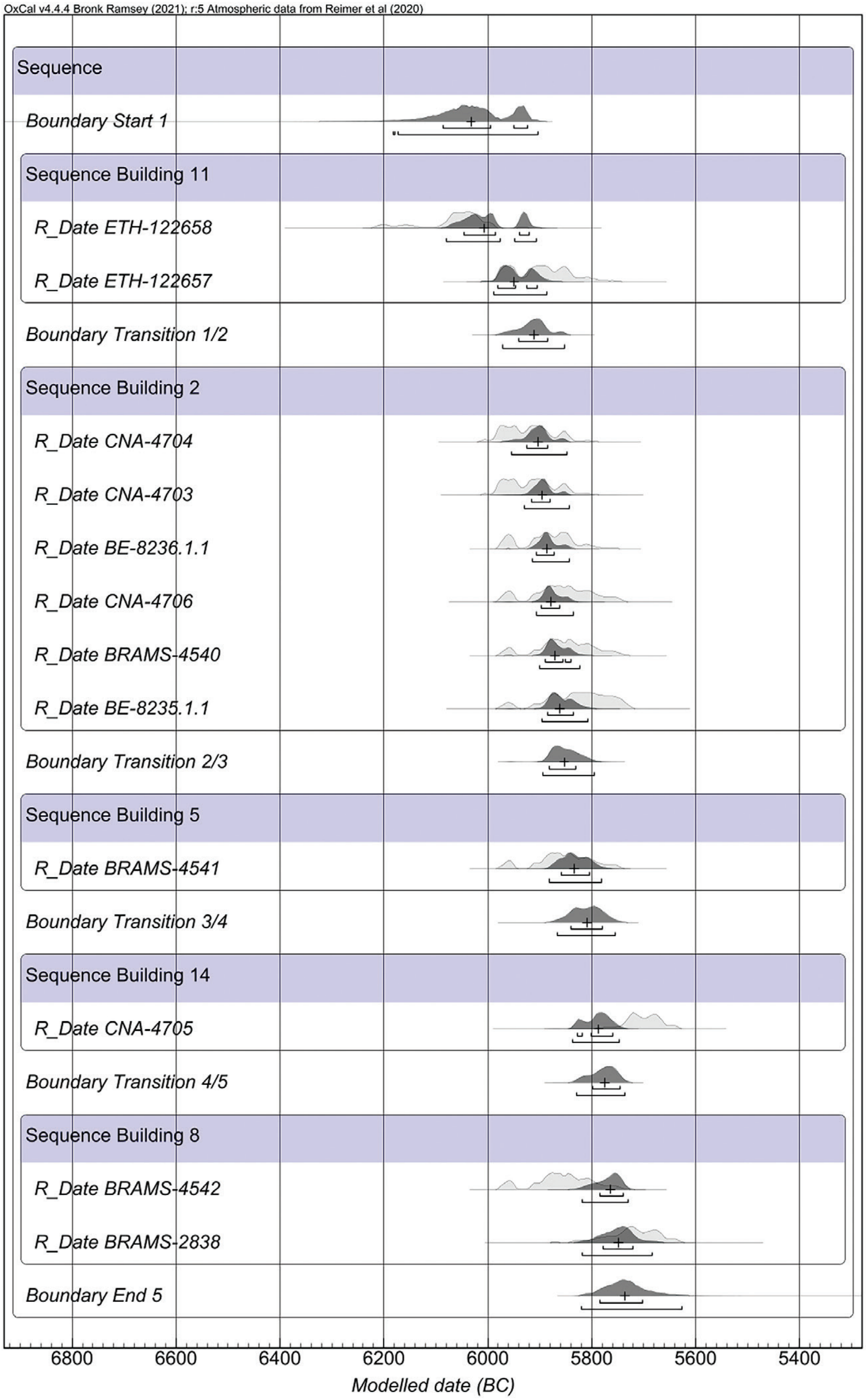

Fig. 10. Radiocarbon dates from Vrbjanska Čuka, modelled according to five building sequences.

tial inhabitation period of this tell is a bit later than the ones at Veluška Tumba and Vrbjanska Čuka. The two dates from Školska Tumba from the 1970s, however, give rather broad results: the earlier one is positioned between 6250 and 5560 cal BC and the later one between 5390 and 4680 cal BC (*Naumov 2023b*). Unfortunately, not only were the samples taken from unidentified charcoal but their standard deviations are also very large. Consequently, they cannot be used in this discussion.

Tumba Porodin is a tell very close to Veluška Tumba and was intensively excavated in the 1950s (*Grbić* et al. *1960*). Although three charcoal samples were dated in the 1970s, one of the seeds was recently sent for radiocarbon analysis. The sample BE-5281 (see Tab. 2) has results between 5840 and 5710 cal BC and a curve peak at approximately 5740 cal BC. Of the three aforementioned charcoal samples, the earliest has a smaller standard deviation and could be set at the end of the 7th millennium, while the two others are with broader results between 6000 and 5600 cal BC. As such they overlap with those from Veluška Tumba which is just 2km away. It appears that the two neighbouring tells may have, at least at times, been used synchronically.

There are three other Neolithic sites in Pelagonia that were dated in the 1970s, but no more recent radiocarbon analysis has been performed. From Čuka at Topolčani two dates are known: the older date has a broad standard deviation and covers the middle of the 7th millennium BC. This date has been discussed in depth since it was regarded as far too old for the Neolithic in North Macedonia, and it was presumed that old wood was used (*Naumov 2016; 2023b*). Besides, its exact context was not provided, and it is unclear as to which layer it belongs (*Srdoć* et al. *1977; Kitanoski* et al. *1978*). The second sample from this site was dated to the first half of 6th millennium BC, which is more or less comparable to the chronology of the other tells in Pelagonia.

Markovi Kuli above the city of Prilep is one of the rare sites that differs in terms of its natural setting and settlement features from the other sites. It is a rock shelter without specific Neolithic architecture, but with some typical pottery for this and the subsequent Chalcolithic period (*Cnotlivi 1990; Naumov, Mitkoski 2018*). The only analysed Neolithic sample comes from an animal bone and it provides a date of around 5600 BC. This overlaps with the date from Porodin and could be considered one of the latest EN dates in Pelagonia (*Naumov 2023b*).

The chronology of Pelagonia in a broader regional context

The detailed chronological overview of Pelagonia enabled a reliable determination of the start and end of the EN in this region. Our current aim is to embed this period into a broader context and particularly trace relationships with surrounding areas in which the Neolithic communities in Pelagonia established networks that are manifested in the material culture. Analogies in pottery and figural representations that reflect not only geographical but also chronological proximity can be observed with the south (Western and Central Macedonia in Greece), west (Lake Ohrid, Lake Prespa, Korça Basin) and north (Ovče Pole and Skopje basin).[5]

Western and Central Macedonia in Greece

Starting with the oldest Pelagonian dates, namely those from Vlaho, the relationship with EN sites in Western and Central Macedonia in Greece is particularly significant. As mentioned above, the southern part of the Pelagonian basin also stretches south of the border between North Macedonia and Greece, into the region of Western Macedonia. The closest comparable site is yet farther south, some 50km south of Vlaho. This site, Mavropigi-Fillotsairi, is located in the hilly area of Ptolemaida (Kozani district). It is a flat site with two separate architectonical phases: an earlier one consisting of mainly pits of different sizes and depths and a later one with quadrangular constructions (*Bonga 2020.Fig. 2; Reingruber 2024.86*).

There are 32 radiocarbon dates from Mavropigi, which cover the whole duration of the EN (*Starnini 2018; Bonga 2020*). The two oldest dates in the sequence fall within a flat portion of the curve and were obtained from charcoal (of an unknown species). Therefore, the sequence may not have started as early as 6600 cal BC, as suggested before (*Karamitrou-Mentessidi 2014.245; Maniatis 2014.207; Karamitrou-Mentessidi* et

5 The connections between the Struma Valley and the areas to the west of it were recently discussed in a comprehensive contribution on the Neolithisation of southeastern Europe (*Krauß 2023.83–105*), so we omit this region from our overview and refer the reader to that study.

al. *2015; Starnini 2018.Tab. 1*), but several decades later (*Reingruber* et al. *2023*).

We have created a model according to Phases 1–3 as developed by the excavators (*Karamitrou-Mentessi* et al. *2015.58*) and discussed by Lily Bonga in her own work (*Bonga 2017; 2020*) and in collaboration with others (*Reingruber et al. 2023*). In our model we are relying on dates obtained on charcoal and seeds, excluding those on human bones (Fig. 11). As some of the dates do not match the sequence they are considered here to be outliers, unfortunately most of them on seeds (Fig. 12). One such outlier is from Phase 1: DEM-1716, 7314±30 BP (6230–6100 cal BC); two others are from Phase 2: MAMS-21099/DEM-2683, 7619±26 BP (6480–6440 cal BC) and OxA-31678, 7470±40 BP (6410–6260 cal BC). In Figure 11, the upper boundary is thus set at 6530 cal BC because the oldest date in the sequence falls onto the plateau in the calibration curve. Therefore, 6530 cal BC can be understood merely as a *TPQ*-mod, although the actual start may have been much later than this, as the date for this phase – which was obtained from seeds – suggests (DEM-2684 with a median of 6360 cal BC; but note that the result of another seed, attributed to Phase 3, DEM-2683, is dated to 6460 cal BC, Fig. 12).

According to the modelled medians, Phase 1 lasted over 200 years, between 6530–6310 cal BC. Phase 2 may have been of comparably short duration (6310–6220 cal BC), whereas Phase 3 has a seemingly longer duration again, between 6220–6000 cal BC. The extreme length of Phase 1 and the huge overlap with Phase 2 are indicative of how difficult it is to accurately separate contexts within pit sites. Moreover, the overlap between Phases 2 and 3 shows that more dates would be needed to derive a solid model without caveats during calculations executed with Oxcal. Therefore, we suggest the start at 6530 cal BC only as *TPQ*-mod and the date of 6460 cal BC, with reservations, as *TaQuo*.

The Pieria region is situated in Central Macedonia, between the lower Aliakmon River and the Aegean Sea. Some of the newly discovered EN sites that are located there have further changed our perception of how the Neolithic disseminated into the Aegean.

Revenia-Korinos is an open-air, flat extended settlement, only 10km away from today's coastline. The site is characterized by pits of varying sizes, some of them identified as subterranean or semi-subterranean pit dwellings. However, at "*6200/6100 BC [...] the pit habitation mode is followed by aboveground, rectangular post-framed structures*" (*Maniatis, Adaktylou 2021.1025*).

Twenty-nine radiocarbon dates have been obtained from Revenia from samples of different materials, among them fish-eating species and charcoal of long-lived oak (*Maniatis, Adaktylou 2021*). It is noteworthy that two of the four oldest dates are either on pig bone (excluded due to the reservoir effect) or charcoal (old-wood effect), and their results need to be treated with care. Additionally, together with a third date, they cover a flat portion of the calibration curve, a so-called plateau (*Reingruber* et al. *2023.Fig. 5*), which artificially lengthens the duration by more than 100 years, between 6600 and 6500 cal BC. A fourth date attributed to the 'Primary habitation phase' was taken from cattle bone and is not affected by the plateau and thus a more reliable result (DEM-2823). These four dates, together with the five dates from charcoal and cattle bones, date the earliest pottery Neolithic at Revenia to between 6560 and 6300 cal BC (according to their medians). The later EN can be dated between 6420–6140 cal BC, according to the calibrated medians from 13 dates (among them seven from human bones). The huge overlap of dates from these two phases between 6420 and 6200 cal BC may reflect possible reusages of pits and the difficulties associated with the chronological assessment of undecorated pottery and/or unidentifiable sherds. Another plateau on the curve between 6240 and 6020 cal BC creates the impression of a long duration of the last phase, when it actually may have been much shorter.

We modelled the dates according to three phases – 'Primary', 'Earlier EN' (EEN) and 'Later EN' (LEN) – including samples obtained on charcoal and cattle (excluding human bones) and obtained a more limited occupation of the sites (Fig. 13). Due to the plateau, the boundary start is set at 6560 cal BC as a *TPQ*-mod. According to the medians, the sequence of the Primary phase lasts between 6520 and 6430 cal BC. The EEN phase covers the period between 6380 and 6320 cal BC whereas the LEN is comparably short, from 6320 to 6240 cal BC. However, this model is only a rough framework, with less heavy re-modellings of the calibrated dates than was the case in Mavropigi. Yet we still encountered some issues during the calculation process. Other than in the model obtained by Yannis Maniatis and Fotini Adaktylou *(2021.1042*), in our model the transition to the LEN – the phase with rectangular buildings – is at 6320 cal BC.

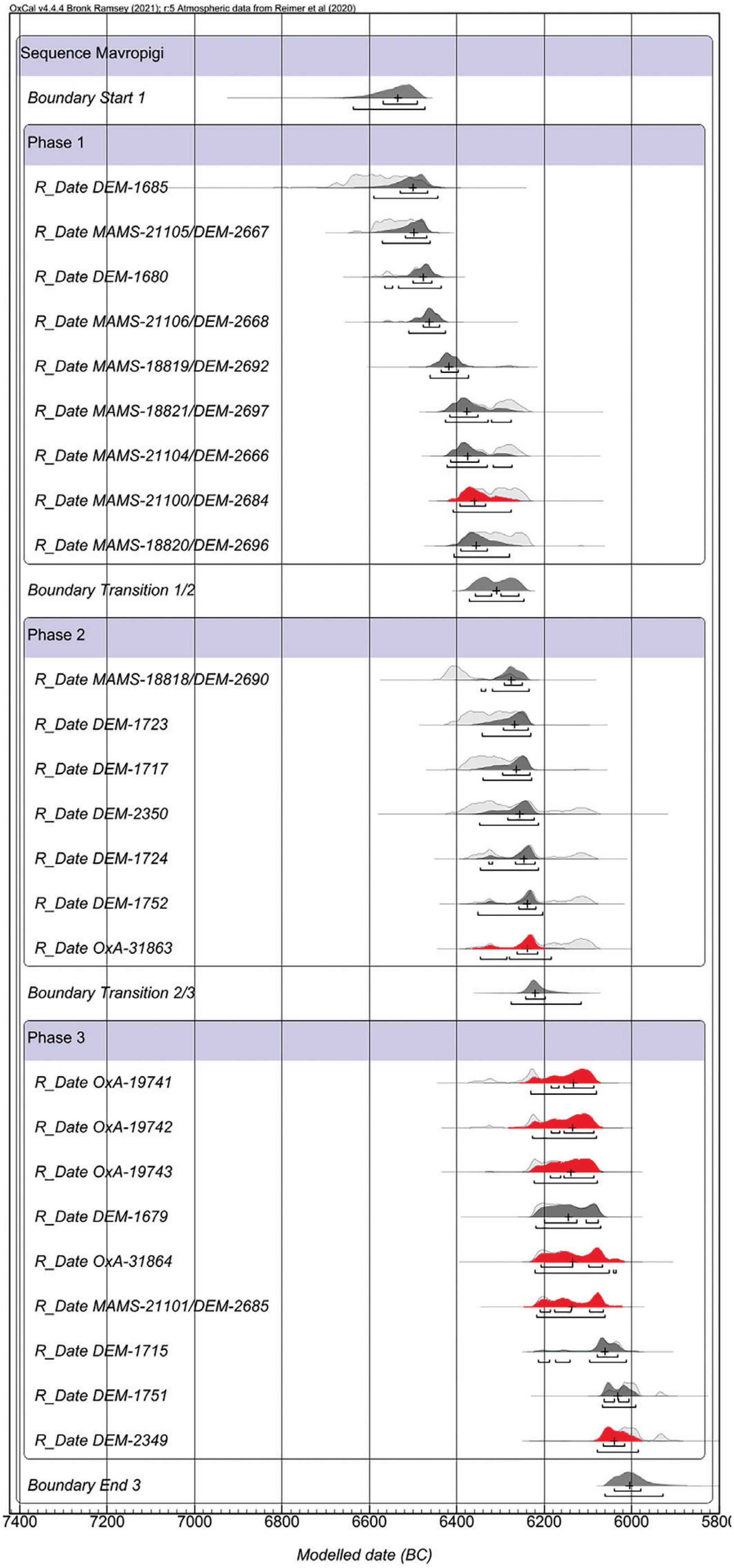

Fig. 11. Radiocarbon dates from Mavropigi, modelled according to three habitation phases (indicated in red are results obtained on grains).

Another site in the Pieria, approximately 20km north from Revenia, is Paliambela-Kolindros. The site is established on a small hill above flatlands and is laid out on terraces. During the later EN and at the transition EN/MN, it was surrounded (at least partially) by ditches. Like in Vlaho, structures like hearths and bedrock-mortars were cut into the soft bedrock (*Tsartsidou, Kotsakis 2020; Naumov* et al. *2021; Sabanov* et al. *2023*).

The sequence of dates from this site is not yet complete, but from the five dates obtained mainly from animal bone (*Maniatis 2014.208, Fig. 3*), the three oldest samples yielded results between 6530 (as *TPQ*-cal) and 6450 cal BC according to their medians (*Reingruber* et al*. 2023. Fig. 7*). The two other dates fall into the EN 2 between 6300 and 6000 cal BC (Fig. 14). Interestingly, and as in Revenia-Korinos, the oldest habitation phase is characterized by pits. There is a major change observable after 6300/6200 cal BC when rectangular constructions were erected above ground.

Exclusively above-ground constructions were encountered in Nea Nikomedeia, again a flat site with only 60 cm accumulation (*Pyke 1996*). As the dates from there have not been published according to contexts, another model will not be proposed here and consequently we rely on those already published (*Reingruber, Thissen 2017; Yanovich 2021*). The sequence starts only after 6300 cal BC (as *TPQ*-cal) and ends around 5900 cal BC. Thus, the change from pit-levels to above-ground constructions at or shortly after 6300 cal BC, as clarified for the previous two sites, can be regarded as secured.

The newly obtained dates from EN sites in Pelagonia, together with those from Pieria and Ptolemaida, thus provide more thorough foundations for the determination of the chronological scale in which social transformations occurred and communities from different sites established networks. If the chronological models proposed for Revenia, Paliambela and Mavropigi are accepted then we can conclude that not all sites were established in the same decades: those closer to the coast (Revenia and Paliambela, 6530/6520 cal BC) seem to be slightly earlier than Mavropigi (6460 cal BC) and Vlaho (6400 cal BC) in the hills. That Vlaho was also part of the initial spread of the Neolithic way of life into the Balkans is further evidenced by the resemblance of pottery technology, its decoration and the architectural features are comparable with the sites in Pieria and Ptolemaida (*Bonga 2017; Naumov, Nasuh 2023*). Particularly important is the relationship between Vlaho and Mavropigi, which are only 50km away from each other and set in similar hilly environments above marshy flatlands. It is interesting that the earliest and latest dated short-lived material – *i.e.* seeds – from both sites are almost identically dated to 6380–6020 cal BC, meaning that the EN-levels may have been at least partly contemporary, and that the sites were abandoned at the same time. Based on these relative and absolute chronological assessments, it should come as no surprise when more and better evidence for networks among these societies is revealed in the future.

Lake areas and basins in the border area of North Macedonia and Albania

Besides the earliest Neolithic sites, the tells in the flatlands of Pelagonia – those with dates between

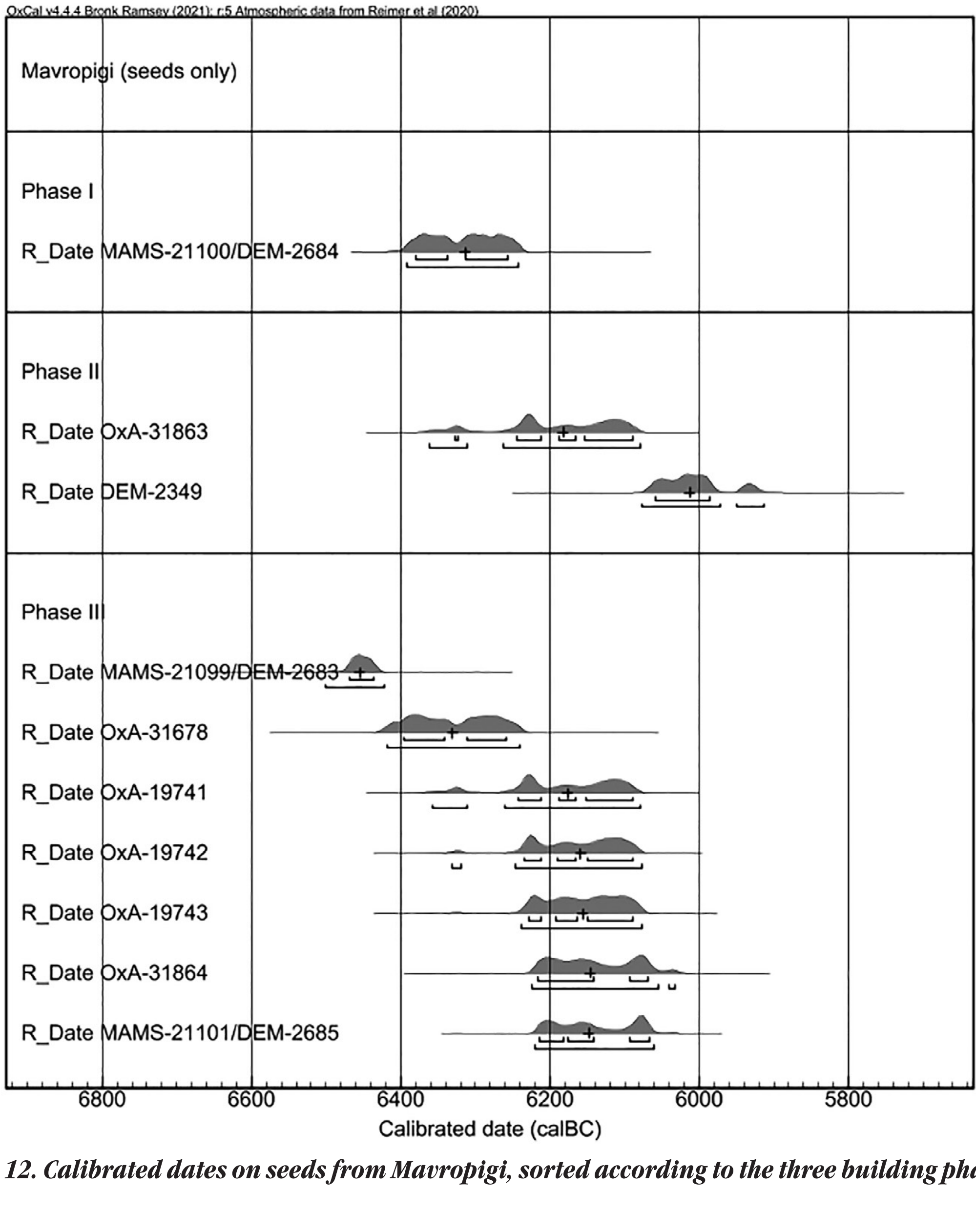

Fig. 12. Calibrated dates on seeds from Mavropigi, sorted according to the three building phases.

6000–5600 cal BC[6] – should also be regarded in a broader regional context. Due to their geographical proximity, the areas of the Lakes Ohrid and Prespa as well as the Korça Basin display the most evident relationships, as has been pointed out on several occasions (*Benac 1979; Sanev 1995; Andoni* et al. *2017*). Networks among wetland societies were certainly established in all periods of prehistory (*Naumov 2018*), although solid radiocarbon dates from the southwestern Balkans are still missing. Considering the Neolithic of Lake Ohrid, the relative chronology developed based on decoration patterns on vessels, figurines, tablets

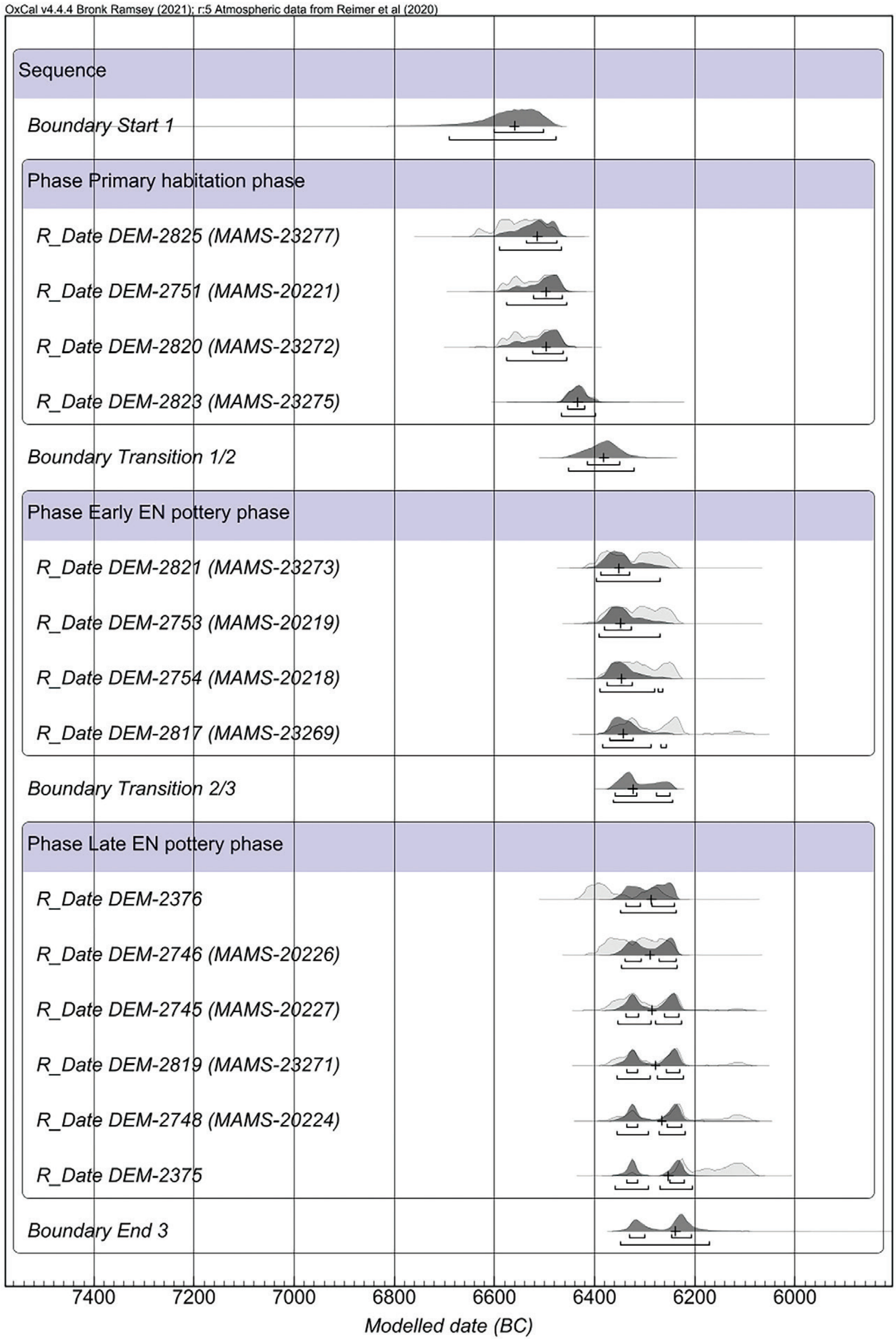

Fig. 13. Radiocarbon dates from Revenia, modelled according to three habitation phases.

6 This period is known as the Middle Neolithic period in Thessaly, but as the Early Neolithic in the Balkan terminology.

and anthropomorphic house models, authenticates the connects with Pelagonia in the Neolithic, and some of the few radiocarbon dates that are available contribute to this. They are related to pile dwellings of Ohridati, Ploča, and Lin 3, and belong to the first half of the 6th millennium BC, *i.e.* the period with the highest density of dates in Pelagonia as well (*Westphal* et al. *2011; Anastasi 2022; Holguin* et al. *in press*). According to the material culture, connections between Pelagonian tells can also be manifested with the dryland sites of Dolno Trnovo and Pogradec. So far, only dates from Pogradec are provided and they range between 6000 and 5800 cal BC (*Andoni 2017*). In the area of Lake Prespa not many Neolithic sites have yet been excavated and dated, except the one at Kallamas that was dated to the second half of the 6th millennium BC (*Oberweiler* et al. *2020*). Consequently, due to the lack of research in this region, only a little information related to the chronological and material connections with Pelagonia can be provided.

Better insights are available from sites in the Korça Basin in Albania, although only two have provided radiocarbon dates. The similarities in terms of painted pottery were already highlighted and they indicate evident communication with Pelagonia (*Korkuti 1982*). Absolute dates are available from sites near Vashtëmi and Podgorie, yet they do not derive from excavations but from coring. This is particularly an issue with the samples from Sovjan and Vashtëmi (dated to the first half of the 7th millennium BC), which are used as indicators for the initial spread of the Neolithic (*Allen* et al. *2014*). Another date from Vashtëmi, around 6400 BC, is also questionable as it is obtained from a charcoal sample from a core. Regardless, if more arguments in support of such early dates in this area are provided in the future, they would fall within the time of occupation of Vlaho. One should note that comparisons based on pottery alone do not suffice to establish early connections, as some pottery features are continuously present up to around 6000 BC.

The regions of Ovče Pole and Skopje basin in North Macedonia

When it comes to the first centuries of the 6th millennium BC, the sites of the so-called Amzabegovo–Vršnik group in particular must be mentioned, although this was traditionally conceived of as two distinct 'cultural groups' (*Garašanin 1979; Sanev 1994; Mitrevski 2013*). Judging from the material culture (pottery, figurines and house models), the farming communities in Pelagonia were closely linked with those in the valleys of Tikveš, Ovče Pole, Polog, and Skopje. To date, only the sites of Amzabegovo and Govrlevo have yielded radiocarbon dates, whereas most sites were never dated or provided only one or few dates per site. Therefore, the chronological comparison with Pelagonia will be based only on two sites. Amzabegovo is one of the rare

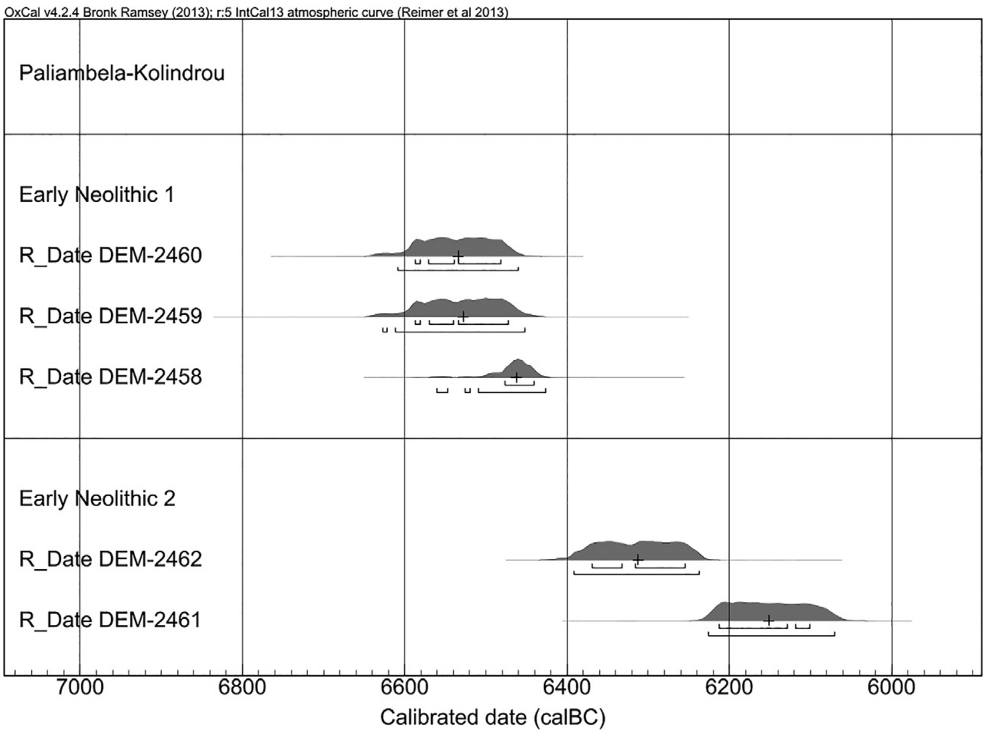

Fig. 14. Calibrated dates from Paliambela, sorted according to the two Early Neolithic phases.

examples of thoroughly explored Macedonian sites with implementation of multidisciplinary research in the 2nd half of the 20th century (*Gimbutas 1976*). Its detailed chronological sequence was later modelled and integrated into the Balkan chronology (*Reingruber, Thissen 2005*). The chronological range between *c.* 6100 and 5000 cal BC indicates the presence of all Neolithic phases at this site, some synchronous to the tells in Pelagonia. This is further supported by the striking resemblance of certain white painted pottery patterns which, besides in Pelagonia, are also present at the sites of Mavropigi and Nea Nikomedeia. Therefore, a possible gradual temporal dispersal of the Neolithic via various routes from the southern to the northern regions would certainly be reasonable.

The site of Cerje near Govrlevo is one of the most systematically excavated in the Skopje Valley, and provides a more exact insight into the Neolithic chronology of this region (*Bilbija 1986; Fidanoski 2012; Fidanoski 2023*). The chronological range of a dozen dates between 5950 and 5750 overlaps with those in Pelagonia and they can be related to a later stage of the Neolithisation process in this part of the Balkans. Similar dates are also present from other sites in the Skopje Valley, *i.e.* Tumba Madjari. Although extensively excavated for several decades only a few reports and radiocarbon dates similar to those from Govrlevo have been published (*Sanev 1988; Commenge 2009; Stojanova Kanzurova 2020*). In this respect, two more sites of the Amzabegovo–Vršnik group from the Ovče Pole region should be mentioned: Vršnik near Tarinci and Grnčarica near Krupište with results from first half of the 6th millennium BC (*Garašanin, Garašanin 1961; Stojanovski 2017*). Similar to Pelagonia, there is also no single date available for the centuries around the mid-6th millennium BC at these sites. The absence of cultural layers of this period (or at least of absolute dates) requires particular attention.

Discussion and conclusions: Pelagonian chronology and the spread of the Neolithic into southeastern Europe

The detailed insight into the chronological sequences of the Neolithic sites in Pelagonia, as well as the overview of the chronologies in the surrounding regions provide a solid time-frame for when and how the first farming communities appeared in North Macedonia. Thirty-nine of the 42 dates (compare Tabs. 1 and 2) rendered results between 6360–5700 cal BC (according to the modelled medians) and 6390–5750 cal BC (according to the calibrated medians). We can therefore ascertain that the Neolithic way of life in Pelagonia started much earlier than previously thought and, as another surprising insight, a change in habitation pattern or in behaviour generally occurred around 5750/5700 cal BC.

The site of Vlaho is of special significance as so far it is the earliest Neolithic site in Pelagonia, as well as one of the earliest sites in the broader Balkan area. Most likely, the initial settlement was established soon after those in the regions of Pieria and Ptolemaida. The sites of Mavropigi, Revenia, and Paliambela share similarities not only in impressed pottery production, which appears in quite a large amount in Vlaho as well, but also in the presence of dug out structures or dwellings (*Karamitrou-Mentessidi* et al*. 2015.Figs. 6–11; Kotsakis 2018.Fig. 3.2; Bonga 2020.Fig. 2; Maniatis, Adaktylou 2021.Fig. 5; Naumov, Nasuh 2023; Naumov* et al. *2023a*).

The revised chronology of the initial stage of Paliambela, *c.* 100 years older than that at Vlaho and Mavropigi, and close to that from Revenia (*Reingruber* et al*. 2023*), indicates the possible trajectories of the advance of Neolithic innovations like farming from the coastal areas to the hinterland of geographical Macedonia. The overlapping dates from Revenia (Primary and Early Phase) and Mavropigi (Phase 1) between *c.* 6500 and 6300 cal BC and those between Mavropigi (Phases 2–3) and Vlaho between 6400 and 6020 cal BC is something that should be used in future studies on demographic processes in the EN of the Balkans.

The distances of the sites to the Aegean Sea have not yet been well investigated, but according to John Bintliff (*1976.Fig. 10*) and Matthieu Ghilardi *et al.* (*2012.47–61*), Nea Nikomedeia was only 5km away from the Thermaic Gulf. Moreover, geological studies from other Aegean coastal areas revealed the proximity of sites to the sea that are nowadays located farther inland (*Horejs 2017.13–15, Fig. 1.3*). The spread of Neolithic innovations into the circum-Aegean area was thus in great part based on the maritime contacts between communities.

Plateaus in the calibration curve around and before 6600 cal BC and again between 6200 and 6000 cal BC (*Reingruber* et al. *2017.Fig.20*) complicate a precise estimation of the beginning or the end of a specific sequence. The former is important in the case of the Aegean, the latter for the Neolithisation of the Balkans.

We have no conclusive dates yet for the time between 6200 and 6000 cal BC from other sites in North Macedonia (apart from Amzabegovo), although it is the time when the first sites were established in other regions of the Balkans, *e.g.,* in Southern Bulgaria (Kovačevo) (*Thissen, Reingruber 2017.137–139*). The extreme decrease in global temperature for at least 200 years, if not longer, around 6200 cal BC (the 8.2 ka-event, *Weninger et al. 2009*) may have triggered the appearance of new sites in river valleys and wetlands (*Thissen, Reingruber 2017.Fig. 2*). Especially at or after 6000 cal BC many new sites appear around the marshes of Pelagonia (*e.g.,* Veluška Tumba, Tumba Porodin, Tumba Optičari, Vrbjanska Čuka and Školska Tumba) (*Naumov 2016*). If the old dates from Markovi Kuli and Čuka-Topolčani can be confirmed by new samples, then this flourishing period of the EN ends around 5600 cal BC.

Vlaho and Mavropigi are positioned in the lower hills of mountain slopes above marshes in the wetlands which nowadays have dried out as a result of the melioration processes in the 20th century (*Karamitrou-Mentessidi* et al. *2015; Naumov* et al*. 2023a*). Paliambela, *c.* 85km away from Vlaho, has also been established in a hilly setting. Three out of four very early sites (the exception being Revenia) are located on lower hills, above the plain. Therefore, we provisionally acknowledge a new settlement pattern that needs confirmation through future research. This is in contrast to previous observations that EN communities exclusively established their settlements in flat areas and on river terraces, while afterwards, in the LN, they moved to higher positions due to intensified conflicts (*Garašanin 1979; Sanev 1995*). Namely, the examples from Paliambela, Mavropigi and Vlaho demonstrate that the first farmers intentionally selected these elevated positions (up to 780 masl) and made modification to the bedrock in order to place the initial structures and hearths (*Kotsos, Urem Kotsou 2006; Karamitrou-Mentessidi* et al. *2015; Naumov* et al. *2021*). This was most likely due to the presence of marshes in the wetlands that were covering large areas in the period before the 8.2 ka event. Studies on the sizes of Thessalian lakes in prehistoric times (nowadays also dried out or drained in the 20th century) are now being carried out, but judging from the current results the lakes changed their outlines over the course of the millennia (*Reingruber, Toufexis 2021.42–43; Caputo* et al. *2022.35–63*). Tells also started to appear around marshes and lakes only a few centuries after the initial establishment of settlements in hilly areas: in Thessaly only after 6500/6400 BC (as a *TPQ*-cal) (*Reingruber 2008; Alexakis* et al*. 2011; Reingruber* et al. *2017*), and in Pelagonia around 6000 BC (*Naumov 2018*).

This habitation model, based on the current chronological results, explains the abrupt appearance of tells in the wetlands of Pelagonia around 6000 BC, after earlier sites in the hilly areas were abandoned. Both prospections and excavations confirm the presence of the majority of tells around marshes in the flatlands, a practice that was maintained in the Late Neolithic, Chalcolithic, and Bronze Age as well (*Alexakis* et al. *2011; Naumov 2016; Reingruber* et al. *2017*)*.* This decision made by the first generation of farmers to settle at the transition between different habitats seems rational, especially if envisaging them as descendants of Mesolithic communities that explored not only water-rich areas like lakes and rivers (providing fish, birds, shells, reptiles, *etc.*), but also woods and hills with their abundant resources for hunting and gathering in the different seasons. We suggest that the later generations were not only 'hunters in transition', but also already well-established farmers for whom direct access to the resources of the wetlands was crucial: fertile soils for farming, mud and reed for buildings, clay for pottery, and water for animals were constantly available in direct proximity to the settlements.

It is evident that this period between 6000 and 5700 cal BC was quite dynamic in Pelagonia and the Balkans in terms of social activity if compared with the existing data before 6000 BC. But when looking at the younger dates, evidence is also scant: for the time around 5600 cal BC we have to rely on the old radiocarbon dates, and even then a temporal gap around 5500 BC becomes apparent, with only few dates from Školska Tumba at Mogila and Tumba at Trn (*Valastro* et al. *1977*), and the dubious one from Veluška Tumba at the end of 6th millennium BC. The situation is a bit different in the Struma Valley of Bulgaria, where at Kovačevo and Balgarčevo levels are present that fit into this temporal gap (*Grebska-Kulow, Zidarov 2021*), although no radiocarbon dates are available yet (*Thissen, Reingruber 2017*). Such a gap could be an artificial one that needs to be closed by future research. Alternatively, social and/or climatic processes may have caused the abandonment of most of the tells before the mid-6th millennium BC. This view is supported by the material culture as no elements of later pottery features are present. As this study focused on the early stages of the Neolithic in Pelagonia, the questions relating to the Middle and Late Neolithic will have to be addressed in a future study.

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Tab. 1. Radiocarbon dates from the three Pelagonian sites, listed according to building units; calibrated and modelled medians are rounded by 10.

Site	Lab. code	BP	StDev (±)	Sample material	Species	Context and layer	cal BC 1σ	cal BC 2σ	Median (cal)	Median (mod)	No.
Vlaho	ETH-132740	7486	26	Bone	*Ovis aries*	Building 2; SU 14, quadrant I	6416–6266	6424–6250	6360	6390	1
Vlaho	ETH-132741	7479	26	Bone	*Bos Taurus*	Building 2; SU 14, quadrant I	6411–6264	6421–6246	6340	6380	2
Vlaho	CNA-6151	7460	36	Cereal	*Triticum sp.*	Building 3; SU 08	6391–6259	6410–6240	6320	6350	3
Vlaho	CNA-6152	7371	36	Cereal	*Triticum sp.*	Building 3; SU 09	6357–6092	6372–6085	6230	6330	4
Vlaho	ETH-122661	7464	28	Cereal	*Tr. timopheevii*	Building 5; SU 7	6393–6259	6408–6243	6320	6240	5
Vlaho	CNA-6150	7151	36	Cereal	*Triticum sp.*	Building 7; SU 01	6058–5992	6072–5926	6020	5920	6
Veluška Tumba	BRAMS-4500	8846	29	Charcoal	*Charcoal*	Earliest layers; VT19-s-08; test trench 8	8172–7856	8205–7807	8000	-	7
Veluška Tumba	BRAMS-4498	7973	28	Wild fruit	*Corylus avellana*	Earliest layers; VT19-s-06	7035–6825	7044–6702	6910	-	8
Veluška Tumba	BRAMS-4499	7143	27	Cereal	*Tr. monococum*	Protosoil; VT19-s-05	6057–5989	6067–5928	6020	5990	9
Veluška Tumba	ETH-122652	7069	28	Pulse	*Lens culinaris*	Building 16; SU 154	5991–5910	6016–5888	5940	5970	10
Veluška Tumba	ETH-122653	7040	28	Cereal	*Triticum sp.*	Building 16; SU 155	5982–5892	5991–5842	5930	5940	11
Veluška Tumba	ETH-122642	7075	41	Cereal (chaff)	*Tr. monococcum*	Building 1; SU 2	6011–5907	6028–5844	5950	5920	12
Veluška Tumba	ETH-122644	7041	33	Cereal (chaff)	*Tr. monococcum*	Building 1; SU 2	5983–5892	5994–5841	5930	5920	13
Veluška Tumba	ETH-122650	7036	28	Pulse	*Pisum sativum*	Building 1; SU 137	5982–5890	5989–5842	5920	5910	14
Veluška Tumba	CNA-6153.1.1	7030	36	Cereal	*Triticum sp.*	Building 1; VT21-SU-153	5982–5850	5993–5831	5920	5900	15
Veluška Tumba	CNA-6154.1.1	6989	35	Cereal	*Triticum sp.*	Building 1; VT21-SU-154	5972–5834	5981–5943	5870	5900	16
Veluška Tumba	ETH-122651	6984	28	Cereal	*Tr. aestivum/durum*	Building 1; SU 140	5969–5832	5979–5773	5870	5890	17
Veluška Tumba	ETH-122645	6862	84	Pulse	*Pisum elatius*	Building 1; SU 2	5833–5667	5971–5625	5760	5890	18
Veluška Tumba	ETH-122649	7002	28	Cereal	*Hordeum vulgare cf. var. nudum*	Building 14; SU 83	5972–5843	5983–5798	5890	5870	19
Veluška Tumba	ETH-122648	6995	30	Wild fruit	*Rubus fruticosus*	Building 2; SU 79	5971–5840	5983–5786	5880	5850	20
Veluška Tumba	ETH-122646	6923	37	Cereal (chaff)	*Tr. monococcum*	Building 2; SU 57	5836–5745	5890–5725	5800	5830	21
Veluška Tumba	BRAMS-4497	6198	26	Cereal	*Tr. aestivum*	Early layers; SU 4	5212–5073	5287–5047	5130	-	22
Vrbjanska Čuka	ETH-122658	7198	47	Cereal (chaff)	*Tr. monococcum*	Building 11; Q24 S508	6083–5996	6220–5984	6050	6010	23
Vrbjanska Čuka	ETH-122657	7010	36	Cereal (chaff)	*Tr. monococcum*	Building 11; Q24 S508	5977–5843	5986–5796	5900	5950	24
Vrbjanska Čuka	ETH-122660	6915	28	Cereal	(Outlier, not included in the model)	Building 11; Q24 S515	5830–5741	5881–5726	5790	-	25
Vrbjanska Čuka	CNA-4704	7036	36	Fruit	*Prunus spinosa*	Building 2	5983–5887	6009–5836	5920	5900	26
Vrbjanska Čuka	CNA-4703	7030	37	Fruit	*Prunus sativa*	Building 2	5982–5850	5995–5804	5920	5900	27
Vrbjanska Čuka	BE-8236.1.1	6995	24	Cereal	*Triticum sp.*	Building 2; VC 28, Q27, Sq A/F, L5-10cm	5969–5842	5980–5798	5880	5890	28

Tab. 1. Continued

Vrbjanska Čuka	CNA-4706	6976	36	Cereal	*Tr. monococcum*	Building 2	5966–5798	5978–5949	5860	5880	29
Vrbjanska Čuka	BRAMS-4540	6971	29	Bone	*Bos taurus*	Building 2; SU 71, kv. 29	5894–5796	5973–5753	5850	5870	30
Vrbjanska Čuka	BE-8235.1.1	6946	44	-	*Cerna spec.*	Building 2; Q27, Sq X(V/X), L0-5cm	5883–5755	5971–5731	5820	5860	31
Vrbjanska Čuka	BRAMS-4541	6972	29	Bone	*Sus domesticus*	Building 5; SU 107, kv. 30	5895–5796	5974–5754	5850	5830	32
Vrbjanska Čuka	ETH-138166	7043	33	Bone	*Homo infans* (not included in the model*)*	Building 16; Q15_SU828	5983–5893	5995–5841	5900	-	33
Vrbjanska Čuka	CNA-4705	6824	35	Pulse	*Pisum sativum*	Building 14	5731–5668	5771–5633	5700	5790	34
Vrbjanska Čuka	BRAMS-4542	6974	29	Bone	*Capra hircus*	Building 8; SU 166, kv. 17	5895–5799	5974–5757	5860	5760	35
Vrbjanska Čuka	BRAMS-2838	6839	47	Residue	*Lipid*	Building 8; SU 78	5758–5663	5831–5634	5720	5750	36

Tab. 2. Radiocarbon dates from other Pelagonian sites recently dated; calibrated medians are rounded by 10.

Site	**Lab. code**	**BP**	**StDev (±)**	**Sample material**	***Species***	**Context and layer**	**cal BC 1σ**	**cal BC 2σ**	**Median (cal)**	**No.**
Tumba-Optičari	BE-5280	7019	22	Seed	*Pisum sativum*	Quadrant I in 1988 excavations	5976-5851	5983-5841	5910	1
Tumba-Optičari	BRAMS-4546	6949	29	Bone	*Bos taurus*	Quadrant I (southern half, spit 12) in 1988 excavations	5883-5774	5965-5737	5820	2
Tumba-Optičari	BRAMS-4545	6935	29	Bone	*Bos taurus*	Quadrant I (southern half, spit 11) in 1988 excavations	5841-5751	5887-5734	5810	3
Tumba-Porodin	BE-5281	6884	22	Seed	*Tr. monococcum*	Quadrant I in 1953 excavations	5784-5727	5831-5720	5760	4
Školska Tumba	BRAMS-4544	6768	29	Bone	*Bos taurus*	Quadrant I (SU 64) in 2014 excavations	5710-5635	5721-5627	5670	5
Školska Tumba	BRAMS-4543	6736	29	Bone	*Bos taurus*	Quadrant I (SU 64) in 2014 excavations	5703-5623	5714-5570	5650	6

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Cataloguing and mapping the Linear Band Pottery sites in Ukraine

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ABSTRACT - *Linearbandkeramik (LBK) is the most well-studied Neolithic culture in Central Europe. However, the easternmost part of its area is less known to European researchers. Addressing this gap, information on 175 reliable and 95 questionable LBK sites and six sub-Neolithic sites with LBK pottery in Ukraine has been collected, verified, and systematized. The precise mapping of these sites provided in this paper allows future analysis of their spatial distribution. Accurate contouring of the eastern boundary of the LBK area has revealed the exploitation and exchange of flint, graphite, and salt as a possible driving force of the first farmers' mobility in the region.*

KEY WORDS – *Neolithic; Linearbandkeramik (LBK); Ukraine*

Katalogiziranje in kartiranje najdišč kulture linearno trakaste keramike v Ukrajini

IZVLEČEK – *Kultura linearno trakaste keramike (LTK) je najbolj raziskana neolitska kultura v srednji Evropi, vendar evropski raziskovalci slabše poznajo najbolj vzhodni del njenega območja. Da bi odpravili to vrzel smo zbrali, preverili in sistemizirali informacije o 175 zanesljivih in 95 vprašljivih najdiščih LTK ter šestih sub-neolitskih najdiščih z lončenino LBK v Ukrajini. Natančno kartiranje teh najdišč omogoča nadaljno analizo njihove prostorske porazdelitve. Določitev vzhodne meje območja LTK razkriva možno izkoriščanje in izmenjavo kremena, grafita in soli kot gonilo silo pri mobilnosti prvih kmetovalcev v regiji.*

KLJUČNE BESEDE – *neolitik; kultura linearno trakaste keramike (LTK); Ukrajina*

Introduction

The beginning of the Neolithic in a large part of temperate Europe is associated with the diffusion of the Linear Band Pottery Culture (hereinafter LBK) populations. The area of this cultural unit stretched from the Drava River to the Baltic Sea and from the Paris Basin to the Dnipro River. Although the LBK is the most studied Neolithic culture in Central Europe, its sites in the territory of Ukraine are the least known to European researchers. For instance, in the recent paper on the colonization dynamics of LBK farmers in Europe published in *Documenta Praehistorica*, Robin Brigand, Jérôme Dubouloz, and Olivier Weller deal with only 45 sites on the territory of Ukraine. The authors noted that the easternmost part of the LBK area has not been studied enough, and most publications written in Cyrillic are not available to European researchers (*Brigand* et al. *2022*). Furthermore, even the available data may not be reliable due to the outdated approaches and errors (*Haskevych 2021.21–22*). This paper presents a complete catalogue of the known LBK

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sites in Ukraine enabling further analysis of the spread of farming, long-distance exchange and human-environment interactions in the Neolithic. In order to achieve this goal, all accessible records have been collected, verified, and entered into a database. Initial locational analysis of these sites resulted in a clear distinguishing of the eastern LBK boundary and made possible the discussion of the potential reasons for the spread of LBK populations in the territory of modern Ukraine.

State of art

Research on the LBK in Ukraine goes back to more than 100 years, and LBK materials were first found during archaeological research at the settlement with multiple occupations in the village of Bilche-Zolote at the very end of the 19th century. However, their cultural interpretation, publication and correct geographical reference occurred much later. In 1921, Włodzimierz Antoniewicz partially excavated several pits that yielded LBK pottery near the village of Torske in the middle stream of the Dniester River (No. 243 in the Appendix, No. 149 in the Supplement) and published this site as the first LBK settlement east of the Carpathians (*Antoniewicz 1921*). Leon Kozłowski found a few LBK vessels and stone shoe-last adzes during regular excavations aimed at the Chalcolithic layers of some multilayered settlements in the Dniester basin in the 1920s. Yakiv Pasternak intentionally excavated LBK sites in the Komarno town and near the village of Kotovane in Galicia in the 1930s and 1940s, respectively. Zygmunt Leski and Jan Fitzke explored several sites in Lutsk City and its outskirts in Volhynia in the late 1930s.

In the second half of the 20th century, research on the LBK in Ukraine was primarily conducted by Yurii Zakharuk, Kateryna Chernysh, Ihor Svieshnikov, Mykola Peleshchyshyn, Oleksander Pozikhovskyi, Hryhorii Okhrimenko and Vitalii Konoplia, who discovered and intentionally explored several representative settlements, interpreted and published the obtained materials. Currently, Taras Tkachuk, Dmytro Kiosak, Serhii Telizhenko, and Andrii Bardetskyi are working intensively on the LBK in this region. Their excavations are accompanied by geophysical prospections, natural science analyses and radiocarbon dating.

At each stage of studying the LBK in Ukraine, researchers compiled site lists and maps of their distribution. In 1932, Yakiv Pasternak mentioned four LBK sites in the Ukrainian part of Galicia (*Pasternak 1932.9–11*). Jan Fitzke (*1938*) was the first who listed 10 'certified' Linear-Band sites in Volhynia. Ten years later, Yakiv Pasternak (*1948*) mentioned 19 sites and places of stray finds from the entire Ukrainian part of the LBK area. Ihor Svieshnikov mapped 15 sites with linear pottery and described and illustrated the findings from there (*Sveshnikov 1954*). However, a common feature of these works is the usage of label 'linear-band pottery' for both the earlier and later sites. The earlier sites are attributed to the LBK in its current understanding, while the later ones are currently attributed to the two Chalcolithic cultures, Malice and Lublin-Volhynian.

The first catalogue of the LBK (as such) sites in the territory of the former Soviet Union was published by Tatiana Passek and Kateryna Chernysh (*Passek, Czernysh 1963*). Their catalogue includes detailed data about 16 sites in the territory of Ukraine. Generally, these are the same sites which were mapped in overviews over the next quarter of a century (*Zakharuk 1971.Map 2; Peleshchyshyn 1974.98, Fig. 27; Zakharuk, Telegin 1985.112, Map 4*).

The intensification of heritage protection in the 1970s and 1980s resulted in discovering and recording sites and compiling their catalogues for the whole territory or its regions. The collection and synthesis of new data allowed Dmytro Telehin (Telegin) the listing and mapping of 32 LBK sites (*Telegin 1979.230, Fig. 1*). Twenty years later, Olga Larina almost doubled their number compiling a list of 62 LBK sites in Ukraine. Her catalogue is designed as a table providing five attributes for each site. These are the site name, administrative location, category of site, character of the intervention, year(s) and author(s) of exploration. The attributes are accompanied by bibliographic references. A distribution map includes 59 captioned marks (*Larina 1999.16, 116–118, Fig. 5*). Until recently, this was the largest published list of LBK sites in the territory of Ukraine. In 10 years, Larina (*2009.58, Fig. 4*) published a map with 72 marked sites but captioned only 34 marks.

In 2013, Olena Lenartovych (Krashanovych) mapped and catalogued 108 sites throughout Ukraine in her unpublished PhD thesis on the LBK in the Upper Dniester and Upper Bug catchments (*Lenartovych 2013.195–255*). However, no more than 50 of these sites are mapped in her publications (*Lenartovych 2009.227, Fig. 1; 2011.67, Fig. 2*). Most recently, Thomas Saile (*2020.220, Fig. 13*) presented a map including the largest number of Ukrainian LBK sites, with about 150 uncaptioned marks.

The short review of the LBK site catalogues presented here identifies several patterns. Let us briefly characterize them.

Most of the cited reviews, as well as non-mentioned regional lists, contain only site names, often as map captions. Detailed information about these sites is either missing or provided in an unstructured, selective and non-uniform manner in the text of publications. This makes it impossible to group the sites according to certain properties and even simple counting. The only structured list, produced by Larina, contains almost no information about the sites and can best be used for research history purposes.

The only attempt to collect, structure and analyse data on the topographic location of the LBK sites in one Ukrainian region was made by Olena Lenartovych (*2011*), based on information about 25 settlements. The evident criterion for including these sites in this sample was the presence of published plans or detailed descriptions of the site locations without regard for the representativeness of the materials found there. The small number of sites she collected brings us to the problem of the completeness and quality of the published records used by researchers, especially with regard to ascertaining geographical location.

Ever since GPS devices became widely available in Ukraine, the accurate localization of newly discovered LBK sites has not caused problems. However, most of the sites were found during the years of the Soviet Union, when topographic maps were considered as secret documents and were almost inaccessible to an average archaeologist. Therefore, site locations were often uncertain, they were imprecisely described and distances were determined using human steps or even just roughly approximated. The plans were also drawn up by hand, and in many cases only part of this information was published. In turn, this led to another problem – without the precise localization of previous explorations, the sites were confused with each other or rediscovered several times. In some regions, this resulted in real chaos with regard to attempts at cataloguing (see more details in *Bardetskyi 2021.132–133*).

A solution to this issue lies in turning to records of the first, undistorted, most complete and accurate information about the sites. This information is represented in field reports, which require a description of a site, its explored features and materials accompanied by field drawings, diaries, photographs and an inventory of the finds. In addition, work with field reports, along with the determination of the precise geographical location of sites, may solve two more issues of cataloguing and mapping. These are:

- gathering information about non-published sites;
- verifying the attribution of sites to the LBK.

Materials and methods

Sites

In this paper, the neutral term 'site' means any archaeological locality, regardless of the number of finds number, the accidental or intentional character of discovery, as well as the nature of the intervention. LBK sites in Ukraine have not been divided into categories because all of them are open-air sites, while human bones were found in only three places. One fragmented skull originates from the settlement of Rovantsi-Hnidavska Hirka tract (*Potiekhina 2018*). One burial was accidentally discovered in the village of Baiv in 1939, and its location and archaeological context remain unknown (*Bardec'kyj* et al. *2013*). The other burial was investigated at the site of Nezvisko-Shkilnyi Horod tract (No. 237 in the Appendix, No. 110 in the Supplement), which is usually interpreted as a settlement (*Czernysh 1959.73–78; Passek, Czernysz 1963.14–20*), although Maciej Dębiec (*2016*) believes that it is a 'ritual-burial complex'.

At the first stage of the work presented here, every site attributed to the LBK at least once was recorded. Numerous sites in which materials were defined as 'Neolithic' were ignored because different researchers and archaeological schools had a varied treatment of this term during the 20th century. Some of the connotations of this term refer to various time units, which are now associated with periods from the Mesolithic to the Bronze Age.

In the second stage, different records about each site were combined to form the maximal complete data array. To verify published data and the attribution of sites not mentioned in publications, more than 1000 field reports (mainly on surveys) across the Ukrainian part of the LBK area were processed in the main depository of field reports in Ukraine, *i.e.* the Scientific Archive at the Institute of Archaeology of the National Academy of Sciences of Ukraine in Kyiv. Unfortunately, not all the required archival files could be found. Some researchers either did not write a report at all or did not send it to the Institute, while a few reports were lost. In addition, reports about the research in the last five to

10 years are not always accessible due to the rule giving researchers a certain time for exclusive publication of their data.

During the next stage, the attribution of sites was verified, and the sites passing through verification were included in a catalogue. According to the reliability of attribution to LBK, each site was referred to one of three groups: 'reliable', 'questionable' and 'false'.

The 'reliable' group includes sites with undoubted LBK materials, the number of which was not counted. Data may be represented by thousands of things or one, but a significant item (*e.g.*, a stone shoe-last adze, a potsherd with the 'music-note' or plastic decoration, or a large undecorated fragment of a fine vessel).

The 'questionable' group predominantly comprises sites for which attribution is based on insufficiently representative materials (*e.g.*, one or several undecorated small fragments of coarse vessels). Of course, the unique technological features of the production of LBK ceramics can be noted even for such finds. However, this requires using a precise analytical procedure or petrographic analysis (*e.g.*, *Chernyak, Kosko 1980; Kadrow* et al. *2018*). Sites where only a few flint artefacts (cores, blades) were attributed to LBK based on 'morphometric indexes' also raise doubts. Such an approach is especially suspicious when single LBK artefacts are identified in large flint assemblages of Chalcolithic time from sites with multiple occupations. Therefore, attribution of one or several finds to the LBK must be well-argued each time and not stated as an accomplished fact in passing. Sites for which there is no specification of finds are also classified as'questionable'. Information about them is usually limited to one expression, such as 'LBK materials were also found there', with no data regarding the number and characteristics of the finds.

The third group includes 'false' sites, the LBK attribution of which has been convincingly refuted in current work or earlier studies by other researchers.

Only 'reliable' and 'questionable' sites were selected for further cataloguing and mapping.

Another issue requiring attention is the proximity of sites located at the distance of 100 to 200 to 300m apart from each other. Should they be combined into one catalogue entry or entered separately? The length of the largest partially excavated LBK site in Ukraine, the Rovantsi-Hnidavska Hirka tract (No. 29 in the Appendix, No. 134 in the Supplement), is about 400m (*Bardetskyi 2021.134, Fig. 2*). Although the synchronicity of its different sectors has not yet been proven, it was decided to consider a half of its length. *i.e.* 200m, as the stipulated shortest space between sites. Two additional conditions complement this proxy. First, sites located at a distance less than 200m from each other are considered different if they are topographically separated by a stream, ravine, depression in relief, *etc.* Second, the proxy applies only to the settlements with high-precision spatial localization. If sites for which the particular location remains in doubt were mapped in approximately the same topographically undivided area, they were considered as a single site despite the distance. This prevents an artificial increase in the number of settlements, which can in any case never be confidently recognized in the terrain (see the details below).

Cataloguing and mapping

The collected information about the LBK sites in Ukraine was entered into a database designed as a workbook of Microsoft Excel 2016 spreadsheets consisting of five worksheets (see Supplement). The first three are 'Reliable LBK sites', 'Questionable LBK sites', and 'Sub-Neolithic with LBK pottery', in which relevant information was entered. Two more worksheets contain lists of the used field reports and publications, respectively. Each site is characterized by 40 parameters. They describe the name, administrative and geographical location, history and character of research, categories and number of finds, and are accompanied by references and (if necessary) comments. Although most of the used attributes and variables are intuitive and traditional for such a work, some require further clarification.

There is no agreed conventional rule of **site naming and spelling** in Ukrainian archaeological tradition. Usually, a name consists of the name of the nearest present-day settlement and (if required) the sequence number of the site in Arabic or Roman numerals. Less often, the native historical name of the area where a site was found is added to the name of a present-day settlement or is used instead. Any area that has such a proper name (regardless of the size, type of relief, vegetation, economic use, formal or informal demarcation) is called the Ukrainian word 'urochyshche', which corresponds to the English word 'tract'. In some cases, street names or postal addresses are the identifiers added to the names of towns and villages.

Sometimes, using a sequence number to identify sites can be confusing due to their rediscovery and occurrence in various lists with alternative numbering. Therefore, the database uses a present-day settlement name accompanied by the name of the tract (if known) as the most reliable identifier. If the tract name is unknown, the number is used instead. If a site has multiple numbers, one is chosen, and the respective list is referenced (*e.g.*, 'Mshana-9', after Konoplia (*1993*). In a few cases where a second part of a site name is required, it is artificially created based on a visible landmark (*e.g.*, 'Busk-School Stadium'). The name of the museum where a stray find is kept has been used as the additional identifier in one case. The database includes the 'alternative names' attribute in order to help users to find sites by any published names and their spellings.

The database records site names in Cyrillic and their transliterated Latin script versions along with the transliterated names of the investigators and geographical units such as tracts, present-day settlements, rivers, and streams. The standard transliteration of the Ukrainian alphabet adopted by the Ukrainian government in 2010 is used. While it does not always accurately convey the sound of the words, this simplifies writing using only the basic Latin alphabet.

The **administrative affiliation** of each site is provided according to the current administrative division stated in Ukraine in 2020. An affiliation to previous administrative units of Ukraine and the Soviet Union, and for older sites to administrative units of interwar Poland, former Austro-Hungarian and Russian empires, is also indicated.

The **geographical position** of sites refers to their geographical coordinates noted as decimal degrees (DD) and location in relation to watercourses and landscape elements.

For localization of the sites found in the last decade researchers generally use the geographic coordinate system. In the current work, the coordinates of the remaining sites are determined with their precise mapping using the Google Earth Pro aerial photographs basing on the text descriptions of sites, field plans and photos from published and archival records. Depending on the accuracy of the information used, sites are divided into four groups.

Group A comprises sites where researchers provided GPS coordinates, a topographic map, or a hand-drawn plan, which allows for accurate determination of the site location. In Google Earth, the marked point is usually within the site's boundaries, typically in its centre or excavated area. An accurate location is also ensured by photographs and detailed textual descriptions, including precise azimuths and distances to clear landmarks such as churches, bridges, *etc*.

Group B includes sites where the given plans and textual descriptions are not clear enough, but still allow for the establishment of the tract within which each site is located. The point falls within the site boundaries or it is placed at a distance of up to 200m from them.

Group C comprises sites which the location is described by approximate direction and distance to landmarks with a long length, such as a river, road, or present-day settlement. This group also includes sites for which more or less detailed descriptions contain internal contradictions. The point is then placed in the most likely place and can fall both within the site boundaries or deviate from them by a distance of up to 1km or even more.

Group D mostly includes sites for which only the name of a present-day settlement determines their location, and such a way of positioning was often used for stray finds. This group also includes sites for which the locations contradict each other in different records, usually due to the confusion with the cardinal directions or the banks of a river. The point is placed in the centre of the relevant village or town and never corresponds with the actual location of a site.

The sites' locations were rarely characterized by geomorphologists. This results in publications and reports with mostly very general and vague descriptions of the surrounding elements and forms of relief. To overcome this issue, a database uses several simplified descriptive variables to distinguish between a dozen variants of sites' locations, such as on eminence within a floodplain, on the edge or prominence of the first terrace, edge or 'nose' of the high terraces generalized here as a 'plateau', *etc*. This approach allows sufficient confidence when determining the location of a site in relation to relief using Google Earth in cases when the author of the discovery did not provide such information. The 'altitude above the nearest watercourse' attribute was filled with published data, archival records or Google Earth data. In the latter case, the altitude was only entered for sites of spatial accuracy 'A' and 'B'. The attribute 'elevation above sea level' was determined for all sites using Google Earth. Thus, for sites of low spatial accuracy, this value is approximate.

Describing the **history of the research** at the given site, the database records every research episode, including those when no LBK materials were found. Despite acknowledging each participant's contribution to a site exploration, usually the name of only one scholar is mentioned here. Most commonly this is a head of the expedition whose name occurs first among the co-authors of the publication or field report.

The vast majority of catalogued sites are places of multiple occupations, and they have mixed materials from different eras and cultures. Therefore, the 'site area' attribute does not describe the area of LBK settlement, but the maximum distribution zone of all archaeological materials scattered on the surface. This information was most commonly provided by investigators, probably due to heritage protection purposes. The 'excavated area' attribute also describes the total area of all excavations regardless of the presence or absence of LBK materials in each trench.

In contrast, the attributes describing LBK **findings** accurately correspond to the area of interest of the current work, noting the presence/absence or quantity of features, pottery, flint artefacts and finds of other categories depending on the available information. The attribute 'feature' in a database refers to any pit or structure, such as the hearth or stone pavement, but not the concentration of finds on the habitat horizon. Due to the rarity of precise data on the number of finds in the records, the database considered any possible way of approximate counting, which includes calculating the number of vessels, potsherds, and flints drawn in the images or calculating the number of marks on the field plans. The number resulting in such counting is accompanied by the symbol 'approximately', 'less', 'more', or 'more than or equal to'.

The **references** accompanying each entry cite field reports and publications about the site and all materials found there, not just LBK ones. Records not mentioning LBK finds are significant because they may contain information regarding site's location or the history of research. Moreover, the absence of information about LBK can be indicative in and of itself, such as when a researcher could not correctly affiliate the relevant finds with a certain culture.

Results

Mentions (even the briefest and most uncertain) of about 400 locations with the LBK materials including stray finds were identified by reviewing hundreds records published in the last 100 years in the first stage of the work. Further critical analysis of the obtained information and its verification based on field reports, as well as consultations with a few researchers, reveal that some sites appear in publications and archival records under two or three (and sometimes more) different names, while some others were mistakenly referred to as the LBK. As a result, the number of locations decreased to 276, with only 175 of them undoubtedly attributed to the LBK. Information about 95 sites is incomplete or contradictory, so they form a 'questionable' group. A small third group includes six sites of the local sub-Neolithic cultures, where 'imports' of LBK pottery were discovered.

Of the **175 reliable sites**, 130 are located in the Black Sea basin, and the remaining 45 are in the Baltic basin. Of the Black Sea sites, 67 belong to the Dnipro catchment, 55 to the Dniester, four to the Southern Buh, three to the Tylihul and one to the Danube catchment. All the sites of the Baltic basin are located near the water streams of the Vistula catchment. The location on the right or left bank of watercourses did not reveal a significant difference. Five sites are currently located on the islands between two branches of the rivers. Most sites are spaced on the banks of small rivers and streams. On the contrary, sites are rarely located on the banks of large rivers, with only 11 on the Dniester, three on the Southern Buh, six on the Bug, eight on Styr, and six on Horyn.

Information ensuring the accuracy of localization A was indicated for 104 sites, B for 29, C for 32, and D for 10 sites. Among the latter, eight are the places of accidental finds, of which five were found in the first half of the twentieth century.

The altitude above the nearest watercourse was reported in the records for 56 sites and determined with Google Earth for 85 sites; it could not be established for 34 sites (of which 33 were of spatial accuracy C and D). Of the 141 sites which altitudes are known, 60 are at altitudes 1–5m, 46 at 6–10m, 19 at 11–20m, and 10 at 21–50m. The altitude of only six sites is more than 50m. Two of them, Bukivna-Zarub tract and Vasyliv-Horodyshche tract, are located on the edge of the plateau above the Dniester, and the remaining four are placed on the edge of the plateau above its tributaries, but no further than 7km along a straight line from the Dniester valley.

The location of sites on river islands and elevations in the floodplain occurs 20 times, on the first floodplain terraces 87 times, on the second and higher terraces – generalized here as 'plateau' – 60 times. This attribute could not be established in eight cases.

In terms of elevation above sea level, the reliable LBK sites range from 74m (Ananiv-Mainova Balka tract on the southern edge of the Podillia Upland) to 363m (Ulychne-1 on the northern spurs of the Carpathians), but the largest number (123 sites) fall into the range of 151–250m.

Data on the character of the intervention was collected for 174 sites. Of these, nine were the location of stray finds, while 82 sites were subjected to purposeful surface surveys. For the remaining 83 sites, trial tranching and excavations were carried out, which are sometimes difficult to distinguish from each other because in some cases the total area of test pits is larger than the area opened with small-scale excavations.

Data on the explored area of 16 sites where fieldwork was carried out could not be found in the records. The uncovered area of some of the remaining 67 sites is known only approximately. According to these rough data, excavations were carried out on a total area of up to $100m^2$ in 23 cases. A total area of 101 to $1000m^2$ was excavated at 31 sites, while it ranges from 1000 to $2000m^2$ at seven sites. More than $2000m^2$ was uncovered in six sites. Among them, the largest total excavated area of $3970m^2$ is recorded for recent rescue research at the settlement with multiple occupations of Chankiv 1, data about which is limited to one brief presentation of some preliminary information (*Petrauskas* et al. *2022*). The cited publication mentions only four LBK features, which means that a large excavated area is not always an indicator of extensive research on an LBK site. For instance, $2703m^2$ of the excavated area in the Bovshiv-Sulyva tract settlement yielded only about 10 LBK potsherds and no features.

The LBK features were explored at 37 sites. Their number does not exceed 10 at 30 sites, and it ranges from 10 to 22 at six sites. A unique case in Ukraine is represented by a site with 135 recorded features. The features were recently excavated at the site of Modrychi 1 (No. 182 in the Appendix, No. 96 in the Supplement), where two discovered LBK long houses yielded numerous postholes (*Silaiev* et al. *2021; Telizhenko, Silaiev 2022*). These 37 sites may confidently be classified as permanent settlements. However, automatically referring to all other sites as camps and settlement traces is premature. Most likely, the lack of features reflects insufficient research at many locations.

Pottery was found in at least 166 sites, but information on the number of shards and vessels is known only for 116 sites. A large amount of approximate data does not allow a clear division of these sites into groups. However, it is certain that approximately half of their collections contain fewer than 100 fragments. Only collections from the Holyshiv-Zarvykhvosty tract (No. 40 in the Appendix, No. 39 in the Supplement), Kam'iane-Zavallia (No. 267 in the Appendix, No. 43 in the Supplement), and Rivne-Pliazh tract-1a (No. 67 in the Appendix, No. 130 in the Supplement) are guaranteed to number more than 1000 potsherds. This short list should probably be extended by the Bilshivtsi-Kuty tract site (No. 197 in the Appendix, No. 13 in the Supplement), where finding of the remains of more than 500 vessels was mentioned in records, and the Tadani-Zamchysko tract (No. 121 in the Appendix, No. 145 in the Supplement), which yielded an undesignated number of fragments of more than 200 vessels. The Yosypivka I site (No. 136 in the Appendix, No. 163 in the Supplement) yielded 966 potsherds.

Flint and/or obsidian artefacts were found at 103 or more sites. Approximately half of these yielded fewer than 100 artefacts. Among the rest, only six sites (Hirka Polonka-Lob tract, Holyshiv-Zarvykhvosty tract, Kam'iane-Zavallia, Medynia-Karier tract, Rivne-Pliazh tract-1a, Yosypivka I) brought more than 500 artefacts each.

Finds of polished stone hoes, axes and adzes are documented for 40 sites, of which four are stray finds. Findings of grinding stones are quite common. Rare finds include a ceramic anthropomorphic figurine from the Khoriv-Brodivshchyna tract (*Becker* et al. *2014*), 10 perforated clay loom weights and one clay zoomorphic figurine from the Nezvysko-Shkilnyi Horod tract (*Passek, Czernysz 1963.15,19, Tab. III.12,16, VI.10*), two mini clay balls from the Ratniv-Ripysko tract (*Telizhenko 2015.66,74, Fig. 4.4,5*), two valves of *Spondylus* with artificial holes from the Rovantsi-Hnidavska Hirka tract (*Bardec'kyj* et al. *2016*), and a polished andesite disk with a round hole in the centre from the Tadani-Zamchysko tract (*Peleshchyshyn 1999.24,37, Fig. 11.14*).

Only nine Ukrainian LBK sites – namely the Ananiv-Mainova Balka tract (No. 264 in the Appendix, No. 2 in the Supplement), Bilshivtsi-Kuty tract, Hirka Polonka-Lob tract (No. 46 in the Appendix, No. 3 in the Supplement), Holyshiv-Zarvykhvosty tract, Kam'iane-Zavallia, Osychky-Hnyla Skelia tract (No. 266 in the Appendix, No. 119 in the Supplement), Ratniv-Ripysko tract (No. 51 in the Appendix, No. 129 in the Supplement), Rivne-Pliazh tract-1a, and Rovantsi-Hnidavska Hirka tract – were a subject of radiocarbon dating. In total, 31 radiocarbon dates were obtained over the last 20 years by the Laboratory for the Analysis of Radiocarbon with AMS at Bern (BE – two dates), the Kyiv Radiocarbon Laboratory at Kyiv (Ki – 13 dates), the Leibniz-Labor at Kiel (KIA – one date), the Klaus-Tschira-Labor at Mannheim (MAMS – one date), the Poznań Radiocarbon Laboratory at Poznań (Poz – 12 dates), and the 14CHRONO Centre for Climate, the Environment, and Chronology at Belfast (UBA – two dates).

Conventional Kyiv dates on animal bones and organic inclusions in the ceramic paste were obtained in the 2000s (*Kotova, Kovaliukh, 2002.105, Tab. 10; Sapozhnikov, Sapozhnikova 2005.91, Tab. 1; Kovaliukh* et al. *2007.16, Tab. 2*). They fall into the wide range from 6570±60 BP to 5825±90 BP that weakly corresponded to relative chronology of these sites in many cases. Eighteen AMS radiocarbon dates were recently obtained in European laboratories working on charcoal, charred grains, and animal and human bones from the sites Kam'iane-Zavallia, Osychky-Hnyla Skelia tract, Ratniv-Ripysko tract and Rovantsi-Hnidavska Hirka tract, and these cover the timespan between 6366±41 BP and 6100±40 BP (*Motuzaitė Matuzevičiūtė, Telizhenko 2016.105, Tab. 1; Kiosak, Salavert 2018; Saile 2020.212, Fig. 4; Kiosak* et al. *2021; 2023; Moskal-del Hoyo* et al. *2023*). These new, more precise measurements are in reasonable correspondence with the pottery with 'music-note' decoration found there, as well as with generally acknowledged views on the time of the LBK Notenkopf phase in Central Europe (*Kiosak* et al. *2023*).

Geophysical prospection was carried out at five sites – Bilshivtsi-Kuty tract, Blyshchanka-Horby tract, Kam'iane-Zavallia, Khoriv-Pidluzhzhia tract, and Novomalyn-Bezodnia tract (*Malieiev, Konoplia 1999.45; Zlatohorskyi* et al. *2013; Saile* et al. *2016.7*). However, these prospections did not result in obtaining settlement plans.

Until recently, the only natural science research on the LBK in Ukraine was the archaeobotanical studies of pottery impressions and archaeozoological studies of mammal bones from the Volhynian sites of the Hirka Polonka-Lob tract, Holyshiv-Zamchysko tract, Rivne-Pliazh tract-1a, and Rovantsi-Hnidavska Hirka tract carried out in the early 1990s (*Pashkevych, Okhrimenko 1991.1–24; Zhuravlov, Okhrimenko 1994; Pashkevich 2000.408–409*). Charred materials from flotation, as well as archaeozoological collection, were investigated at one more Volhynian site of the Ratniv-Ripysko tract in 2015 (*Telizhenko, Yanish 2015.214, 218; Motuzaitė Matuzevičiūtė, Telizhenko 2016*). A comprehensive natural science study of the Kam'iane-Zavallia site, including archaeobotanical, pedological and palaeoenvironmental analyses, has been carried out in recent years (*Salavert* et al. *2021; Kiosak, Matviishyna 2023; Moskal-del Hoyo* et al. *2023*). Plant impressions on pottery from the Rovantsi-Hnidavska Hirka tract have been re-identified using scanning electron microscopy and an improved silicone casting method (*Endo* et al. *2022.6*). The study of the craniology and DNA of a skull from the Rovantsi-Hnidavska Hirka tract settlement became the first of its kind in the Ukrainian part of the LBK area (*Bardetskiy* et al. *2017; Potiekhina 2018; Mazanec* et al. *2020*).

Most of the **95 questionable sites** are located on the banks of small rivers and streams. Only 12 sites are located in the valleys of the large rivers Dniester, Bug, Prut, and Styr. Information about the location of 29 sites in the landscape was not provided in the records. Of the remaining sites, 18 are placed on the plateau, 39 on the first terrace, and nine on the elevations in the floodplains.

It is not surprising that, unlike the 'reliable' group, only less than a half of the questionable sites were recorded with high accuracy of localization A and B (31 and 12, respectively). The nature of the intervention is also less known – it is established in 67 cases. Thus, 18 sites were excavated on an area from 45 to 1836m^2, 10 sites were explored with test pits, surface surveys were carried out in 34 cases, and stray finds were found in five cases.

The character and number of finds was established with varying accuracy in 42 cases. Finds attributed to LBK include only fragments of pottery from 14 sites, pottery and flint artefacts from 12 sites, only flint artefacts from 11 sites, and only polished stone adzes from five sites. As for adzes, they belong to the types known among materials of both the LBK and some other cultures, for example, Trypillia and the Funnel Beaker Culture, which raise doubts about the correctness of the attribution.

Discussion

Although the presented work does not claim to be an exhaustive coverage of all the related data, it is clear that the compiled list of LBK sites in Ukraine is the most complete and detailed to date. Despite a significant increase in the number of recorded sites compared to previous lists, only some of these sites yielded features and materials suitable for full-fledged traditional archaeological research on the typology of finds, periodization, and local specificity. Furthermore, there are only a few LBK settlements in Ukraine that have been studied comprehensively and can provide detailed data for generalizations and reconstructions. In most other cases, the LBK materials were found by chance during rescue excavations or the intentional exploration of earlier or later sites. Often, the authors of excavations specializing in other periods did not pay enough attention to the LBK finds. Finally, many sites were detected by heritage protection organizations during superficial observations or by amateurs, and discoveries of this kind left almost no traces in scientific documentation or publications. Therefore, the information entered the database thanks to the webpages of local authorities or public organizations (*e.g., Derzhavnyi reiestr 2023*) and very brief mentions in abstracts of reports at regional conferences (*e.g., Konoplia* et al. *1995*). Considering the described peculiarity of the records used and the history of the research, it is no surprise that the questionable sites exceed a third of the total number.

Mapping of all 270 LBK sites reveals their uneven spatial distribution. Most of sites are concentrated in several clusters within the territory of Volhynian Upland, in the upper part of the Bug River catchment, and in a few areas in the Upper and Middle Dniester regions. These zones with a dense settlement concentration are separated from each other by areas without or with very scattered sites (Fig. 1). It is generally accepted that such a distribution is typical for the whole LBK area. However, there is no confidence that the clusters of LBK sites detected in Ukraine reflect only settlement patterns of the past and are not biased by the intensity of research in different micro-regions. This bias seems to be probable when it comes to site clusters near large cities like Rivne, Lutsk, Lviv, and Ivano-Frankivsk, or museum centres like towns of Ostroh, Dubno, Halych.

Unfortunately, the issues listed with regard to the quality of records and uneven archaeological exploration of sites and micro-regions do yet not allow detailed studying of patterns in the spatial distribution of units and networks of LBK sites. This would require analytical work based on data on the sites' chronology, their area, the number of dwellings, and the characteristics of economic activity in at least one well-studied region. However, cataloguing and precise mapping opens up the possibility of using GIS analysis to study settlement distribution in association with the environment. Until such work is carried out, only very general tentative observations can be made using small-scale maps. This involves mapping the entire area instead of mapping individual sites and their clusters. Clarification of the LBK boundaries has given the first significant result in this context.

Firstly, the current research has clarified the northern border of the LBK range in Ukraine. On some published maps, several sites are marked within the Polissia (Polesye) Lowland, a sandy, swampy outwash land located north of the loess Volhynian Upland (*e.g.*, *Dębiec, Saile 2015.16, Abb. 15; Saile 2020.209, Fig. 2*). However, a critical analysis showed the fallacy or insufficient argumentation for their LBK attribution. In the case of the Poliany-Kamenyste tract site, whose uniqueness is emphasized by some researchers (*Okhrimenko* et al. *2016.183*), an editorial error resulted in the publishing of the drawings for one article (*Pozikhovskyi 2002*) in another paper by the same author (*Pozikhovskyi, Romanchuk 2003*). Unpublished (and lost) materials from the village of Ustia on the Sluch River were attributed to the LBK along with the other sites of 'early and late phases' of the culture in the 1930s (*Fitzke 1938*), when a sense of these terms was much broader than now. The Fasova site, located to the northeast of Volhynia, has been repeatedly referred to as part of the LBK after Janusz Krzysztof Kozłowski (*1985.68, Fig. 12*) first published this attribution. However, the field report has shown that only one, and subsequently lost, fragment of LBK pottery was found there in 1971, while recent surveys and test excavations have evidenced the presence of sub-Neolithic materials at the site (*Haskevych* et al. *2023*).

Secondly, the division of the LBK area in Ukraine into two separate parts, one along the Dniester River and the other in the Volhynian Upland, was confirmed in the current research, although these have been combined into one area in some studies (*e.g., Czekaj-Zastawny 2008a.33, Fig. 1; Kadrow, Rauba-Bukowska 2017.262, Fig. 1*). This may have been due to published maps with several uncaptioned points in the upper reaches of the Southern Buh River (*Larina 1999.11, Figs. 1,2; 2009.*

51, Fig. 1; Dębiec, Saile 2015.16, Abb. 15; Larina, Dergachev 2017.9, Fig. 3), as well as the relatively weak study of the region outside areas with a concentration of sites. However, a number of errors in mapping sites in the Southern Buh region have recently been proven (*Haskevych 2021.21–22*). In addition, the current systematic study of all available records has revealed that archaeologists have satisfactorily explored the territory between Volhynia and the Dniester. Moreover, the absence of LBK sites in the very well-studied vicinities of the provincial centres of Ternopil City and Khmelnytskyi City likely indicates that LBK populations did not inhabit this area.

The absence of LBK sites to the north of the Volhynian Upland seems correlated with the steep drop in soil fertility. However, the reasons for the complicated configuration of the eastern border of the LBK area require explanation. A comparison of the distribution of LBK sites with small-scale environmental maps[1] showed that the majority of Ukrainian LBK settlements are located in the broadleaf forest landscapes zone, which continues east to the Dnipro River and beyond (Fig. 2). Regarding geomorphology, the Volhynian settlements of LBK are located in the valleys of watercourses cutting into highly dissected loess plains. The more southern area, uninhabited by LBK groups, is also represented by a loess plain, but is less dissected (Fig. 3). In terms of present-day soils, the location of the most Ukrainian LBK sites correlates with grey and dark grey, podzolized and podzolized gleyed soils, as well as podzolized chernozems (Greyzems, Phaenozems and Chernozems, respectively, according to the soil major group code of the STU from the 1990 FAO UNESCO Soil Legend in the European Soil Database (ESDAC), esdac.jrc.ec.europa.eu, European Commission, Joint Research Centre). The same soils extend to the east and southeast, where the LBK settlements are not found (Fig. 4).

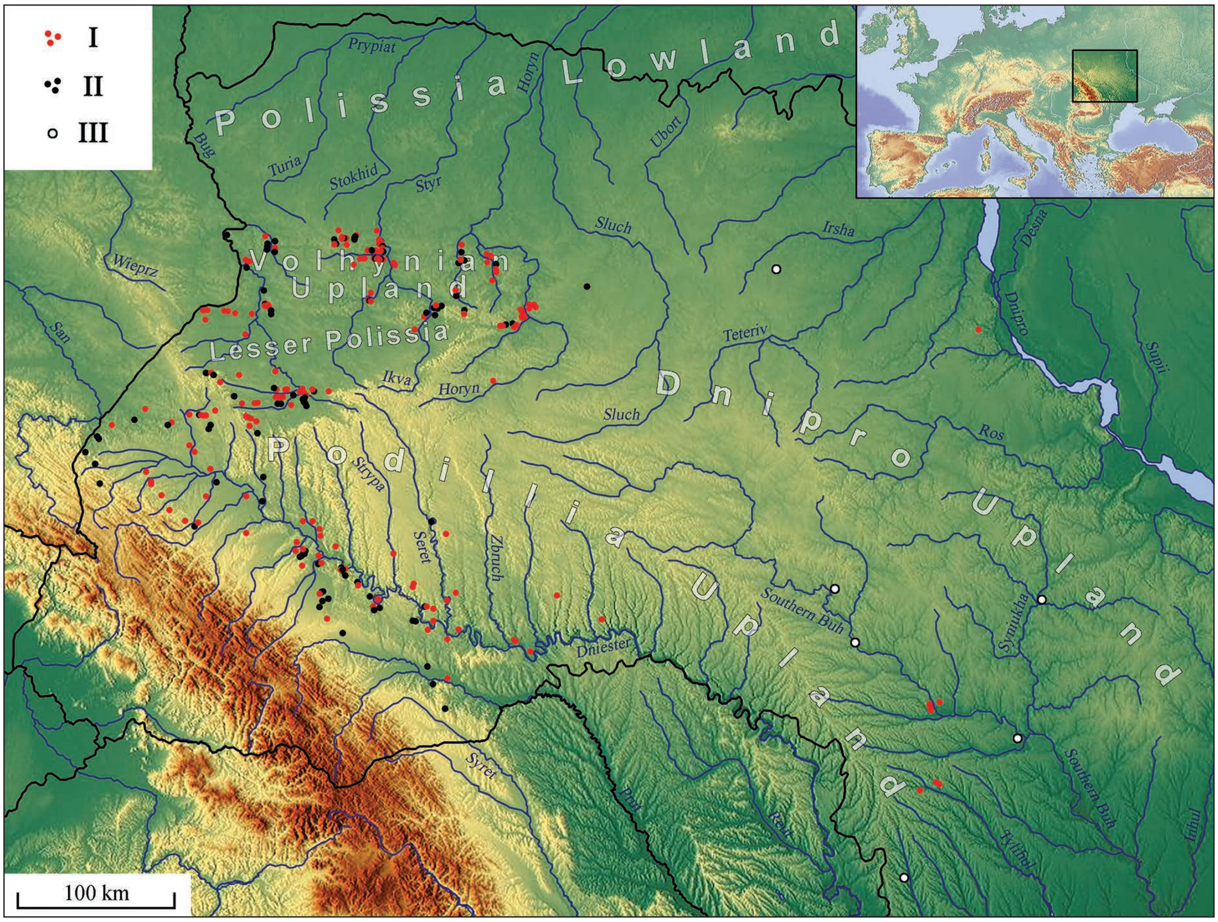

Fig. 1. The LBK sites (*I *reliable;* II *questionable) and the sub-Neolithic sites with LBK pottery (*III*) on a relief map of Ukraine. Base maps: https://maps-for-free.com/. For names of the sites, see Appendix. For detailed information about the sites, see Supplement.

1 Unfortunately, Ukrainian online services dealing with all kinds of media-scale and large-scale maps are currently inaccessible for civilian use due to the ongoing Russian aggression.

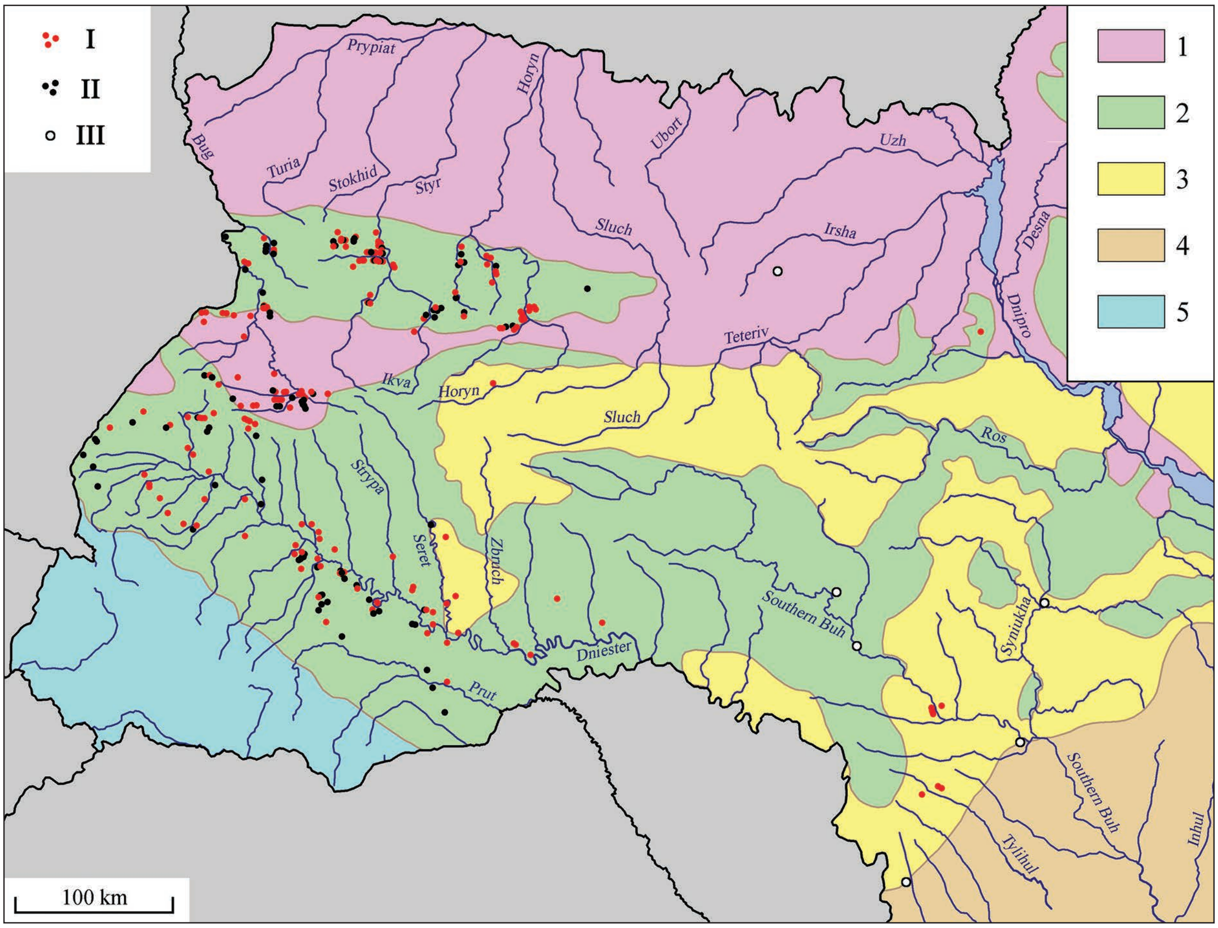

Fig. 2. The LBK sites and the sub-Neolithic sites with LBK pottery (for detail, see Fig. 1) on a map of the present-day landscapes. Base map:* Loza 2010.30–31, Fig. 1.08*, with simplification. Legend:* 1 *coniferous-deciduous forest landscapes,* 2 *broadleaf forest landscapes,* 3 *meadow-steppe landscapes,* 4 *steppe landscapes,* 5 *mountain-forest and mountain-meadow landscapes.

Observations during the current work and the results of thorough research on data from Central Europe (*Brigand* et al. *2022*) revealed that LBK agriculture quite easily adapted to various natural conditions. Therefore, the reason for the absence of LBK sites in the vast fertile loess plain between Volhynia and the Dniester is most likely not related to subsistence strategies. In this regard, it is important to note that, except for a narrow strip of lowlands of Lesser Polissia, there are no sites of Late Mesolithic and sub-Neolithic cultures in this region (*Matskevoi 1991*), which excludes competition between the newly arrived farmers and local hunter-gatherers.

Most likely, the factor determining the complicated configuration of the eastern LBK area is the geological structure of the region, where Quaternary loess overlies different rocks. These are Cretaceous deposits in the Volhynian Upland, in the very west of the Podillia Upland, and in the deep canyon valleys of the Dniester and the lower reaches of its left tributaries. In contrast, the weakly dissected higher plain, from which the tributaries of the Pryp'iat, Southern Buh and Middle Dniester flow, is composed mainly of the Neogene sediments of the Miocene and Pliocene series. Thus, clusters of LBK sites are generally located near outcrops of Cretaceous rocks. The only explanation for this is the presence of flint. The highest quality, fine-grained, grey to brown, smoked-transparent flint occurs in the deposits of the Turonian Stage, and lower quality coarse-grained, light-grey yellowish to black, untransparent flint occurs in the Cenomanian sediments (Fig. 5).

There are no special studies on the flint raw materials from the LBK sites in Ukraine. However, in the records processed while completing the database, researchers mention high-quality Turonian flint as the primary raw material used for knapping, although often they incorrectly called it 'Volhynian'. Artefacts made of it dominate in the chipped stone assemblages of the sites in the Eastern Galicia and Volhynia (*Konoplia 1999.131; 2008.206; 2009.101; 2010.385; Okhrimenko 2001.52; Telizhenko 2015.66; Pelisiak 2021.372; Telizhenko,* *Silaiev 2022.18–19*), particularly of the earliest, pre-music-note, settlements of Rivne-Plyazh tract-1a and Yosypivka I (*Piasetskyi, Okhrimenko 1990.77; Shydlovskyi 2018.63*). Thus, the high-quality Turonian flint could be a main factor influencing the vectors of colonization of the eastern part of the LBK area, along with the fertile soils.

It is extremely significant that the artefacts made of Turonian flint make up about 90% of the stone collection of the Kam'iane-Zavallia settlement on the Southern Buh located approximately 180km from the nearest deposits of such raw materials (*Kiosak 2017.263*). Moreover, only Turonian flint was found at the easternmost LBK site of Vita-Poshtova 2 (No. 270 in the Appendix, No. 158 in the Supplement), located on the outskirts of Kyiv, 10.5km west of the Dnipro valley, and 270km east of the nearest reliable LBK site Mohyliany I in Volhynia (*Gaskevych 2006.213*). The above cases of the two easternmost LBK sites are exceptions to the observed pattern, since the lack of high-quality flint near Kyiv and on the Southern Buh excludes the previously mentioned motive for migration. The question thus remains of what inspired the early farmers to move so far east, although behind them remained huge fertile loess plains uncultivated by farmers?

Kam'iane-Zavallia is the central settlement in a cluster of four LBK sites known in the Southern Buh River basin up to date (*Kiosak 2017*). They are placed several kilometres apart and form a triangle, which outlines the Zavallia graphite deposit, the largest in Europe and one of the largest in the world. Several promising graphite ore occurrences are up to 30km from this location (*Kropivnyi* et al. *2019.97*). Some of these are outcrops which were still being exploited by hand as recently as the beginning of the 20th century (*Shpylovyi, Biletskyi 2019*).

In the place, where the Southern Buh eroded graphite-bearing clays, the local hunter-gatherers of the Buh-Dniester Culture (BDC) made their ceramic vessels out of paste oversaturated with graphite, which gave the

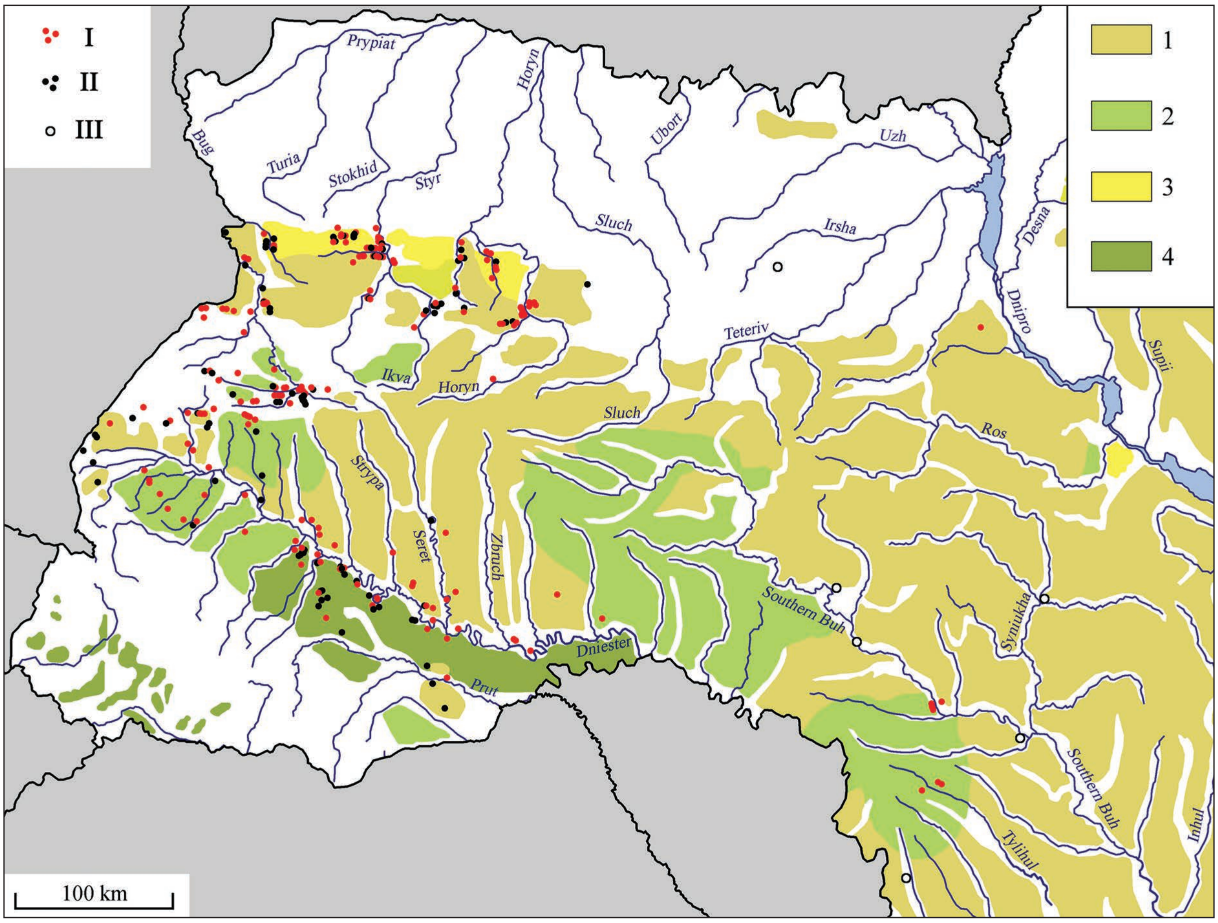

Fig. 3. The LBK sites and the sub-Neolithic sites with LBK pottery (for detail, see Fig. 1) on a map of loess distribution in Ukraine. Base map: **Haase *et al.* 2007**, ***with modification. Legend:*** **1 *loess, > 5m;* 2 *loess, < 2m;* 3 *sandy loess;* 4 *loess derivates.***

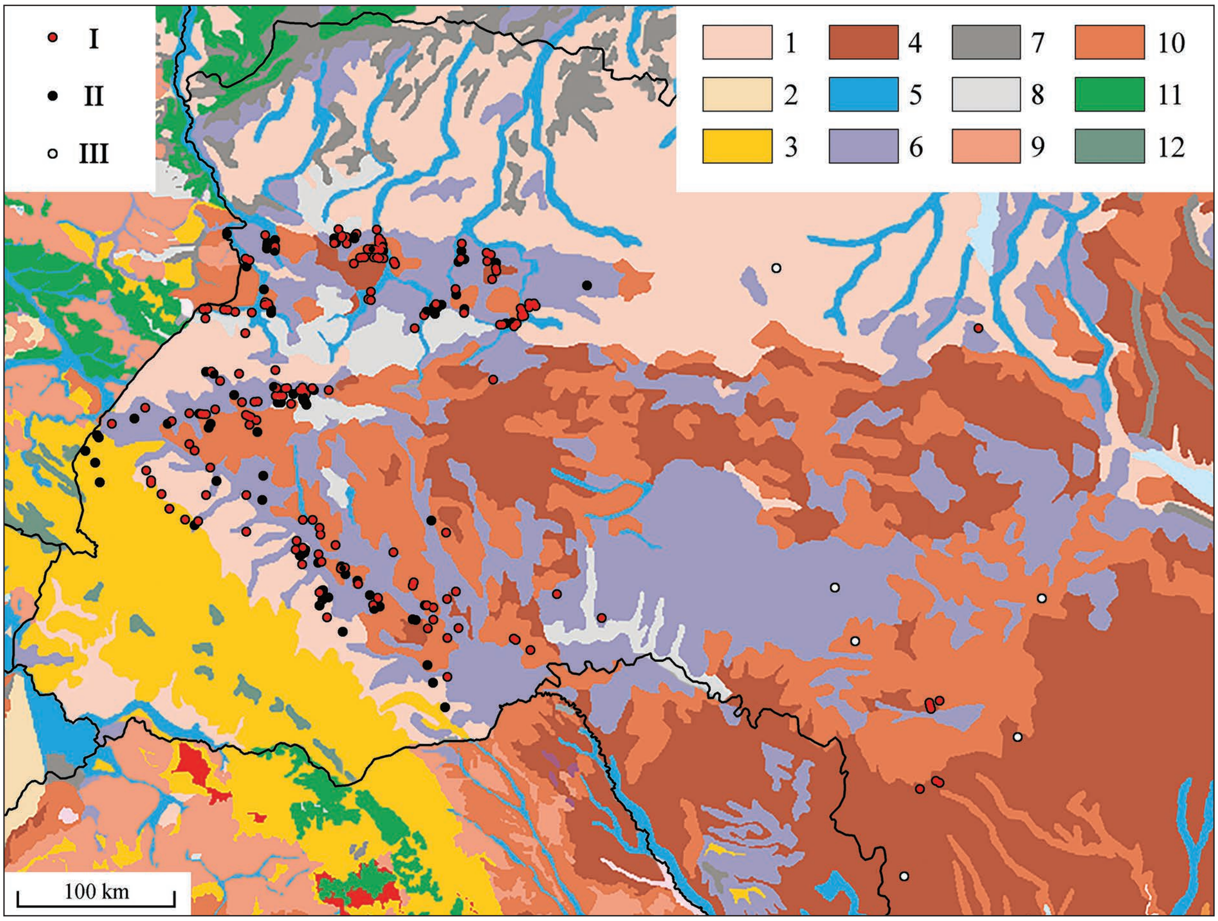

Fig. 4. The LBK sites and the sub-Neolithic sites with LBK pottery (for detail, see Fig. 1) on a map of present-day soil distribution in Ukraine. Base map: **Jones *et al.* (eds.). 2005.42–43, Pl. 1. *Legend:* 1 *Albeluvisol,* 2 *Arenosol,* 3 *Cambisol,* 4 *Chernozem,* 5 *Fluvisol,* 6 *Gleysol,* 7 *Histosol,* 8 *Leptosol,* 9 *Luvisol,* 10 *Phaeozem,* 11 *Podzol,* 12 *Umbrisol.***

pottery a shiny metallic luster. It is believed that this kind of BDC pottery (hereinafter referred to as graphite pottery), found on sites in areas to the west and east of the Southern Buh basin from the Dniester to the Dnipro River, was made of graphite ore from Zavallia (list of the sites see: *Gaydarska* et al. *2020.339, Fig. 5.32*). As such, information about the deposit was widely known in ancient times, and the place itself probably had some value and was a centre of exchange.

Importantly, the inhabitants of the Kam'iane-Zavallia also made graphite pottery (*Kiosak 2017.258*). This feature is never mentioned when describing finds from other LBK sites in Moldova and Ukraine, but graphite and graphite-coated pottery is characteristic for some LBK sites within the Upper Danube area in Austria, Moravia and Bavaria (*Tichý 1961; Pechtl, Eibl 2011; Kitzig, Ramminger 2016*). A shoe-last adze, made of metabasite from the Iser Mountains in northern Bohemia, was found in the Kam'iane-Zavallia site (*Saile* et al. *2016.7*), and this may indirectly indicate the close connections between the populations of these remote territories. Because of this, the assumption was made that the natives of Bavaria or Bohemia, who preserved the traditional Upper Danube attitude of graphite materials as prestige goods, brought this tradition to one of the eastern LBK groups. Graphite exploitation could this be the reason for the farmers' migration to this place on the Southern Buh, both to satisfy their own needs with regard to graphite ceramics and for exchange purposes (*Gaskevych 2017.42; Haskevych 2021.42–45*).

The second exceptional case is the settlement Vita Poshtova 2, located deep on a plateau on the gentle slopes of the valley of an unnamed stream at 30–35m above the Vita River, the right tributary of the Dnipro. This area represents the border of two landscape zones. A sandy covered zone with mixed forests of the Polissia Lowland stretches to the northwest. The forest-steppe landscape, similar to Volhynian, extends south of the site. This is the loess Dnipro Upland (Dnieper Upland), crossed by ravines, covered with grey forest soils and podzolized chernozems. To the northeast, a narrow ridge of the upland about 25km long stretches north along the Dnipro River. This loess 'tongue' is named the 'Kyiv Mountains' because the city of Kyiv was established there in the ninth century. There are a dozen sites of local sub-Neolithic Kyiv-Cherkasy Culture in the wide Dnipro valley just about 10–20km away from the Vita Poshtova 2.

The site was found during archaeological exploration of the territory of a just-abandoned military base in 1995. A number of sparse finds from different periods extended on the surface in the area of about 1.5 hectares. The authors of the discovery, specializing in medieval archaeology, collected the material and excavated 66m^2 in the place of the maximal concentration of finds. They did not find any features and attributed all the materials to the Bronze Age and Middle Ages. Unfortunately, this unique site was immediately given over to the development of private houses. After this, the author of the current paper, a student at that time, saw the finds and associated them with the LBK. Some years later, visits to the built-on area resulted in replenishment of the Neolithic collection by a third – up to 11 flint artefacts and about 50 sherds of at least eight fine and coarse vessels from the music-note phase of the culture (*Gaskevych 2006*).

No deposits of valuable natural resources are known near the site. The fertility of the land in this area does not stand out among other places that were convenient for settlement, but are located much closer to Volhynia. However, the benefits of migrating so far away were probably worth the effort and risk. The only motive that comes to mind, but has not yet been proven, is the proximity to the centre of the exchange network of native peoples on the territory of present-day Kyiv. One of the largest medieval cities in Europe arose at this site because of the crossing of land and water trade routes, among which the main ones are the Dnipro River and its tributaries – Desna, Trubezh, Teteriv, Irpin, and Stuhna. There is no doubt that these same factors were important for exchanges in earlier times,

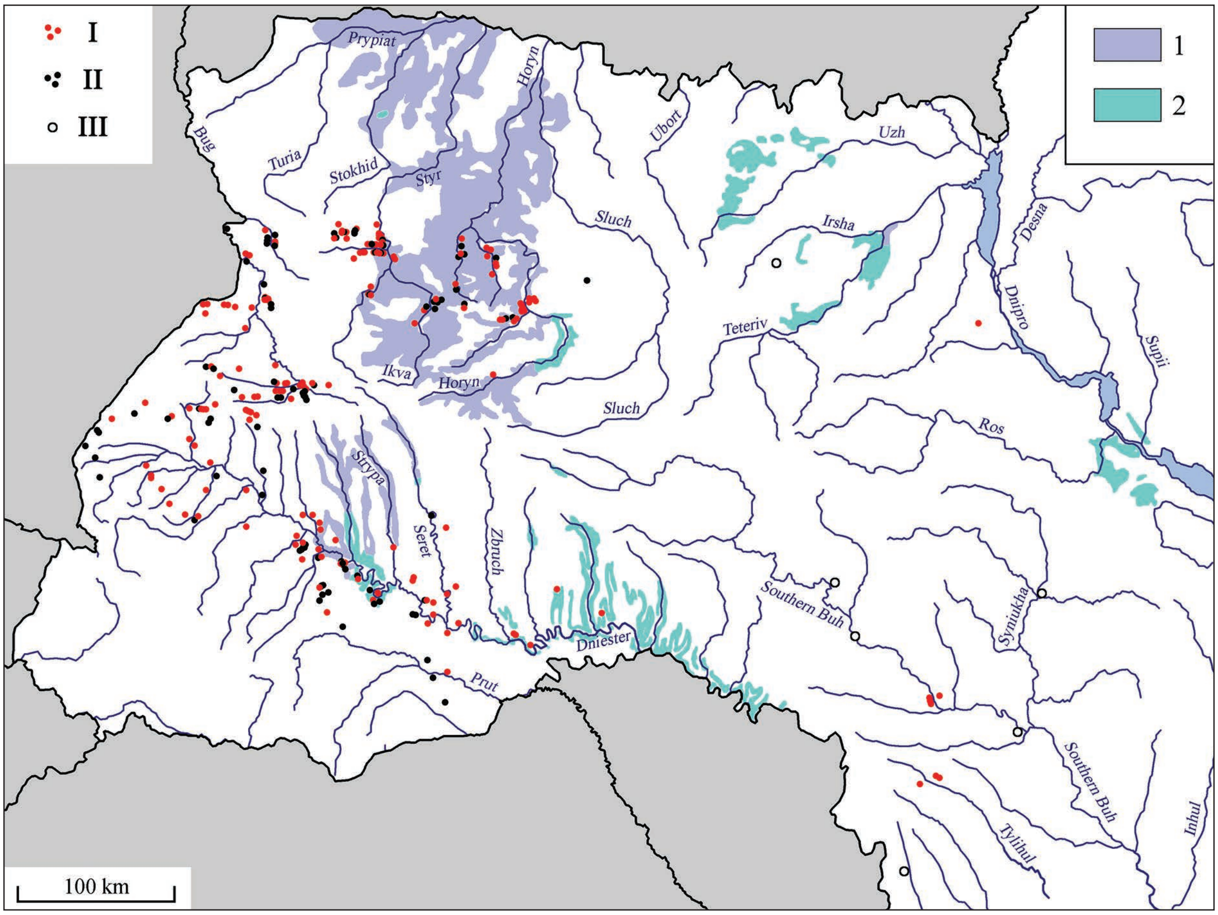

Fig. 5. The LBK sites and the sub-Neolithic sites with LBK pottery (for detail, see Fig. 1) on a map of the Turonian (1) and Cenomanian (2) sediment distribution in Ukraine. Base map: https://geomap.land.kiev.ua/geology.html (according to data from* Velikanov *et al.* 2007*) with modification.

as evidenced by the high concentration of sites of all periods since the Palaeolithic.

Six sub-Neolithic sites with finds of LBK pottery in a catalogue confirm that the farmers who arrived were involved in the exchange networks of the local hunter-gatherers. One LBK potsherd per site was found at Rudnia-Fasova in the Polissia Lowland in the north of Ukraine (*Telegin 1979.231–233, Fig. 2.13*), the Shchurivtsi-Porih tract on the Southern Buh (*Haskevych 2008.164,169–173, Fig. 4.1*), as well as at the Hirzhove site on the Kuchurhan River in the Dniester basin (*Petrenko 2012.236, Fig. 3*). One entire vessel with music-note decoration comes from the site Bohdanivka-Gard tract (*Tovkailo 2014.201–203, Fig. 11.3*). The Skybyntsi-Bazkiv Ostriv tract site on the Southern Buh yielded nine potsherds of two fine vessels with the 'music-note' decoration (*Danilenko 1969.62–70, Figs. 16.12,13, 19.1,2,4; Haskevych 2021.11–13, Fig. 2.1–8*), and the Dobrianka-3 site, located in the catchment of the Syniukha River, a left tributary of the Southern Buh, yielded 12 potsherds of three vessels (*Zalizniak* et al. *2013.228,234, Fig. 25.4–8*), one of which is a fine LBK bowl decorated in the Šárka style.

The listed LBK vessels could have been considered as prestigious goods and containers for some valuable substances or liquids by hunters. It can be hypothesized that salt was one of these goods. Salty springs appear almost everywhere along the northeastern and eastern foothills of the Carpathians, and geologists count about 800 salt brine deposits in Eastern Galicia and 50 in Bukovina. Since salty waters lie close to the surface, the exploitation of salty springs was available to the ancient population (*Vakulenko 2010.184*).

In Ukraine, the earliest archaeological evidence of salt making dates back to the Chalcolithic (*Krushelnytska 2002.140*), and thus the extraction of salt by the LBK people is undocumented here as in other regions (*Czekaj-Zastawny 2008b.108; Saile 2012.226–228; Weller 2015*). The absence of flint deposits and the lower fertility of local podsolised soils (Albeluvisols or Retisols in the last editions of WRB) at a land elevated more than 300m above sea level suggests that the presence of salt could be one of the primary reasons for the interest of the LBK communities in this territory.

Summarizing the discussion, the relevance of the traditional view linking migrations of the LBK groups to searching for patches of fertile loess land raises doubts in the case of the forest-steppe territories east of the Carpathians, where fertile soils dominate. In this territory, covered by loess almost everywhere, settlement location was primarily determined by access to mineral resources such as flint, salt or graphite, along with the ability for internal and external exchange. Therefore, models emphasizing the factor of social prestige as a driving force of the first farmers' mobility (*Hofmann 2016.238–239; Spriggs 2016.486–487*) deserve more attention when dealing with LBK sites in the analysed area.

Conclusion

The results obtained by cataloguing the LBK sites in Ukraine revealed a more intensive populating of this territory than previously expected. Accurate mapping of these sites would make possible detailed GIS-based studies of the location patterns in future research. A preliminary comparison of the corrected eastern border of the LBK area with the distribution of loess and present-day soils demonstrated that the vast forest-steppe plains suitable for agriculture were not inhabited by the LBK populations between the Volhynian Upland and Dniester Valley and further to the east. The locational choice was probably stimulated not only by soil fertility, but also by the availability of natural resources – high-quality Turonian flint, graphite, and salt. The location of the easternmost site Vita-Poshtova 2 near the Dnipro River, as well as the presence of LBK pottery among finds of local sub-Neolithic cultures, indicate the existence of an exchange between the arrived farmers and local hunter-gatherers. The extraction and exchange of natural resources to achieve social prestige could play an essential role in the spread of the LBK people in the territory of Ukraine.

Supplementary data

Supplementary data including the database and set of the Google Earth points presented in this paper can be found online at https://doi.org/10.4312/dp.51.1.

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Appendix

Table and maps of the LBK sites (1–270) and the sub-Neolithic sites with the LBK pottery (271–276) in Ukraine[2].

No. on the maps	Name of site	Spatial accuracy	No. in the Supplement
1	Ambukiv*	D	176
2	Horychiv	C	41
3	Selets*	D	242
4	Cherchychi*	C	190
5	Bubniv*	C	185
6	Bubniv-Kurhan tract*	A	186
7	Markostav-Ostrivky tract	A	91
8	Markostav-Panske tract	C	92
9	Markostav-Val tract*	C	223
10	Movnyky	C	103
11	Lytovezh-Kumynka tract	C	85
12	Lytovezh-Zamchysko tract*	B	219
13	Khorokhoryn	A	50
14	Velykyi Okorsk*	C	256
15	Malyi Okorsk	C	87
16	Sarnivka*	C	241
17	Torchyn XII	A	147
18	Smolyhiv III	B	139

2 Asterisk (*) indicates the questionable LBK sites. For legend on the map, see caption to Fig. 1.

Table continued …

19	Torchyn-Zastryzhzhia tract*	B	251
20	Torchyn-PTU	A	148
21	Usychi-khutir Valentyniv*	B	255
22	Usychi XII*	B	254
23	Shepel	C	138
24	Usychi*	C	253
25	Rokyni-Bairak tract	C	133
26	Lutsk-Cherchytsi tract	B	80
27	Lutsk-Krasne tract	B	81
28	Lutsk-Popivska Hirka tract	A	83
29	Rovantsi-Hnidavska Hirka tract	A	134
30	Boratyn-Mohylky tract*	B	184
31	Boratyn-Hrebelki tract	D	16
32	Novostav-Holyshiv*	C	232
33	Korshovets III, after Okhrimenko 1984	C	66
34	Korshovets II, after Okhrimenko 1984	C	65
35	Holyshiv III, after Okhrimenko 1984	C	37
36	Korshovets I, after Okhrimenko 1984	C	64
37	Korshovets	C	63
38	Holyshiv II, after Okhrimenko 1984	C	36
39	Holyshiv-Zamchysko tract	A	38
40	Holyshiv-Zarvykhvosty tract	A	39
41	Korshovets-Prydatky tract	C	67
42	Korshovets-vidhodivelnyi kompleks*	A	210
43	Lutsk-Polonski Futory tract	C	82
44	Polonka-Kut tract*	A	239
45	Hirka Polonka-Polonka	A	33
46	Hirka Polonka-Lob tract	A	32
47	Hirka Polonka-Ohorodnia Bryhada tract*	C	199
48	Baiv-Panske tract	A	6
49	Baiv-Ostriv tract	A	5
50	Baiv-burial	D	4
51	Ratniv-Ripysko tract	A	129
52	Tseperiv	C	150
53	Viktoriany IV	A	156
54	Nesvich-12	A	109
55	Chekno	A	27
56	Chekno-Kar’ier tract	A	28
57	Klevan-Vapelnia tract	A	54
58	Dykiv*	D	198
59	Peresopnytsia-sadyba M. Fedoryshyna	A	122
60	Peresopnytsia-Baranivka tract-2*	A	238
61	Novostav Dalnii-Zamostia tract*	B	231
62	Horodok-Kurhany tract	A	40
63	Zoziv-Kut tract	B	173

Table continued ...

64	Zoziv-Prydatky tract	C	174
65	Shpaniv 4*	A	243
66	Rivne-vul. Shkilna, 69	A	131
67	Rivne-Pliazh tract-1a	A	130
68	Kvasyliv	D	76
69	Kylykyiv*	B	216
70	Mohyliany I	B	97
71	Mohyliany II	B	98
72	Mohyliany-Shkilna dilianka	B	99
73	Mohyliany-Zavodske selyshche	C	100
74	Khoriv-Ozhohoshcha tract	A	48
75	Khoriv-Brodivshchyna tract	A	47
76	Khoriv-Pidluzhzhia tract	A	49
77	Rozvazh	C	135
78	Ostroh-vul. Akademichna, 12	A	117
79	Ostroh-Zamkova Hora tract	B	118
80	Ostroh-Staryi Pliazh tract	B	116
81	Mezhyrich-Sviato-Troitskyi monastyr	A	95
82	Mezhyrich-Popivshchyna tract	C	94
83	Liuchyn-Roz'izdy tract*	A	218
84	Novomalyn-Ivanova Hora tract*	A	230
85	Novomalyn-Bezodnia tract	A	112
86	Novomalyn-Podobanka tract	A	113
87	Vilshanytsia	A	157
88	Zhorniv-Zaobuvets tract	A	169
89	Kryliv-Horody tract*	A	214
90	Ostriv-Horodyshche tract*	B	237
91	Naraiv-Brodky tract	A	108
92	Myrohoshcha-3*	A	226
93	Pantaliia-Ostriv tract	A	120
94	Dubno-Surmychi tract-3*	A	196
95	Dubno-Surmychi tract-2*	A	195
96	Tarakaniv-2*	A	250
97	Dubno-vul. Starytskoho*	A	197
98	Kam'ianytsia-Zabolottia tract-2	A	44
99	Ptycha-3	A	128
100	Naberezhne-Terno tract	C	107
101	Khrinnyky-Baza Lisnytstva tract	A	52
102	Khrinnyky-Serednii Mys tract*	A	205
103	Khrinnyky-Krai Lisu tract	A	53
104	Zastavne-18	A	165
105	Zastavne-20	A	166
106	Kariv XIII	A	45
107	Belz-1	A	8
108	Belz-5	A	9

Table continued ...

109	Belz-Hora tract	B	10
110	Chervonohrad-Rynok tract	A	29
111	Sokal*	D	246
112	Komariv-vul. Shevchenka	A	60
113	Komariv-Pered Tsvyntarem tract*	A	208
114	Komariv-Pered Mostom tract	A	58
115	Komariv-sklad mindobryv	C	59
116	Komariv-Baiorovi Duby tract	A	56
117	Komariv-Hrusha tract	A	57
118	Volytsia-Za Tserkvoiu tract*	A	265
119	Volytsia-Vysoka Nyvka tract*	A	264
120	Velyki Mosty	A	155
121	Tadani-Zamchysko tract	A	145
122	Baniunyn-2*	A	180
123	Baniunyn 5	B	7
124	Lisok-Zamok tract	B	77
125	Khreniv-6	A	51
126	Novosilky-2	A	114
127	Kudyriavtsi-1	A	71
128	Kudyriavtsi-2	B	72
129	Bezbrody-17*	B	182
130	Busk-shkilnyi stadion	A	23
131	Busk-vul. Yevhena Petrushevycha	A	25
132	Busk-maietok Badeni	A	22
133	Busk-vul. Buzka	A	24
134	Chuchmany-12	B	30
135	Humnyska-9*	D	203
136	Yosypivka I	A	163
137	Krasne-Buzetske tract*	C	211
138	Krasne-Zolotyi Lan tract*	C	212
139	Andriivka-VI*	A	178
140	Andriivka-IV*	A	177
141	Andriivka-XXVIII*	A	179
142	Kutkir 10	A	74
143	Zadvir'ia 2*	C	269
144	Zadvir'ia 1*	C	268
145	Krekhiv*	D	213
146	Nova Skvariava II	C	111
147	Nova Skvariava III*	C	229
148	Blyshchyvody-2	A	15
149	Mokrotyn	D	101
150	Hriada-II*	A	201
151	Staryi Yarychiv-1	A	141
152	Staryi Yarychiv-2	A	142
153	Dubliany-4	B	31

Table continued …

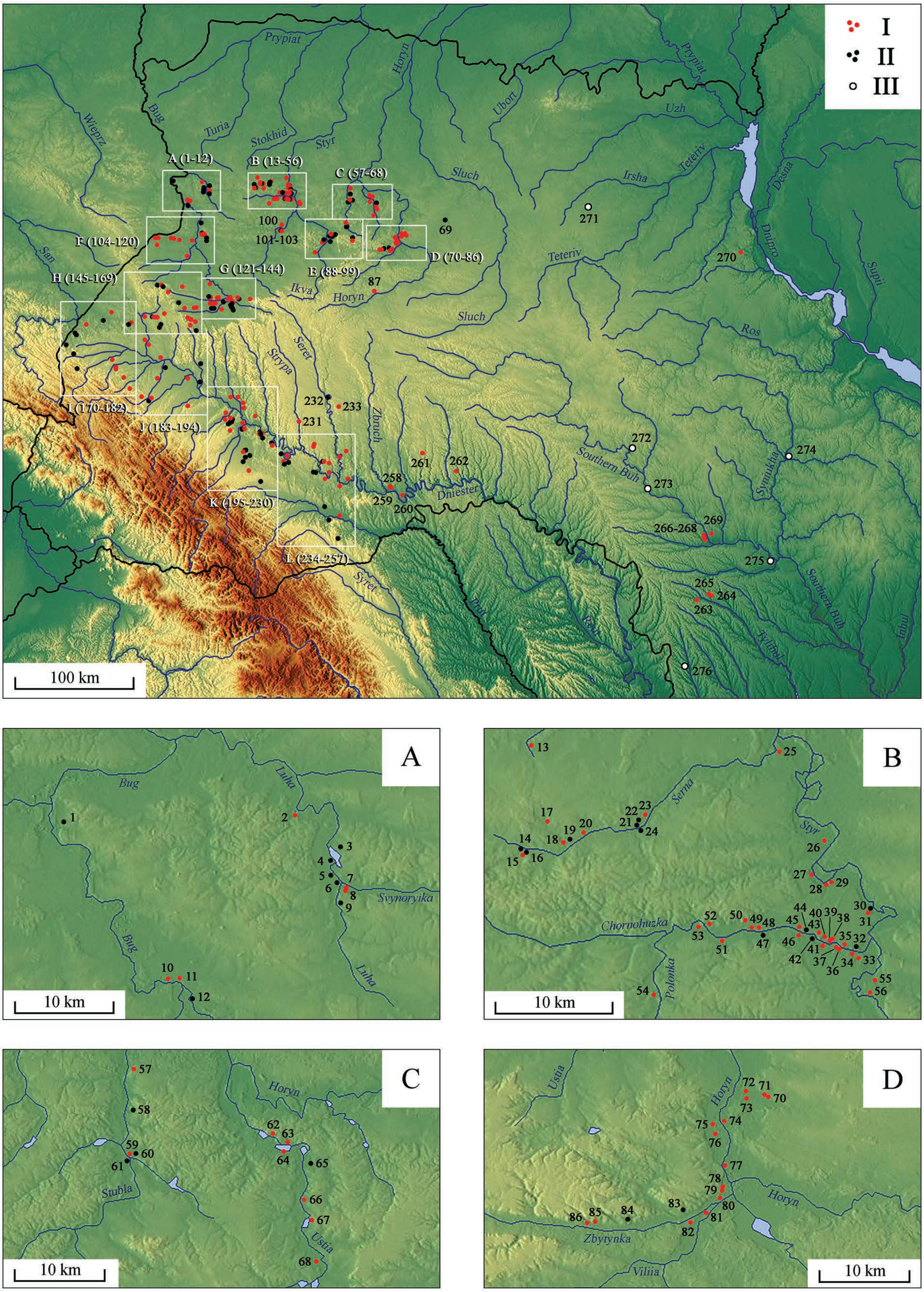
154	Rudne IV	C	136
155	Mshana-Pid Tserkvoiu tract	B	106
156	Mshana-9, after Konoplia	B	105
157	Mshana-10, after Konoplia	B	104
158	Mshana-11, after Konoplia*	C	225
159	Zavereshytsia-3	B	167
160	Rodatychi 1	A	132
161	Bar-3*	A	181
162	Obroshyne-Na Husiatnyku tract*	A	233
163	Stavchany-Vyzdra tract*	A	247
164	Vynnyky-vul. Ivana Lypy	A	160
165	Pidberiztsi-Lazky tract	A	123
166	Pidberiztsi-Pidluzhzhia tract	A	124
167	Pidberiztsi-Zahumenky tract	A	125
168	Vynnychky-khutir Liudvyn	A	159
169	Zvenyhorod*	D	270
170	Oselia 15	A	115
171	Hostyntseve 27*	D	200
172	Khatky-1	A	46
173	Drozdovychi III *	C	194
174	Mizhenets 2*	C	224
175	Hubychi-2*	C	202
176	Khyriv-Posada Khyrivska*	D	206
177	Bilychi-2*	C	183
178	Kulchytsi VI	C	73
179	Kotovane-Dubyna tract	C	68
180	Kotovane-Zapust tract	A	69
181	Monastyr-Lishnianskyi-1	A	102
182	Modrychi 1	A	96
183	Lytovka	A	86
184	Komarno-Na Dibrovi tract	B	61
185	Lystv’ianyi	D	84
186	Rudnyky II*	A	240
187	Bilche-1	A	12
188	Ulychne-1	C	153
189	Kolodnytsia	D	55
190	Kolodnytsia, after Peleshchyshyn 1995*	C	207
191	Zhydachiv-Bazyivka tract	B	172
192	Chornyi Ostriv*	D	191
193	Dobrivliany 1*	A	192
194	Korchivka	D	62
195	Bovshiv-Sulyva tract	B	18
196	Bovshiv-Pidlisky tract	C	17
197	Bilshivtsi-Kuty tract	A	13
198	Tustan	A	151

Table continued ...

199	Temyrivtsi-Pryima tract	A	146
200	Medynia-Karier tract	B	93
201	Sokil-Skelia tract	A	140
202	Viktoriv-Pushykova Hora tract*	A	262
203	Viktoriv-Hoisanivka tract*	A	258
204	Viktoriv-Harmaziivka tract*	A	257
205	Viktoriv-Hora tract*	D	259
206	Viktoriv-Soprykova Hora tract*	C	263
207	Viktoriv-Korneleva Hora tract*	C	261
208	Viktoriv-Kaskova Hora tract*	C	260
209	Pavlivka-Kaminne tract	A	121
210	Yezupil-Selyshche tract*	B	267
211	Yezupil-Mohyla tract	B	162
212	Yezupil-Harnizon tract	A	161
213	Kremydiv-Piddivyche tract	A	70
214	Bukivna-Korchivka tract and Posich tract*	C	188
215	Bukivna-Lviv Historical Museum	D	20
216	Bukivna-Horodyshche tract*	C	187
217	Bukivna-Zarub tract	A	21
218	Bukivna-Za Stepom tract*	C	189
219	Oleshiv-Za Restoranom tract*	C	235
220	Kutyshche-Bubleva tract*	C	215
221	Kutyshche-Tretii Horb tract	A	75
222	Markivtsi-Hora tract and Stav tract*	C	221
223	Markivtsi-Hora tract IV*	C	220
224	Markivtsi-Hora tract and Tsvyntar tract*	B	222
225	Markivtsi-Markovetska Hora tract	A	90
226	Odai-Sukhyi Stav tract*	C	234
227	Slobidka-Budynchyshche tract*	C	244
228	Vorona-Mlynivka tract*	C	266
229	Holoskiv-Khashch tract	B	35
230	Lisna Slobidka-Hriada tract*	C	217
231	Buchach-Hora Fedir tract	B	19
232	Dolyna*	D	193
233	Sukhostav-Holdry tract	B	143
234	Isakiv-Pid Zamchyshchem tract*	C	204
235	Luka X	C	78
236	Luka-Za Fermoiu tract	B	79
237	Nezvysko-Shkilnyi Horod tract	A	110
238	Nezvysko-Pid Klynom tract*	C	228
239	Nezvysko-Ksondzova Hora tract*	C	227
240	Popivtsi-Bilia Kaplychky tract	D	126
241	Popivtsi-Haiok tract	C	127
242	Torske-Chorne tract*	A	252
243	Torske-Shantsi tract	A	149

Table continued ...

244	Strilche-Portky tract*	C	249
245	Strilche-Hora tract*	C	248
246	Zveniachyn	C	175
247	Zalishchyky	A	164
248	Uhrynkivtsi-Popova Dolyna tract	B	152
249	Blyshchanka-Horby tract	A	14
250	Bilche Zolote-Park tract	B	11
251	Hlybochok-Stinka tract	A	34
252	Synkiv	D	144
253	Vasyliv-Horodyshche tract	B	154
254	Oshykhliby*	C	236
255	Mamaivtsi-Selyshche tract	A	89
256	Korostuvata-Vyviz tract*	C	209
257	Sniachiv*	D	245
258	Zhvanets-Lysa Hora tract	A	170
259	Zhvanets-Shchovb tract	A	171
260	Malynivtsi-Sharivka tract	A	88
261	Chankiv 1	A	26
262	Shebutyntsi-Kylyna tract	A	137
263	Ananiv	C	1
264	Ananiv-Mainova Balka tract	A	2
265	Ananiv-Popova Dacha tract	A	3
266	Osychky-Hnyla Skelia tract	A	119
267	Kam’iane-Zavallia	A	43
268	Kam’iane-Synie Ozero tract	A	42
269	Zhakchyk III	A	168
270	Vita-Poshtova 2	A	158
271	Fasova	A	274
272	Shchurivtsi-Porih tract	B	275
273	Skybyntsi-Bazkiv Ostriv tract	B	276
274	Dobrianka-3	A	272
275	Bohdanivka-Gard tract	A	271
276	Hirzhove	B	273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Desna
Dnipro
Supii
San
Ikva
Ros
Seret
Strypa
Zbruch
Southern Buh
Syniukha
Dniester
Syret
Prut
Kodyma
Inhul
A (1-12)
B (13-56)
C (57-68)
D (70-86)
E (88-99)
F (104-120)
G (121-144)
H (145-169)
I (170-182)
J (183-194)
K (195-230)
L (234-257)
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101-103
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Bug
Luha
Svynoryka
1 2 3 4 5 6 7 8 9 10 11 12
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B
Serna
Styr
Chornohuzka
Polonka
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10 km
C
Horyn
Stubla
Ustia
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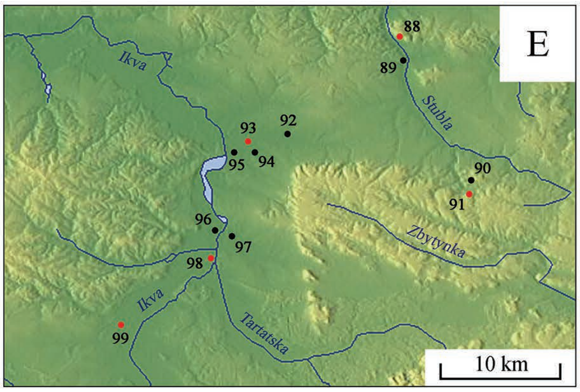
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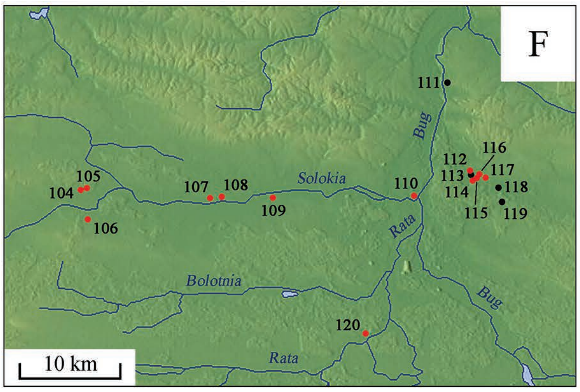
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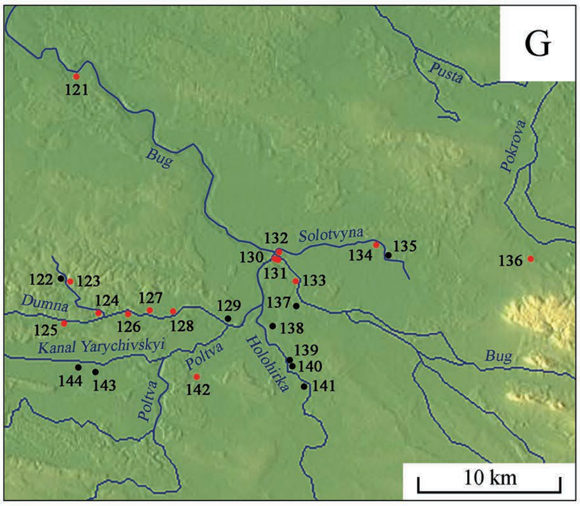
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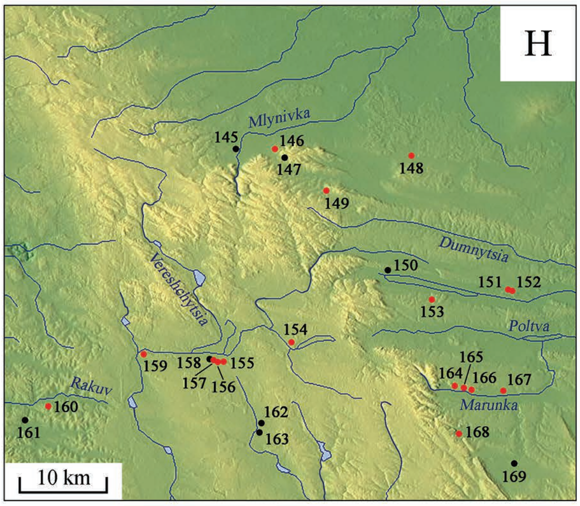
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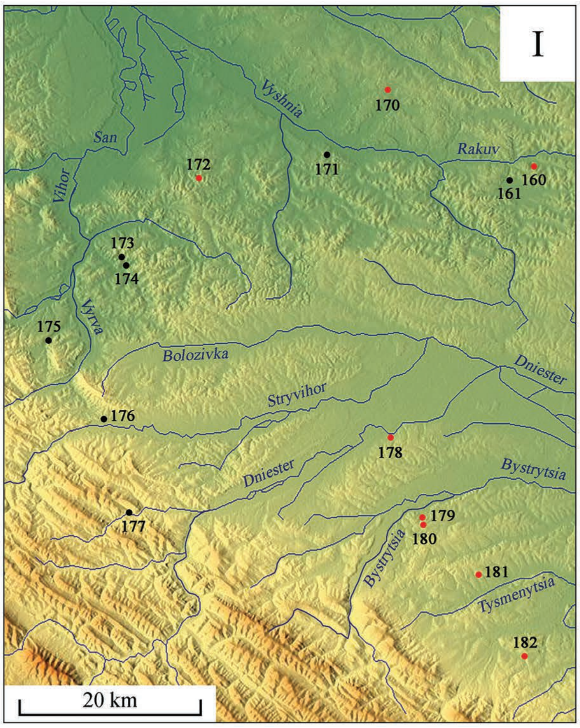
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San
Vihor
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Bolozivka
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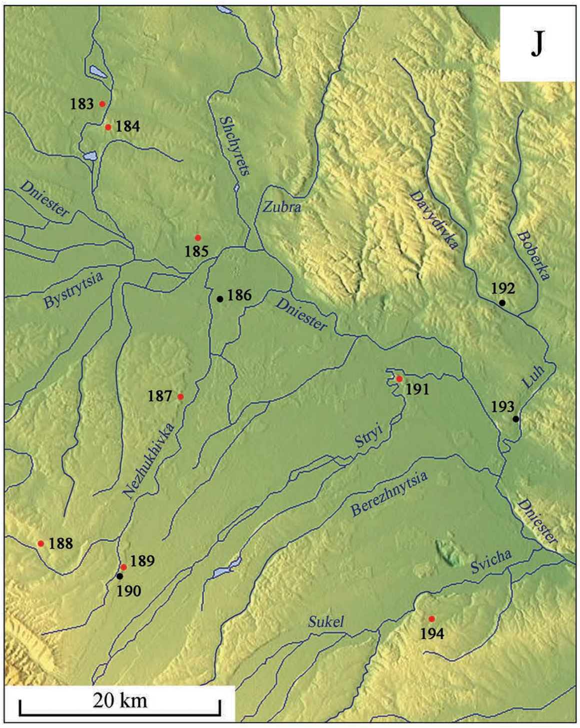
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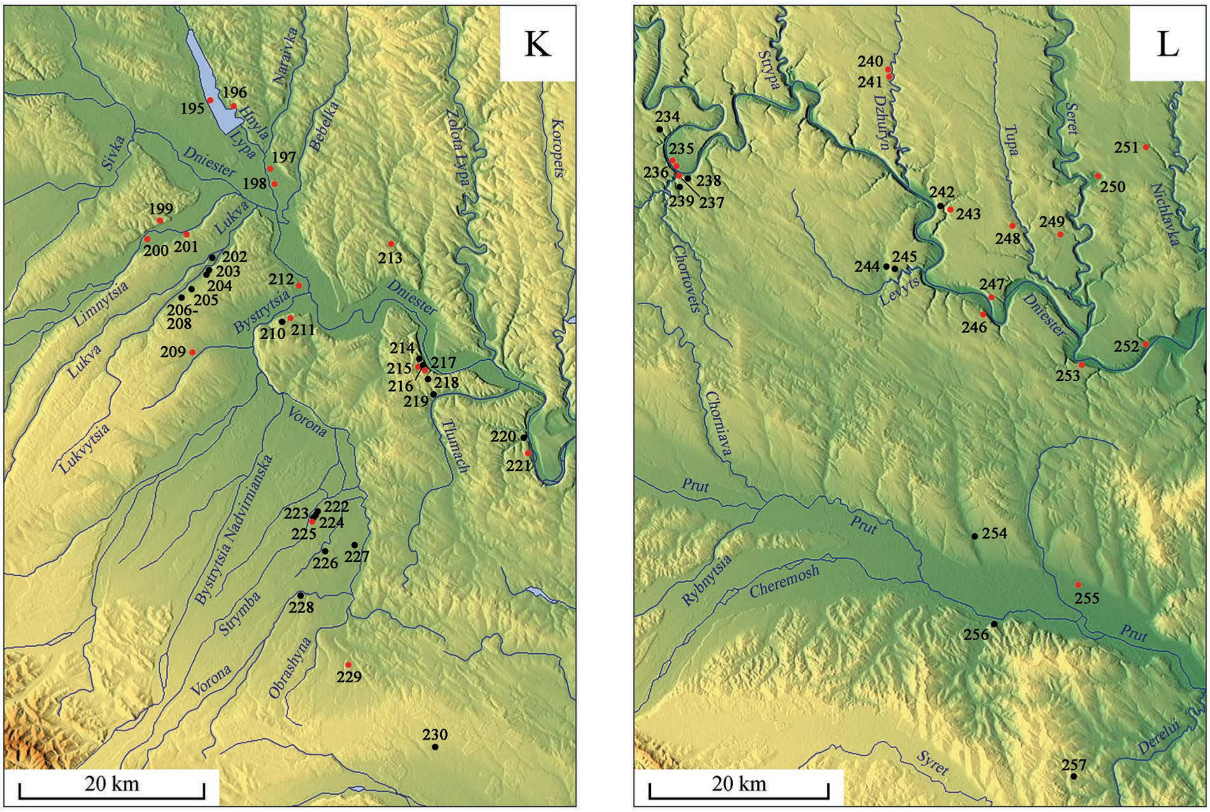

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The beginning of the Neolithic in the central Balkans: knowns and unknowns

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ABSTRACT - *Since 2020 a wealth of new data has been generated on the beginning of the Neolithic in the central Balkans. The picture that has emerged is broadly consistent with the Wave of Advance model, with the first farmers arriving in the region around 6250 BC and expanding gradually towards the north. In this paper, an updated review of the evidence and interpretations is presented, and potentially problematic or ambiguous aspects of the current interpretations of the Neolithic expansion in the Balkans are identified. Alternative hypotheses and means of their testing are also discussed.*

KEY WORDS – *Neolithic; central Balkans; Wave of Advance; first farmers; radiocarbon dating*

Začetek neolitika na osrednjem Balkanu: znano in neznano

IZVLEČEK – *Po letu 2020 je na voljo mnogo novih podatkov o začetku neolitika na osrednjem Balkanu. Nova podoba je na splošno skladna z modelom vala napredovanja, pri čemer so prvi kmetje prispeli v regijo okoli leta 6250 pr. n. št. in se postopoma širili proti severu. V prispevku predstavljamo posodobljen pregled dokazov in interpretacij in potencialno vprašljivih ali dvoumnih vidikov sedanjih interpretacij neolitske ekspanzije na Balkanu. Obravnavane so tudi alternativne hipoteze in načini njihovega preverjanja.*

KLJUČNE BESEDE – *neolitik; osrednji Balkan; val napredovanja; prvi kmetje; radiokarbonsko datiranje*

Introduction

The central Balkans region[1] (Fig. 1) was one of the main corridors for the expansion of the first European farmers from northern Greece. As such, it is an important region for researchers interested in the beginning of the Neolithic in Europe (*e.g., Garašanin 1982; Bailey 2000; Tringham 2000; Whittle* et al. *2002; Tasić 2009; Borić 2011; Shennan 2018; Reingruber 2020; Krauß 2023; Vander Linden 2023*). One of the critical aspects of Early Neolithic research has been the establishment of absolute chronology, to determine the arrival time of the first farmers, as well as to test different hypotheses and models about the mechanism, tempo, and

1 Strictly speaking, the northern boundaries of the Balkan peninsula are demarcated by the rivers Sava and Danube. However, it is important to note that the region of Vojvodina (northern province of the Republic of Serbia) lies immediately to the north of these rivers. In this review, I will include Vojvodina, as well, as it represents a transitional zone between Balkans and Central Europe. Moreover, the Neolithic communities in this area are integral to understanding the expansion process across the central Balkans. The boundaries of the central Balkan region itself are not clearly and unambiguously defined in the literature, but the core of the region consists of western Serbia, central Serbia (Šumadija), southern Serbia and Kosovo. Therefore, the study region in this paper will include these core territories plus Vojvodina.

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demographic aspects of the Neolithic expansion. In this region of Europe, the establishment of absolute chronology depends primarily on the number and quality of radiocarbon dates. This number was relatively low in the last quarter of the 20th century. The situation improved in the early 2000s with the study by Alasdair Whittle *et al.* (*2002*), but until recently, the total number of dates for the Early Neolithic in the central Balkans (excluding the Danube Gorges microregion) was less than one hundred (*Porčić* et al. *2016*). In the early 2020s, the ERC-funded BIRTH project, directed by Sofija Stefanović, contributed to the marked increase in the quantity of radiocarbon and bioarchaeological data related to the beginning of the Neolithic in the region (*Porčić* et al. *2016; 2020; 2021a; 2021b; Blagojević* et al. *2017; Jovanović* et al. *2021a; 2021b; Stefanović* et al. *2019; Penezić* et al. *2020; Stojanovski* et al. *2020*).

From this recently published research, a more detailed and complex picture of the Neolithic expansion and demography in the central Balkans emerged (*Porčić* et al. *2020; 2021a; 2021b*). The set of almost 300 new radiocarbon dates enabled the researchers to estimate the timing and speed of the Neolithic expansion across this region (*Porčić* et al. *2020*), as well as to reconstruct population dynamics of the Early Neolithic communities (*Porčić* et al. *2021a*). Computer simulation constrained by the radiocarbon evidence was used to investigate the mode and demographic parameters of the expansion – to estimate the fertility and mortality rates, and population size thresholds of community fission related to migrations (*Porčić et al. 2021b*).

The Wave of Advance model (WoA) (*Ammerman, Cavalli-Sforza 1979; 1984*) coupled with the theory of the Neolithic Demographic Transition (NDT) (*Bocquet-Appel 2008; 2011a; 2011b; 2014; Bocquet-Appel, Bar-Yosef 2008*) was used as the main theoretical framework for modelling and interpretation of the data. In short, this scenario assumes that the first farming communities gradually spread from the southern Balkans to the central Balkans as a consequence of local population growth. This growth was fueled by an increase in fertility (increased number of children), resulting from a sedentary lifestyle and cereal-oriented subsistence. The expansion of the farmers is seen as a consequence of community fission when certain population thresholds are reached. In our interpretation of the empirical evidence, this threshold was social, related to scalar stress (*Johnson 1982*),rather than ecological (*i.e.* related to environmental carrying capacity) (*Porčić 2021b*).

In this paper, I will first make an updated review of the available evidence, and then I will critically reflect on the current interpretation. In the research published with my colleagues, a version of the WoA model was established as the interpretation of the

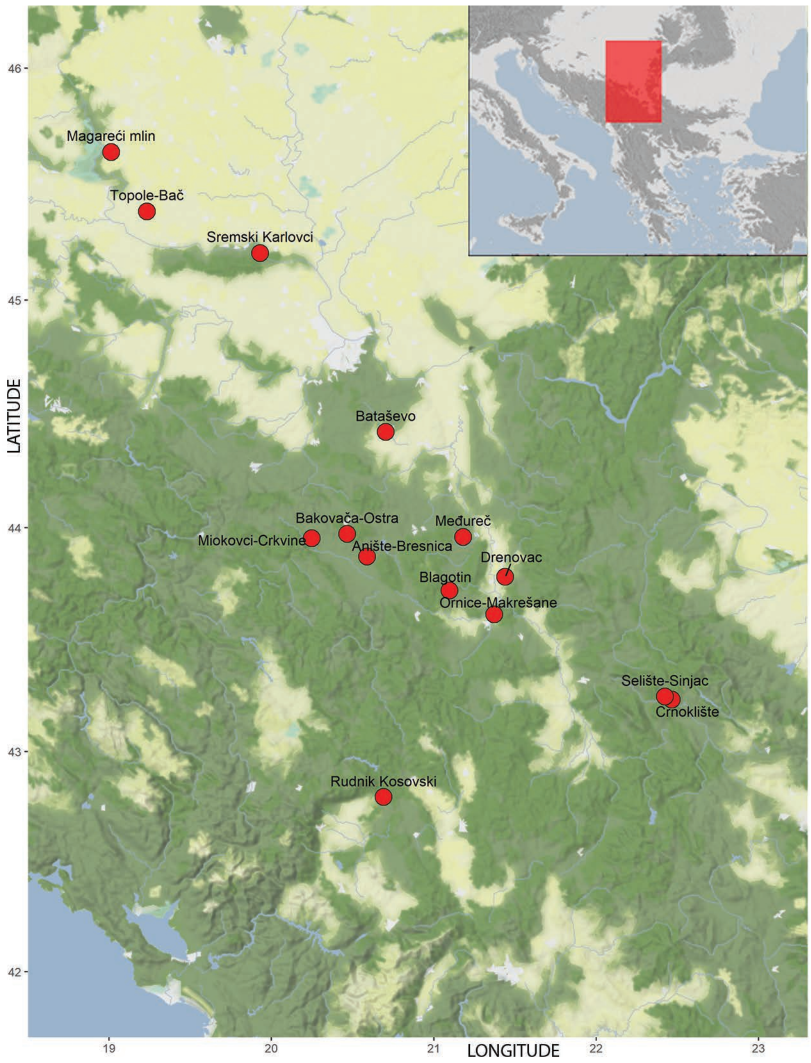

Fig. 1. The study region (see footnote 1 in the main text for the definition of the study region) and the sites mentioned in the text.

data – I will refer to it as the standard interpretation or the standard model. However, in this text, I wish to address the potentially problematic or ambiguous aspects of this interpretation. The evidence is such that, although it does support the standard model, it leaves room for alternative hypotheses and models, as suggested by Marko Porčić *et al.* (*2021b*). In other words, the available data does not fully constrain our models of the Neolithic expansion in the central Balkans. So, even though I consider the standard interpretation based on the WoA model as the currently best explanation (as I will argue in more detail below), it is still necessary to formulate and discuss alternative hypotheses and means of their testing.

The main questions regarding the beginning of the Neolithic that I will address in this paper are:

- When did the Neolithic begin in the central Balkans – when did the first farmers settle in this region?
- What was the tempo and mode of the expansion?
- What drove the expansion?
- How did population size change during the Early Neolithic?

What we (think that we) know: "*the standard interpretation*"

Porčić *et al.* (*2020*) suggested that the first Neolithic populations reached southern parts of the central Balkans, *i.e.* northern parts of North Macedonia and southern parts of Serbia, between 6250 and 6200 BC. The reconstructed speed of the expansion front was around 1.5–2km/year (*Porčić* et al. *2020*). The general gradient of the expansion follows the south-north axis of the major river valleys of South and Great Morava (*Porčić* et al. *2020*). Therefore, the observed spatio-temporal pattern is broadly consistent with the WoA model.

The method of summed probability distributions of calibrated radiocarbon dates (SPD) was used to reconstruct the population dynamics of the first farmers in this region (Fig. 2). The SPD demographic proxy curve suggests a rapid increase in population after the arrival of the first farmers, and the population rapidly increased between 6200 and 6000 (*Porčić* et al. *2021a*). However, the SPD curve suddenly goes downafter 6050–6000 BC, suggesting a population crash. The minimum is reached around 5800 BC, after which the SPD proxy starts to increase again, reaching a second peak around 5650 BC. After this second peak, the SPD curve suggests a population crash (or a lack of dates, in more neutral terms) between around 5500 and around 5300 BC, a phenomenon which is related to the start of the Late Neolithic in the region, which is discussed elsewhere (*Porčić 2020*).

The estimated growth rates, also based on the frequency of radiocarbon dates, are high. Porčić *et al*. (*2021a*) used the Approximate Bayesian Computation method to estimate population growth rate. The results suggest a growth rate of 2.36% (95% credible interval 0.9–3.97%). Tamara Blagojević *et al*. (*2024*) used hierarchical Bayesian modeling (*Crema, Shoda 2021*) to estimate growth rates and the resulting estimates are even higher – 3.25% (95% credible interval 0.96–5.97%).

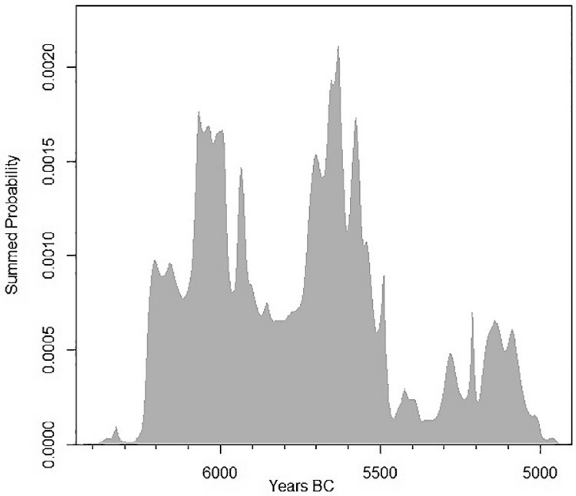

Fig. 2. Summed probability distribution demographic proxy curve based on all Neolithic radiocarbon dates from the central Balkans (after* Porčić *et al.* 2021.Fig. 2, panel c*).

Computer simulation based on the modified WoA model was used to infer the demographic parameters (fertility, mortality and the settlement fission threshold) of the expanding Neolithic populations (*Porčić* et al. *2021b*). The results of the simulation suggest that fertility rates must have been very high, with an estimated total fertility rate of around 10 children, which is at the very upper end of the ethnographically and historically recorded spectrum (*Wood 1990; Bentley* et al. *1993a; 1993b*). The simulation also suggests that fission thresholds for settlements must have been relatively low due to scalar stress – when a settlement population size reached 30–60 people, part of the community would migrate somewhere else, thus contributing to the expansion of the Neolithic population front.

Updating the arrival time and expansion speed estimates

Arrival time revisited

The question of when the Neolithic in the central Balkans started is yet another instance of a general problem of determining the temporal beginnings of phenomena in archaeology (*Perreault 2011; Lipo* et al. *2021*). The problem is twofold: what is the target event in question (*e.g.,* is it the date when the first, wandering farmer set foot in the central Balkan area, or the date when the first settlement was established?) and how can we know that we genuinely have the earliest date for the target event, given the fragmentary nature of the archaeological record and the incompleteness of archaeological research? The first part of the question can be defined with relative clarity – we are interested in the date of establishment of the earliest Neolithic settlement in the central Balkans. But estimating this date is a serious methodological challenge (*Perreault 2011; Lipo* et al. *2021; Crema* et al. *2022*). We can be almost certain that we will not have the exact date for our target event, for at least two reasons:

❶ The probability that the actual earliest site was archaeologically discovered and investigated is low.
❷ Even if the earliest site is found and excavated, the probability that the earliest context (*i.e.* the first built dwelling) is identified is also low, as the sites are rarely excavated in their totality.

The samples, which were collected for the BIRTH project, were chosen randomly. There was no effort to identify the earliest context. This is so because the dates were primarily collected for the application of SPD method of demographic inference, which ideally requires a random sample of datable material. Therefore, we can be almost certain that none of the dates come from the earliest contexts at a given site.

For this reason, Porčić *et al*. (*2020*) made an educated guess that the actual arrival time (*i.e.* the establishment of the first Neolithic settlement) in the central Balkans (in southern Serbia and Kosovo), was earlier than the 6200 BC date suggested by the radiocarbon dates. But there are three problems with this 6250–6200 BC estimate:

❶ The dates were originally calibrated with the Intcal13 curve (*Reimer* et al. *2013*), which yielded slightly older dates in this period than the current Intcal2020 curve (*Reimer* et al. *2020*).

❷ The oldest date on a cattle bone from Miokovci site is potentially problematic, as the precise zooarchaeological determination of the bone fragment is not possible and the site from which the sample comes is in the central area of the central Balkans rather than the south (*Blagojević 2023*). It was identified as *Bos* sp. (*Porčić* et al. *2020; 2021a*), meaning that it is not certain if this bone belonged to a domesticated (*Bos taurus*) or wild cattle (*Bos primigenius*). If the latter is the case, it could potentially be a residual sample, but it could also be authentically Neolithic given that *Bos primigenius* is found, although in low frequencies, in the Early Neolithic faunal assemblages in this region (*Vuković 2021*). However, it is mostly problematic from the perspective of the WoA model as the Miokovci date is too early for this part of Serbia. So, excluding it only on this ground would be circular reasoning, if we wish to use the dates to test the WoA model. The inclusion or exclusion of this individual date does not make a significant difference to any of the results, so Idecided to keep it for analysis in this paper, as there is no evidence beyond reasonable doubt to exclude it.

❸ The bulk of calibrated probability distribution for the oldest samples, especially the one from the site of Rudnik Kosovski, which is the second oldest date after the sample from Miokovci, is between 6200 and 6100 BC.

Therefore, there is a need to update and critically review the results related to the arrival time of the Neolithic. I recalibrated the oldest dates from Miokovci and Rudnik Kosovski with the Intcal20 curve (*Reimer* et al. *2020*) in OxCal 4.4 (*Bronk Ramsey 2001*). The resulting distributions are shown in Figure 3. Although the means of calibrated distributions suggest dates closer to 6200 BC, a significant part of the calibrated probability distribution is between 6200 and 6100 BC. So, we know that the date of the target event is earlier than the earliest dated event, but we do not know what is the difference, and more importantly, we do not know what is the precise date of the dated event – is it closer to 6200 or 6100 BC?

To go beyond an educated guess and offer a more formal estimate of the arrival time, I will use the optimal linear estimation (OLE) method advocated by Alastair Key *et al*. (*2021*), implemented in the sExtinct package for R (*Clements 2013*) and suitable for estimating the full range of archaeological phenomena – *i.e.* the beginnings and endings. The OLE method estimates the first or the last occurrence of an archaeo-

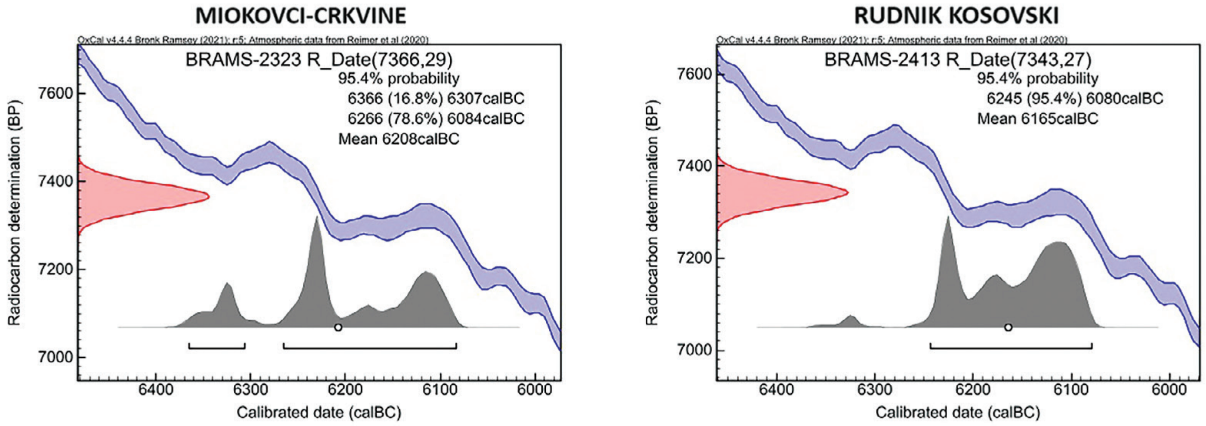

Fig. 3. The earliest Neolithic radiocarbon dates from the central Balkans.

logical phenomenon based on the *n* first or last observations. In this case, I used the 10 earliest dates from Kosovo, South and West Morava river valleys (Tab. 1). As radiocarbon dates are not simple point estimates of calendar ages, the OLE earliest date estimate is not going to be a single estimate but a distribution of estimates based on the Monte Carlo sampling from the calibrated distributions of these particular 10 dates (method and R code adapted from *Porčić* et al. *2020*). In short, the computer will sample 10 000 potential realizations of the calendar years for each radiocarbon date from its corresponding calibrated distribution. For each set of the sampled calendar dates, an OLE estimate is calculated. Based on the latest radiocarbon evidence from the site of Vlaho in North Macedonia, the first farmers reached the southern part of this country around 6300 BC (*Naumov* et al. *2023*). As it is reasonable to assume that the Neolithic arrived earlier in North Macedonia than Serbia, I limit the potential OLE estimates only to the dates which are younger than 6324 BC, which is the mean value of the calibrated distribution of the oldest radiocarbon date from Vlaho.

The results of the Monte Carlo OLE estimation are shownin Figure 4. The mean of estimated mean earliest dates for the beginning of the Neolithic is 6250 BC (with a standard deviation of 25 years)[2], in line with an informal estimate proposed by Porčić *et al*. (*2020*). However, it should be emphasized that the OLE estimate is based on an empirical generalization and a generic statistical model, rather than the underlying population dynamics model and its parameters, which in reality govern the probabilities of discovering the earliest sites and the earliest datable items from a site, and thus these results should be considered as tentative. The matter can only be resolved with new dates, sampled specifically for Bayesian modeling.

Expansion speed revisited

To revise the estimate of the expansion speed, I used the earliest dates from sites grouped in 50km wide bins (Tab. 2) – binning is performed relative to the distance of a site from the Early Neolithic site of Mavropigi in Greece (see *Porčić* et al. *2020* for a detailed explanation of the spatial bins). In other words, I only use the earliest dates from each successive 50km wide (in the

Site	Date label	^{14}C Age	Error	Mean	95% Confidence Interval	Reference for the ^{14}C date
Rudnik Kosovski	BRAMS-2413	7343	27	6165	6245-6080	*Porčić* et al. *2020; 2021*
Crnoklište	BRAMS-2290	7293	29	6153	6225-6076	*Porčić* et al. *2020; 2021*
Selište Sinjac	BRAMS-2303	7300	30	6154	6226-6078	*Porčić* et al. *2020; 2021*
Ornice-Makrešane	BRAMS-2223	7335	31	6162	6241-6079	*Porčić* et al. *2020; 2021*
Blagotin	OxA-8609	7270	50	6141	6231-6029	*Whittle* et al. *2002*
Drenovac	BRAMS-2244	7309	28	6155	6227-6082	*Porčić* et al. *2020; 2021*
Anište Bresnica	BRAMS-2331	7306	28	6154	6226-6081	*Porčić* et al. *2020; 2021*
Međureč	BRAMS-2251	7316	29	6156	6230-6081	*Porčić* et al. *2020; 2021*
Bakovača Ostra	BRAMS-2329	7299	27	6154	6225-6078	*Porčić* et al. *2020; 2021*
Miokovci Crkvine	BRAMS-2323	7366	29	6208	6366-6084	*Porčić* et al. *2020; 2021*

Tab. 1. 10 earliest dates used for the OLE estimation of the arrival time of the first farmers to the central Balkans region. Dates calibrated in OxCal with Intcal20.

2 Each OLE estimate has its confidence intervals. I only presented the distribution of mean estimates here.

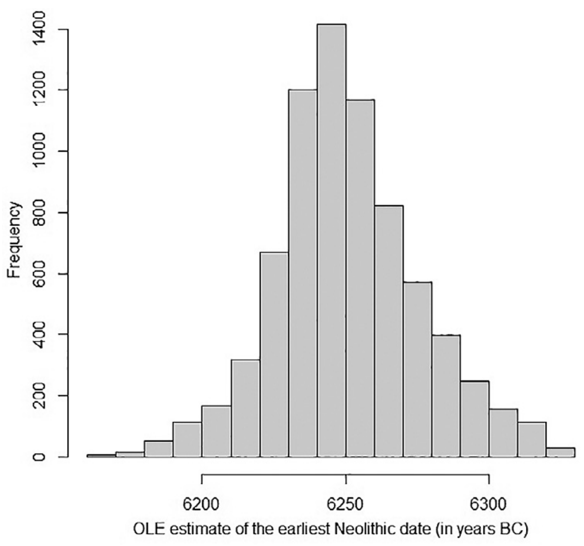

Fig. 4. Distribution of the Neolithic arrival time estimates based on the OLE method implemented with Monte Carlo sampling of the calendar dates from probability distributions of calibrated radiocarbon dates.

south-north direction) microregion from the central Balkans as an approximation of the arrival of the Neolithic population front at that particular latitude. In addition to the dates used in Porčić *et al*. (*2020*), I also include the oldest date from North Macedonia, from the site of Vlaho (*Naumov* et al. *2023*). I use the Monte Carlo method of estimation, with two regression techniques – ordinary least squares (OLS) and reduced major axis regression (RMA) (for a detailed description of the method and dedicated R code, see *Porčić* et al. *2020*).

The results suggest that the average expansion speed was around 1.6km/ or 2km/year, depending on the regression technique (Tab. 3, Fig. 5). When the means of calibrated dates, as point estimates of front arrival dates, are plotted against the distance from Mavropigi, we can see that even though a linear model gives a relatively good fit (mean Pearson's correlation coefficient value is 0.8 with standard deviation of 0.1), there seems to be a difference in the expansion speeds between the regions of Kosovo, southern and central Serbia on one side, and northern Serbia (Vojvodina) on the other (Fig. 6). The slope is lower in the former case,suggesting a higher speed[3] of expansion, and lower in the latter, suggesting a lower speed of expansion once the Sava and Danube are crossed. This is in line with the local speed estimates made by Blagojević (*2023*).

Cracks in the interpretative edifice

In this section, I will focus on some of the results of previous research which leave room for doubt regarding the 'standard interpretation', *i.e.* the WoA model (see also the discussion in *Porčić* et al. *2021b*):

- The estimated fertility rate of around 10 children per woman is possible, but suspiciously high, as it is at the very upper end of the ethnographically recorded spectrum (*cf. Bentley* et al. *1993a; 1993b*).

- The mean estimated population growth rates are also very high, around 2.5–3% (*Porčić* et al. *2021a; Blagojević* et al. *2024*), but the confidence intervals suggest that they may have been even higher, outside the ethnographically and historically recorded range. This would suggest that the model which assumes only local population growth due to increased fertility is not an adequate explanation.

- The estimated expansion speed is higher than the continental average of 1–1.3km (*Ammerman, Cavalli-Sforza 1971; Gkiasta* et al. *2003; Pinhasi* et al. *2005; Bocquet-Appel* et al. *2012; Henderson* et al.

Site	Distance from Mavropigi (km)	Date label	^{14}C Age	Error	Mean	References
Miokovci-Crkvine	408	BRAMS-2323	7366	29	6208	*Porčić* et al. *2020; 2021*
Rudnik Kosovski	275	BRAMS-2413	7343	27	6165	*Porčić* et al. *2020; 2021*
Ornice-Makrešane	353	BRAMS-2223	7335	31	6162	*Porčić* et al. *2020; 2021*
Bataševo	450	BRAMS-2227	7331	27	6158	*Porčić* et al. *2020; 2021*
Selište Sinjac	316	BRAMS-2303	7300	30	6154	*Porčić* et al. *2020; 2021*
Sremski Karlovci	548	BRAMS-2423	7233	28	6102	*Porčić* et al. *2020; 2021*
Topole Bač	585	OxA-8693	7170	50	6036	*Whittle* et al. *2002*
Magareći mlin	617	Grn-15973	7130	60	5997	*Whittle* et al. *2002*
Vlaho	55	CAN-6151	7460	36	6324	*Naumov* et al. *2023*

Tab. 2. Radiocarbon dates used for the estimation of the Neolithic front expansion speed.

3 As time is regressed on distance in this case, speed is equal to the reciprocal value of the slope, therefore, lower slopes indicate higher expansion speeds, and vice versa.

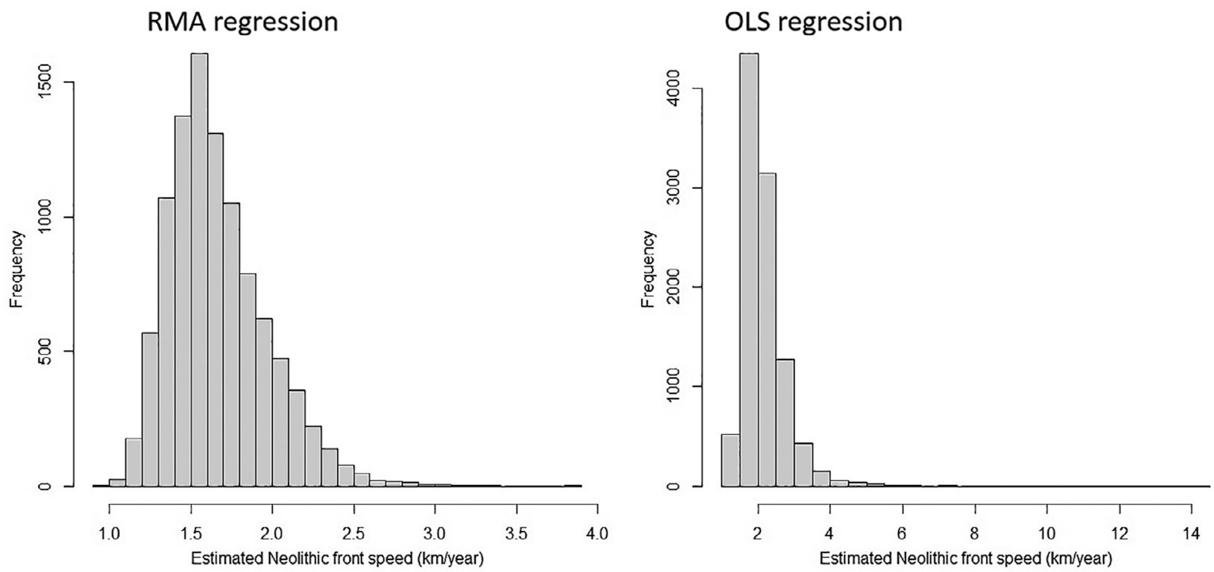

Fig. 5. Distributions of the expansion speed estimates based on the reduced major axis regression (left) and ordinary least squares regression, with Monte Carlo sampling of the calendar dates from probability distributions of calibrated radiocarbon dates.

2014). It is especially high in the area of southern and central Serbia (*Blagojević 2023*). Translated into more neutral terms, there is a very rapid appearance of Neolithic sites in the region.

- The most puzzling result is the abrupt drop of the SPD curve after 6050 BC (Fig. 2). This pattern is difficult to explain and correlate with other phenomena in the archaeological or environmental record.

As I will argue in the last section, none of these observations is sufficient to falsify the standard interpretation, but they open possibilities for alternative interpretations and formulations of alternative models of the beginning of the Neolithic in the central Balkans.

Alternative hypotheses

There are alternative hypotheses that can be formulated to accommodate the data, and in some form they are already present in the literature (*Porčić* et al. *2021b*). In this section, I will present these hypotheses, evaluate them against current evidence and suggest how they can be tested.

The Mesolithic hypothesis

The Mesolithic presence in the central Balkans seemed to be limited to the Danube Gorges area (*Gurova, Bonsall 2014*), but more recent research suggests that Mesolithic populations may have been present in other parts of the region, as well (*Petrović, Starović 2016; Živaljević* et al. *2021*). If there was an underlying Mesolithic population, then the process of the Neolithic expansion would have been more complex and would have probably involved interactions with the local Mesolithic population, similar to what is documented in the Danube Gorges area between 6200 and 6000 BC (*Borić 2011*).

The Mesolithic hypothesis assumes that most of the earliest Neolithic sites, dated to a period before 6050 BC,are not outposts of the migrating farmers of the Anatolian/Aegean origin, but seasonal settlements of the local (semi)mobile hunter-gatherers which became archaeologically visible as they adopted the Neolithic material culture (pottery), as well as domesticated plantsand animals by a process of cultural diffusion. The true arrival of the farmers, *i.e.* the demic diffusion, and their subsequent demographic growth (which would in this scenario correspond to the second peak of the SPD curve around 6250 BC in Fig. 2) would occur only after 6050 BC in this scenario.

This hypothesis has several merits (pros):
❶ It would explain an unusually high estimated speed of expansion in southern and central Serbia. If the actual farmers arrived in the south of Serbia around

	Mean expansion speed estimate (km/year)	Standard deviation of the estimate
RMA	1.66	0.30
OLS	2.14	0.59

Tab. 3. Summary of the Monte Carlo expansion speed estimates.

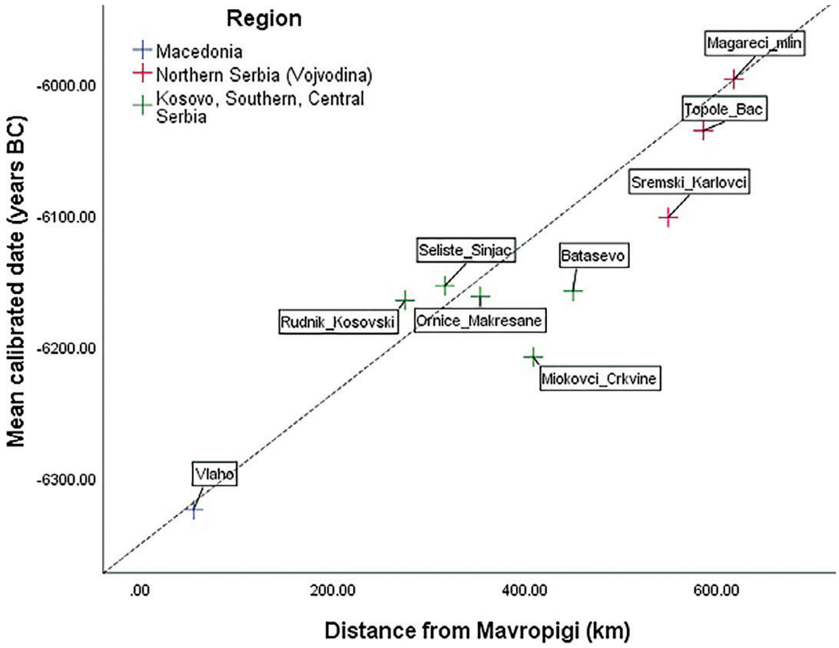

Fig. 6. Plot of the means of the calibrated distributions of the earliest radiocarbon dates against distance from the Mavropigi site in Greece. The dashed line represents an ordinary least squares regression line with distance from Mavropigi as the independent variable, and the mean of distribution of calibrated radiocarbon date as the dependent variable.

6250 BC, it would have taken around 200 years for themto reach central Serbia and Šumadija if their speedof expansion was equal to the continental average.

❷ It would explain differences in architecture and settlement layout between the settlements in the southern and northern parts of the central Balkans. In contrast to the Neolithic in North Macedonia and southern parts of Serbia, where Neolithic settlements consisted of solidly built wattle-and-daub houses with rectangular plans (*Gimbutas 1976; Horejs* et al*. 2022; Naumov* et al*. 2023*), as in the Neolithic sites in Thessaly and Greek Macedonia[4] (*Perlès 2001*), the Neolithic settlements in the north (central Balkans and the Pannonian plain) consisted mostly of pit-houses (*e.g., Bogdanović 1988; Minichreiter 1992; 2007; Greenfield, Drasovean 1994; Greenfield, Jongsma 2006; Marić 2013; Greenfield* et al. *2014; Oross* et al. *2016*), and in rare cases, lightly built above ground houses (*e.g., Bogdanović 1988; Minichreiter 2010*). This low investment in dwelling architecture would be consistent with the less sedentary and more mobile lifestyle (*McGuire, Schiffer 1983; Binford 1990*). Early Neolithic sites in the central Balkans are flat sites with little or no vertical stratification of habitation horizons. For these reasons,many scholars share the view that these sites represent the remains of short-lived settlements, frequently relocated with high residential mobility (*Bailey 2000.58; Tringham 2000; Greenfield, Jongsma 2006; Greenfield* et al*. 2014; Klindžić, Hršak 2014; Greenfield, Lawson 2020*).

❸ Most importantly, this hypothesis would explain the drop of the SPD proxy curve. If the first farmers came in greater numbers only after 6000 BC, replaced the local hunter-gatherers, and started to live in sedentary settlements, the number of sites and datable material would decrease between 6000 and 5800 BC, only to rise again as the Neolithic population in the central Balkans started to grow as suggested by the second peak of the SPD curve and predicted by the NDT theory.

However, there are also arguments against the Mesolithic hypothesis (cons):

❶ Individuals with genotypes indicating Anatolian descent are already present in the Danube Gorges before 6000 BC. According to the recent paleogenetic study by Maxime Brami *et al*. (*2022*), the mean calibrated date for the oldest individual (the adult male from grave 18) buried at Lepenski Vir with admixed Aegean/Anatolian and Mesolithic ancestry is 6099 BC (95% CI: 6230–5984 BC). This means that demic diffusion did take place earlier, in accord with the standard model, but on the other hand, these pre-6000 BC contacts could be limited to individual interactions, not an advancement of the Neolithic expansion front.

❷ Individuals who are found in pre-6050 BC contexts are usually buried in a flexed position (*Jovanović* et al.

4 It should be noted that pit-houses are dominant at the earliest Neolithic sites in Greece, such as Mavropigi, Paliambela and Revenia (*Karamitrou-Mentessidi* et al. *2013; Tsartsidou, Kotsakis 2020; Maniatis, Adaktylou 2021*), but after around 6400 BC above ground houses are built more often, and became the norm on tell sites.

2021a), which is the typical Neolithic funerary practice of the first farmers in SE Europe. People of Mesolithic origin in the second half of the 6th millennium BC in the Danube Gorges are usually buried in the supine position (*Radovanović 1996*)

❸ The sudden drop of the SPD curve would mean that the curve stops tracking the Mesolithic people with pottery and elements of the Neolithic package which increase their visibility, and starts tracking the Neolithic farmers who are present at first in low numbers. But the question in this case is what happened to the hypothesized Mesolithic population, why would they simply disappear and how?

The Mesolithic hypothesis can be tested primarily with the aDNA data. If this hypothesis is true, then most individuals buried before 6050 BC should be of local Mesolithic, rather than Anatolian/Aegean, descent. It is possible that some of the individuals with pure or mixed Anatolian descent occur in pre-6050 BC contexts, even if the Mesolithic hypothesis is true, but the majority would have to be predominantly local.

Changes in mobility and residence patterns influenced by environmental factors

In a previously published paper (*Porčić* et al. *2021a*), it was proposed that the puzzling decrease of the SPD curve after 6050–6000BC could have been caused by changes in residential mobility of the first farmers rather than drastic changes in population size: "*If the communities prior to 6000 BC were for some reason (*e.g., *unstable climate due to 8.2 ky event) more mobile than communities afterwards* i.e. *that the average duration of the pre-6000 BC settlements was lower than the average duration of post-6000 BC settlements, then the number of pre-6000 BC sites would be higher than the number of post-6000 BC sites, even if there was no difference in population size.Assuming the random sampling of sites for radiocarbon dating, this would result in a higher number of pre-6000 BC dates relative to the post-6000 BC dates. In terms of the SCPD curve, this might produce a pattern of increase and decrease similar to the one observed. The first peak of the curve would reflect higher mobility in the pre-6000 BC period. After 6000 BC, if the residential mobility was reduced, this would explain the abrupt drop of the SCPD curve. The second episode of growth, after 5800 BC, would represent the growth of population due to the NDT. Therefore, this hypothesis would suggest that we only have one process of population growth as predicted by the major theories but that it is distorted by the effect of the changes in settlement pattern on the SCPD curve. Instead of observing a monotonically increasing SCPD curve, we would observe a falsepeak around 6000 BC due to these effects*." (*Porčić* et al. *2021a.Supplementary File 1.21–22*).

In this paper I will present slightly modified version of this hypothesis: the initial expansion of farmers in the central Balkans was accompanied by increased residential mobility as a consequence of the encounter with new environment and/or the consequences of the 8.2 ky event.

The migration to the central Balkans from the southern Balkans was a shift from one climatic regime, Mediterranean and Sub-Mediterranean in the south, to another – Sub-continental and Continental climate in the north (*Ivanova* et al. *2018; Krauß* et al. *2018; de Vareilles* et al. *2022; Vander Linden 2023*). This change in the environment had implications for the farming systems in terms of the exploited plant and animal species and their diversity (*Orton* et al. *2016; Ivanova* et al. *2018; de Vareilles* et al. *2022*). In addition to the environmental shift associated with geography, the expansion of the Neolithic across the central Balkans broadly coincided with the climatic 8.2 ky event (*Budja 2007; Krauß 2023; Vander Linden 2023*). The 8.2 ky event is the Holocene cold climatic event which peaked between approximately 6250BC and 6200 BC and ended before the start of the 6th millennium BC (*Weninger* et al. *2006; Pross* et al. *2009; Flohr* et al. *2016*). It was a period of colder climate broadly comparable to the historically recorded Little Ice Age (*cf. Fagan 2000*).

If the environment of the central Balkans presented new challenges to the first farmers, for intrinsic geographic reasons related to climate, specific conditions related to the 8.2 ky event, or both, it is possible that failure to establish permanent residence in some microregions occurred, with the net result being higher residential mobility. After two centuries, the sociocultural system adapted in such a way that settlements became more permanent, and therefore, less numerous in the archaeological record. This would account for the sudden drop of the SPD proxy at the end of the 7th millennium BC. The increase in the SPD curve from around 5800 BC and around 5600 BC would be due to population growth related to the Neolithic Demographic Transition.

It should be noted that this hypothesis is not in contradiction with the WoA standard model. The main difference lies in the mechanism of expansion. Whereas the WoA model assumes that the expansion occurs primarily because the surplus population diffuses over space, this hypothesis assumes that the Neolithic front is moving primarily due to high residential mobility, which may or may not be related to climate-induced factors.

The arguments in favor of this hypothesis (pros) are as follows:

❶ As both theoretical frameworks (*McGuire, Schiffer 1983*) and empirical data (*Binford 1990*) suggest, more mobile communities have lighter and less durable architecture. Again, this would account for the abovementioned difference in the Early Neolithic settlement architecture between southern and northern parts of the Balkans, where above-ground rectangular houses dominate in the south, extending approximately to southern parts of Serbia and Kosovo, whereas pithouses are the dominant architectural form north of this line.

❷ The idea that the first farmers were in exploration mode is consistent with the higher diversity of environments as reflected in the higher altitudinal variance of settlements in the pre-6000 BC period (*Porčić* et al. *2021a.Supplementary file 1*).

The main argument against this hypothesis (con) is that there is no apparent difference in the settlement size, layout and architecture between settlements founded before and after 6000 BC. For example, settlements consisting of pit-houses are present well into the 57th century BC, at sites such as Starčevo, Vinča-Belo Brdo, Jaričište and so on. If there was a shift to a more permanent settlement type, we would expect this to be reflected in the architecture as well. However, it should be emphasized that this absence of apparent evidence may be due more to less extensive (*i.e.* a small percentage of the total site area excavated) and less intensive (no Bayesian modelling of dates, no attempts at pottery seriation, or micromorphological studies) researchon most sites. Therefore, a way to test this hypothesis would include several lines of research:

❶ Targeted sampling for radiocarbon dating, specifically for Bayesian modelling to determine, as precisely as possible, the duration and continuity of the settlement occupations before and after ~6000 BC. Even though the number of radiocarbon dates is rather large for the central Balkans, they were mostly sampled for the SPD method, where the sampling design, with random sampling (see *Porčić* et al. *2021a*), is precisely the opposite of the one needed for Bayesian modelling.

❷ Micromorphological and geoarchaeological research of sediments to establish how settlements were used, in terms of permanence and continuity of habitation, for settlements before and after ~6000 BC.

❸ Bioarchaeological research using stable isotopes (*e.g.,* strontium, oxygen) to reconstruct the mobility patterns of humans and animals before and after ~6000 BC.

❹ Paleoclimatological research aimed at reconstructing environmental conditions in the central Balkans during the 8.2 ky event. As there are no climate proxies from the central Balkans itself, we can only extrapolate or interpolate climatic and environmental reconstructions from the surrounding proxies. However, we need to have more precise environmental reconstructions in order to evaluate the impact of the 8.2 ky event on early farming with more confidence.

Salvaging the standard model

This section may seem anticlimactic, as many words are spent in this paper criticizing the standard model. However, it seems appropriate to evaluate the ability of the standard model to resist criticism, *i.e.* to explore whether the potential cracks in the interpretative edifice can be patched.

Let us begin with the expansion speed. First of all, 1–1.3km/year is the continental average, and variability is expected and does occur at the regional level (*Bocquet-Appel* et al. *2012; Blagojević 2023*). However, the question persists: why was the expansion speedgreater in the central Balkans? Fort's modified WoA model with anisotropic expansion[5] might be an answer (*Fort 2020*). The differences in expansion speedbetween the mountainous and hilly lands south of Sava and Danube and the Pannonian plain to the north can be explained by a shift from anisotropic

5 Isotropic expansion refers to the case where all directions are equally probable for the migration, whereas anisotropic expansions refer to the case when one or several directions are preferred over others.

migration in the former region, to isotropic migration in the latter. As the main corridors for the expansion in the rugged terrain were valleys of rivers that flow in thesouth-north direction, this kind of topography channeled the demic diffusion of farmers, making the northern direction more probable than any other, and thus increasing the speed of the expansion. Once the farming front reached the plain, it slowed down as all directions became relatively equally probable for the expansion. This would explain both why the average speed is high (as most of the central Balkan region is mountainous or hilly) and it would also explain the difference in the expansion speed between regions south and north of the Danube and Sava rivers.[6]

When it comes to growth rates, the unusually high growth rate estimates can be explained by sampling bias.Even though the number of radiocarbon-dated sites from different parts of the central Balkans is representative in relation to the number of Early Neolithic sites in different regions of the central Balkans (see *Porčić* et al. *2021a.Supplementary file 1*), the distribution of archaeologically recorded (dated or not) sites between regions may be biased due to modern regional differences in economy and research intensity (*cf. Palmisano* et al. *2021*). It could be argued that, as southern Serbia and Kosovo were among the poorest regions in ex-Yugoslavia, the intensity of research was lower, so the overall number of discovered sites was lower. If we are systematically missing the earliest part of the population growth curve, *i.e.* if we have a spatio-temporally biased sample, then our estimate of the growth rate will also be biased. The dates from the southern parts of the study area contribute most to the SPD demographic proxy curve in the earliest times of Neolithic expansion. As the frequency of these dates will be lower than in reality due to regional sampling bias, the increase of the SPD curve will appear sharper than it is, leading to higher growth rate estimates. This is one possible explanation for the unusually high growth rate estimates reported in Blagojević *et al*. (*2024*).

As new data become available, they seem to fill the blanks which led to doubts about the standard interpretation based on the WoA model. For example, one of the important reasons for the mistrust in the standard interpretation was the lack of reliable pre-6200 BC dates in North Macedonia (see the discussion in *Porčić* et al. *2020*). However, with the discovery and dating of the site of Vlaho (*Naumov* et al. *2023*), located in the southernmost part of North Macedonia, a gap was filled between the oldest dates in Greece, from sites such as Mavropigi, Revenia-Korinos and Paliambela (*Karamitrou-Mentessidi* et al. *2013; Maniatis 2014; Reingruber 2020; Tsartsidou, Kotsakis 2020; Urem-Kotsou, Kotsos 2020; Maniatis, Adaktylou 2021*), and Serbia.

When it comes to the puzzling decrease of the SPD proxy curve after 6050 BC, it can indeed be due to a population decrease. Demographic boom and bust patterns have been observed in almost all parts of Europe in the Neolithic (*Shennan* et al. *2013; Timpson* et al. *2014*), and recent research suggests that violent conflicts, triggered by high population density and competition for resources, might have caused the bust episodes (*Kondor* et al. *2023*). Currently, there is insufficient material (human skeletons or extensively excavated settlements) from the 6000–5800 BC period in the central Balkans to evaluate this hypothesis.

Cultural evolutionary theory suggests that a population decrease should result in the reduced stylistic diversity of the material culture (*Neiman 1995; Rorabaugh 2014*) and a significant change in style after the population bottleneck (*Shennan 2000*). A study by Nenad Tasić (*2009*) suggests that there was a temporal discontinuity of painted pottery styles after ~5800 BC in the central Balkans. This observation is consistent with the demographic interpretation of the SPD curve (*i.e.* a population crash), but it should be tested more rigorously with quantified data on pottery variability, including all pottery types, not just painted pottery, which is scarce.

Conclusion

This paper has summarized the available evidence and critically reflected on the proposed interpretations related to the onset of the Neolithic period in the central Balkans. The data support a version of the WoA model, but there is still room for other hypotheses. These hypotheses are elaborated here and means of their test-

6 The simulation in Porčić *et al*. (*2021b*) does take the topography into account, so directional expansion is effectively taking place in the simulation, yet it still returns a high total fertility rate. It is possible though that the settlement threshold was in reality much higher than allowed for in our simulations, meaning that farmers were more demanding when it came to choosing their settlement locations than we allowed for. This would increase the speed of expansion without the need to increase the fertility and growth rates.

ing are proposed. The fact that we are still left with uncertainties and questions, despite a large quantity of empirical data amassed in the last decade, highlights how complex the Neolithisation process was. In other words, more research is needed before we reach a full (or adequate) understanding of the historical events and processes which unfolded at the end of the 7th millennium BC in the central Balkans. Fortunately, the road ahead does not seem too long, as all hypotheses and questions discussed in this paper are within the reach of modern archaeological methods.

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Beyond the sum: evaluating the potential and limitations of analysing Neolithic population dynamics based on fluctuations in radiocarbon dates and sites (Scheldt basin, Northern France and Belgium)

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ABSTRACT - *This study presents a multiproxy palaeodemographic perspective by combining radiocarbon dates with counts of archaeological site phases in the western Scheldt basin, spanning from the beginning of the Neolithic to the Early Bronze Age. The results were assessed critically, accounting for differences in research methodology, soil conditions and changes in building traditions. The results indicate a dynamic region characterized by almost continual growth. Moreover, two distinct sub-regions of the basin could be compared, thereby elucidating the sub-regional differences. It is clear that palaeodemographic studies are only feasible when a multiproxy analysis is used on a detailed, highly scrutinized dataset.*

KEY WORDS – *radiocarbon data; site count data; palaeodemographical dynamics; Neolithic period; Bronze Age*

Onkraj vsote: vrednotenje potenciala in omejitev analiz neolitskih populacijskih dinamik na osnovi fluktuacije radiokarbonskih datumov in najdišč (povodje Scheldt, severna Francija in Belgija)

IZVLEČEK – *Študija predstavlja večplastno projekcijo glede na kombinacijo radiokarbonskih datumov in števila faz na arheoloških najdišč v zahodnem povodju reke Scheldt, ki segajo od začetka neolitika do zgodnje bronaste dobe. Rezutati so bili kritično vrednoteni glede na razlike v raziskovalni metodologiji, vrste tal in spremembah v gradbenih tradicijah. Ti kažejo dinamično regijo s skoraj stalno demografsko rastjo. V porečju bi lahko primerjali dve podregiji in tako pojasnili regionalne razlike. Jasno je, da so paleodemografske študije izvedljive samo z uporabo večplastne analize na detajlnem in natančno preverjenem naboru podatkov.*

KLJUČNE BESEDE – *radiokarbonski datumi; podatki o najdišču; paleodemografske dinamike; neolitik; bronasta doba*

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Introduction

Studies examining population dynamics during the prehistoric period have proliferated in recent decades. The utilization of summed probability distributions of radiocarbon dates (SPD) has emerged as a standard method for reconstructing palaeodemography, as evidenced by numerous studies (*Riede 2009; Shennan 2013; Crema* et al. *2016; Bevan* et al. *2017; McLaughlin 2019; Lawrence* et al. *2021; Palmisano* et al. *2021a*). Early criticisms highlighting potential sources of bias – *e.g.,* Val Attenbrow and Peter Hiscock (*2015*), Jesse A. M. Ballenger and Jonathan B. Mabry (*2011*), Alex Bayliss *et al.* (*2007*), Lorena Becerra-Valdivia *et al.* (*2020*), Daniel A. Contreras and John Meadows (*2014*), Philippe Crombé and Erick Robinson (*2014*), Danuta J. Michczyńska and Anna Pazdur (*2004*), Mike Smith (*2016*), James Steele (*2010*), Todd A. Surovell and Jeffrey P. Brantingham (*2007*), Tobias Torfing (*2015b*), and Alan N. Williams (*2012*) – prompted numerous improvements to the method, *e.g.,* Contreras and Meadows (*2014*), Enrico R. Crema and Shinya Shoda (*2021*), Martin Hinz (*2020*), Adrian Timpson, Katie Manning and Stephen Shennan (*2015*), and Torfing (*2015a*; *2015b*). Furthermore, these refinements increasingly involve a multiproxy approach to address methodological limitations and validate perceived trends (*e.g., Williams 2012; Crombé*, *Robinson 2014; Feeser* et al. *2019; Crema*, *Kobayashi 2020; Robinson* et al. *2020; Tallavaara*, *Pesonen 2020; Bergsvik* et al. *2021; Edinborough* et al. *2021; Lawrence* et al. *2021; Palmisano* et al. *2021a*). For a comprehensive review of the method, we direct readers to Crema (*2022*).

Considerable attention has been devoted to examining demographic shifts during the transition from Mesolithic hunter-gatherer communities to Neolithic farming communities – the ‘Neolithisation process’ – and subsequent dynamics during the Neolithic Period (*Gkiasta* et al. *2003; Shennan*, *Edinborough 2007; Riede 2009; Shennan 2009; Collard* et al. *2010; Shennan* et al. *2013; Edinborough* et al. *2021; Palmisano* et al. *2021a*). Some common trends are observed across many of these studies: a continuous decline in population during the Mesolithic, a significant population surge following the introduction of agriculture and the emergence of the first Neolithic groups, *i.e.* the Linearbandkeramik (LBK) in the European loess area and the Funnel Beaker culture (TRB) in the NW European Plain, respectively around the middle of the 6th millennium BCE and beginning of the 4rd millennium cal BCE. This is followed by a swift and significant decline during the Middle Neolithic, persisting until the onset of the Late/Final Neolithic around the middle of the 4th millennium BCE. This observed pattern is discernible in various regions across N(W) Europe, including Denmark, England, Poland, Germany, and Norway, among others (*Shennan 2013; Bevan* et al. *2017; Nielsen* et al. *2019; Tallavaara*, *Pesonen 2020; Bergsvik* et al. *2021; Kolář* et al. *2022*).

However, there is often insufficient consideration given to potential biasing factors such as site taphonomy, changing settlement organization, and building traditions, and variations in research foci and methodology. In this study, we aim to scrutinize radiocarbon evidence alongside data on Neolithic site densities from the western Scheldt (Belgium) basin to assess the reliability of the commonly utilized ‘dates as data’ approach (*Rick 1987*).

Geographical setting

The western Scheldt basin spans around 15 200km^2 in Western Belgium and Northern France, and is positioned at the western periphery of the NW-European coversand plain and the Central-European loess belt (Fig. 1). The Scheldt basin comprises two distinct subregions: the Lower Scheldt basin, situated in NW Belgium, characterized by a lowland dune landscape, and the Upper Scheldt basin, located in Western Belgium and Northern France, exhibiting more pronounced topography with hills rising up to 165m above sea level and deep river valleys. Additionally, the pedological characteristics differ between the two regions. While the Lower Scheldt basin is typified by sandy topsoils, the Upper Scheldt basin is predominantly covered by (sandy-)loess. The western Scheldt basin encompasses the valleys of the Scheldt River and several of its tributaries, such as the Lys, Dender, Rupel and Kale/Durme.

This area boasts a rich history characterized by extensive archaeological survey by means of arial photography, field-walking and trial-trenching, and large-scale excavation projects (*Crombé*, *Vanmontfort 2007; De Clercq* et al. *2012*). Over the past two decades, the advent of developer-led archaeology, particularly in the Lower Scheldt region and northern France, has significantly augmented the database. These initiatives were not driven by specific research agendas but rather by infrastructure projects. However, it is important to note that the database may not be entirely unbiased, as certain phases of the Neolithic have received more intensive and targeted research attention than others. For instance, considerable focus has been directed towards the LBK and Blicquy culture (BQY) settlements of the Early Neolithic (*Jadin 2003*), the flint mines spanning the Middle to Late Neolithic (*Collet* et al. *2016*) and the barrows from the Final Neolithic to the Middle Bronze Age (*Bourgeois* et al. *1998; De Reu, Bourgeois 2013*). In this paper we will explore these biases, examining their potential impact on the radiocarbon and site evidence.

Materials and methods

Sampling

All dates were manually gathered from published sources or online databases, including the Radiocarbon Laboratories of the Royal Institute for Cultural Heritage in Brussels (http://c14.kikirpa.be/, and http://radiocarbon.kikirpa.be/) as well as Louvain-la-Neuve (*Gilot 1997*). Additionally, data were sourced from archaeological excavation reports and personal communications.

Similarly, information on sites and their respective phases were compiled from published databases, online repositories managed by government entities (CAI for the Flemish part of the study area) and excavation reports from private archaeological companies. Detailed inventories of sites pertaining to specific time periods or site categories have already been established. For instance, Ivan Jadin (*2003*) concentrated on the Early Neolithic, while Bart Vanmontfort (*2004*) summarized sites associated with the Michelsberg culture from the Middle Neolithic period. Monuments from the Late Neolithic to Bronze Age, particularly barrows, have been extensively documented by Carole Ampe *et al.* (*1995*), Jean Bourgeois, Marck Meganck and Jacques Semey (*1998*), Bourgeois *et al.* (*1999*) and Jeroen De Reu and Jean Bourgeois (*2013*).

Radiocarbon dates

The radiocarbon database underwent screening procedures based on the methodology detailed in Elliot Van Maldegem *et al.* (*2021*), which itself was adjusted from Paul Barry Pettitt *et al.* (*2003*). The screening process involved the exclusion of samples exhibiting excessively wide chronological ranges (>100years, referred to as legacy dates), contaminated samples (as determined by the original source or researchers), improperly cremated bones (which would skew results) and undetermined wood (which could be influenced by old-wood effect). In addition dates that could not be securely attributed to human activities were excluded

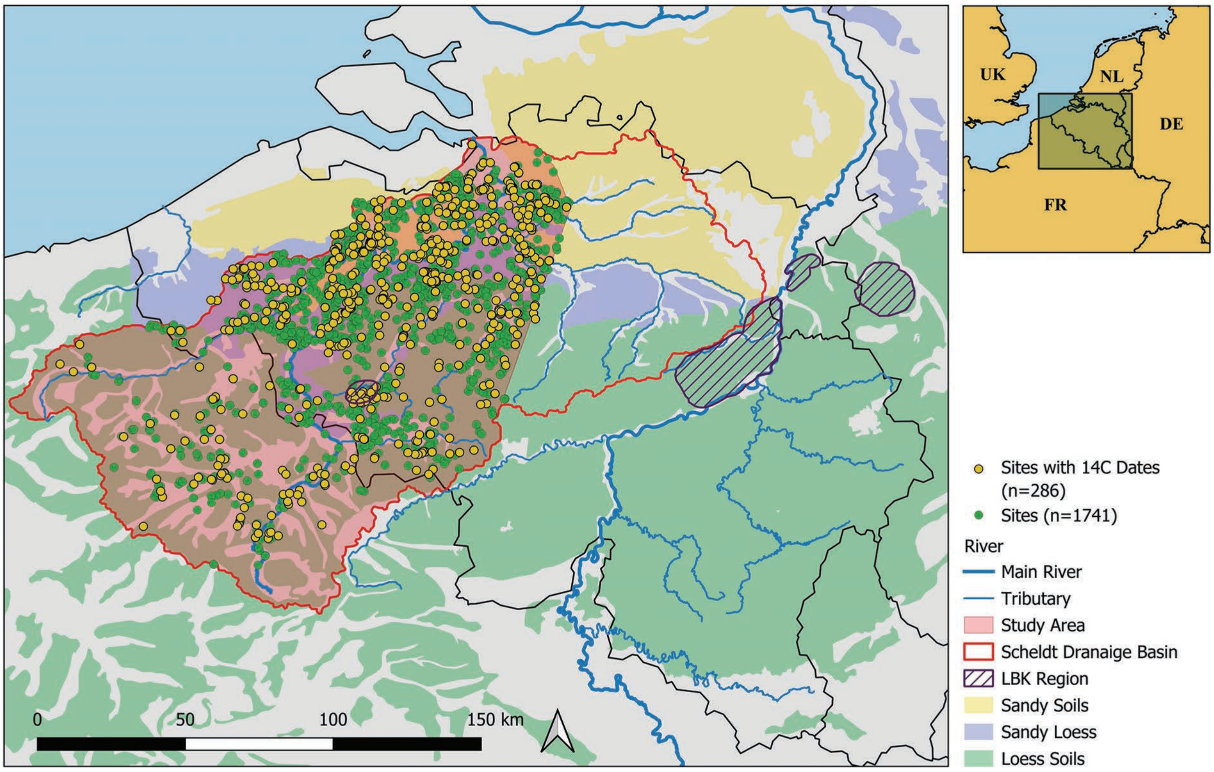

Fig. 1. Map of the study area with a geographic spread of the archaeological sites displaying radiocarbon dates and archaeological site phases. Dominant soil type (*Panagos et al.* 2022), LKB region adapted after Marc Lodewijck (*2009*).

from the database. This was based on an objective scoring system, where a score between one and three was given in four categories: dating material, context, dating method and precision. Twice the weight was given to material and context to ensure that the resulting SPD reflects human activity as accurately as possible. Applying this scoring system, the maximum score a date could receive was 18. It was decided that a score of 15 or more was sufficient to be included. The majority of the dates were performed on samples of charcoal, followed by bone (both cremated and unburnt), hazelnut shells and seeds. No dates on marine resources are included in the database (Tab. 1). This implies that modelling was done only on samples with a small inbuilt age.

A total of 1616 dates (Mean Standard Deviation = 43.20), originating from 286 sites, spanning from 9500 to 2700 uncal BP, were gathered from the study area. This range is broader than the period addressed in this paper, encompassing the Neolithic era and extending from the Late Mesolithic to the Bronze Age, spanning approximately from *c.* 6600 to 1400 cal BCE, to accommodate for edge-effects. After critical filtering of the database, 1276 dates were retained (Mean Standard Deviation = 37.20) from 241 sites. Given the relatively small size of the study area, homogeneity in taphonomic processes – and therefore losses – as well as dating strategies can be assumed, which together facilitate control over this potential bias and enable comparisons across different subregions within the study area (*Williams 2012; Timpson* et al. *2014; Crema 2022*). This smaller scale offers an opportunity to investigate inter-regional differences in population dynamics, which might be obscured in larger areas (*Waddington*, *Wicks 2017*). Analyses were conducted using the rcarbon package (v. 1.5.1) (*Crema*, *Bevan 2021*) within the RStudio environment (*RStudio Team 2020*) utilizing R (v. 4.3.1) (*R Core Team 2023*) with the Intcal20 calibration curve (*Reimer* et al. *2020*).

The impact of oversampling specific site-phases was addressed by combining uncalibrated dates within *h years* of each other in bins and subsequently dividing them by the number of dates within this bin. Through sensitivity analyses utilizing the binPrep function in rcarbon and visually evaluating the resulting summed probability distributions (SPDs) with *h cut-off* values ranging from 50 to 200 years, we determined an h value of 100 years to be optimal, resulting in 619 bins. Additionally, to minimize the influence and noise stemming from spurious fluctuations caused by the calibration curve, a rolling mean of 200 years was implemented, as proposed by Timpson *et al.* (*2014*) (Fig. 2).

We utilized both Monte-Carlo simulation methods (MC Method), initially proposed by Shennan *et al.* (*2013*), further refined by Timpson *et al*. (*2014*) and implemented by Crema *et al*. (*2016*), as well as Kernal Density Estimations (KDE) (*Bronk Ramsey 2017; Feeser* et al. *2019; McLaughlin 2019*).

Three models were fitted: a logistic model, an exponential model and a composite logistic-exponential model. The logistic model operates under the assumption of diminishing growth as the population nears its maximum carrying capacity. Deviations above the confidence interval indicate growth surpassing the carrying capacity, constituting overshoot. Such overshoot renders the population vulnerable, particularly in conjunction with climatic downturns, which could lead to dramatic consequences. Dan Lawrence *et al*. (*2021*) note that even in the absence of climatic downturns, such situations may prove unsustainable. In contrast, the exponential model assumes continuous exponential growth while also accounting for taphonomic loss over time (*Surovell*, *Brantingham 2007; Palmisano* et al. *2021b*). Lastly, a composite logistic-exponential model was fitted. Assuming logistic growth until 5300 cal BCE (marking the onset of the Neolithic period within the study area) and exponential growth until the end of the Bronze Age. This approach aims to capture the significant impact of transitioning from a hunter-gatherer lifestyle to agriculture on population growth momentum (for an illustration of fitting two types of models to a single dataset, we refer to Manuel Arroyo-Kalin and Philip Riris (*2021*)). As each model has distinct null hypotheses, we present them concurrently for comparison (Fig. 3).

The KDE approach offers the advantage of smoothing calibration noise and capturing the uncertainty associated with oversampling individual site phases. This

Material Category	Number of Dates
Charcoal	611
Cremated Bone	283
Hazelnut Shell	211
Bone	204
Organic Remains	181
Ceramics	94
Charred Organic Remains	15
Other	14

Tab. 1. Amount of dates per material category.

approach entails constructing a KDE by randomly sampling calendar dates from the probability density distribution of calibrated radiocarbon bins, followed by estimating a Gaussian kernel density using an optimal kernel bandwidth, set at 30 in this study (*cf. McLaughlin 2019; Seidensticker* et al. *2021*). This process was iterated 1000 times to generate 95% confidence interval (*Crema, Bevan 2021*). A narrower confidence interval indicates a higher likelihood that the pattern accurately reflects reality. The KDE was generated 1000 times and is visualized over the MCMC model (Fig. 4).

To account for spatial variations in the density of radiocarbon dates, stemming from variations in sampling strategies or population dynamics, a mark permutation test was implemented using the permTest function in the rcarbon package (Fig. 5). This test involved separately comparing the SPDs from the Upper and Lower Scheldt basin regions with confidence intervals derived from the SPD of the entire study area. This approach generates a 95% confidence interval by reshuffling the labels that identify the region of origin for each date or bin, thereby generating n SPDs, and in this study we iterated this process 1000 times. The width of the confidence interval is proportional to the amount of bins in each region. Positive and negative deviations from this confidence interval, indicating population increases or decreases bigger or smaller than the general trend of the entire Scheldt region, are marked in red and blue, respectively, similar to the theoretical null model (as described earlier) (*Crema, Bevan 2021*). Additionally, an exponential model was fitted to each of the subregions following the methods outlined previously (*cf.* supra) (Fig. 6).

Site counts

As an additional proxy for changes in population and human activity, we employed site counts. Raw counts of archaeological sites are one of the most common proxies for reconstructing regional population dynamics (*Drennan* et al. *2015; Lawrence* et al. *2021*), and are independent of radiocarbon dates. Site phase counts offer an added advantage as they can encompass various types of data, such as from excavations, surveys, aerial photography, and so on. Unlike SPDs, which rely on radiocarbon dates usually obtained from excavated sites, site counts provide a broader perspective on archaeological activity across different methodologies.

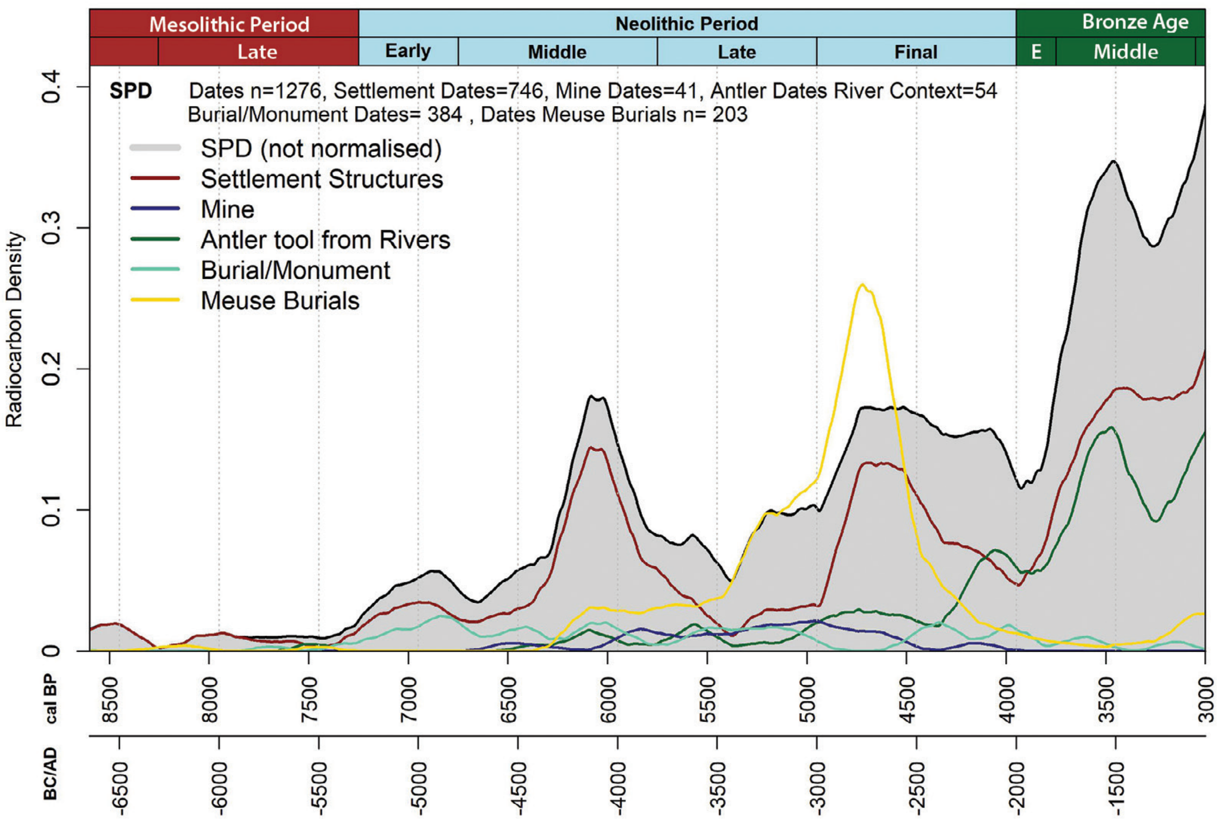

Fig. 2. Summed Probability Distribution of all retained radiocarbon dates, settlement structures, mines, antler tools from river contexts, burials/monuments and burials from the Meuse basin.

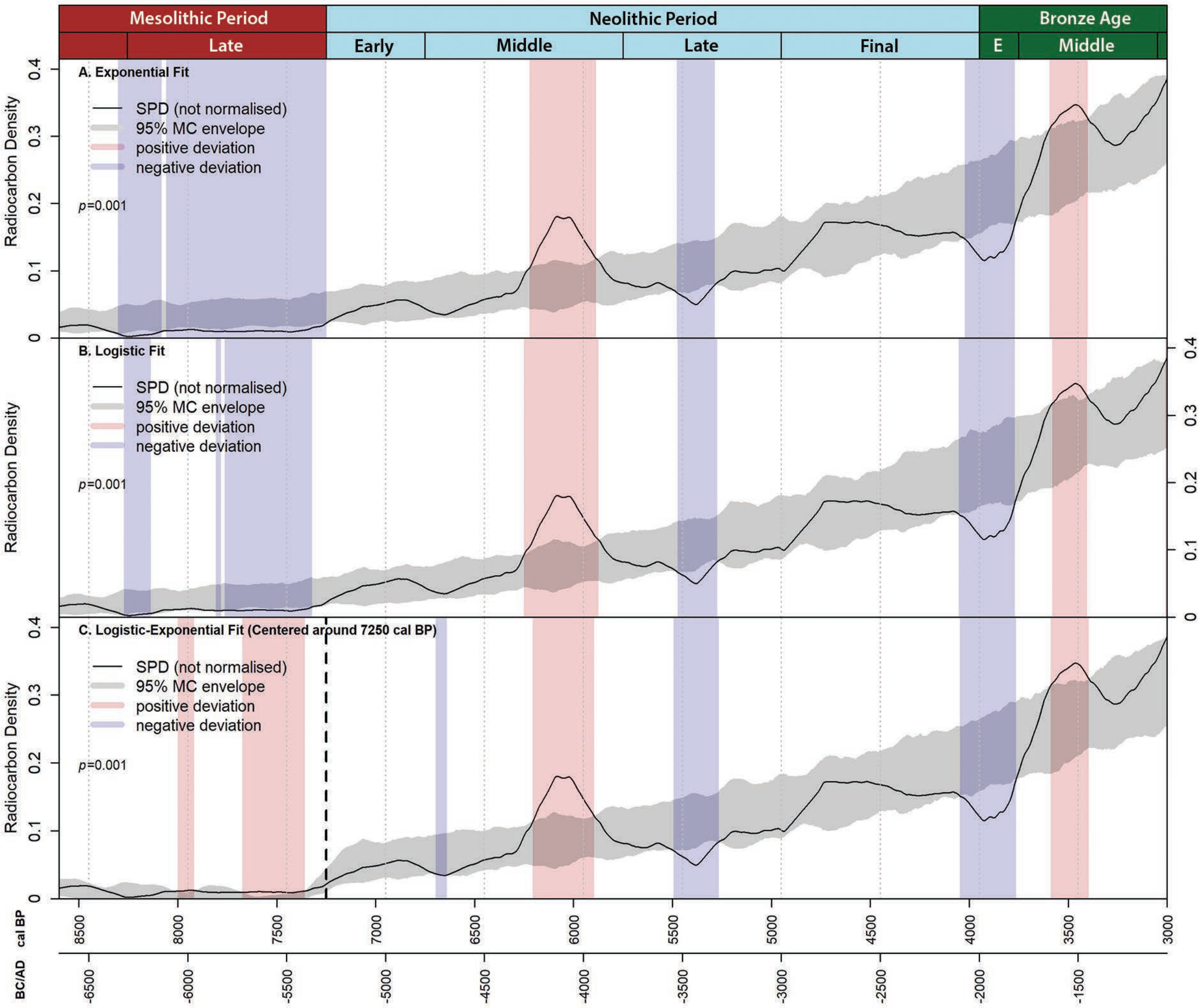

Fig. 3. Comparison between the different null models applied on the dataset. **A** ***Exponential Model,*** **B** ***Logistic model,*** **C** ***model with a logistic fit until the end of the Mesolithic (*****c.** ***5300 cal BCE) followed by a model with an exponential fit.***

We compiled all site phases between approximately 6600 to 1100 cal BCE, although a wider chronological scope (*c.* 9500 to 2700 uncal BP) was covered to avoid edge effects. An extensive dataset was assembled through the manual compilation of excavation and survey reports, published research and the online SMR-database of *Agentschap Onroerend Erfgoed* (CAI) (*Onroerend Erfgoed 2021*). The Mesolithic period has already been discussed in an earlier study (*Van Maldegem* et al. *2021*). The dataset encompasses a total of 2293 site phases from 1741 sites. In order to better reconstruct short-term changes, we opted to eliminate site phases that were inaccurately dated and often encompassed entire archaeological periods, such as the Mesolithic to Neolithic. These phases typically comprised loose finds of uncertain provenance and were therefore excluded from the dataset. They are referred to as 'General Periods' in the figures (Figs. 4 and 7).

The archaeological site phases have been binned into time intervals of 200 years. If a site would fall in multiple bins, it is counted for all respective bins in raw counts. Since not all archaeological phases have equal durations (*e.g.,* the Final Neolithic spans approximately 1000 years while the Early Bronze Age covers only about 200 years), raw counts may exhibit bias toward longer phases. To address this, aoristic approaches were applied, following the methods outlined by Alessio Palmisano *et al.* (*2017; 2019; 2021a; 2021b*), also employed by Lawrence *et al.* (*2021*). Aoristic methodologies operate under the assumption that the total probability of an archaeological event occurring is 1. This probability is then distributed across the number of temporal bins covered by the site phase, reflecting the likelihood of the event occurring within the time interval of each bin. There is no consensus regarding the size of the bins used, while Palmisano *et al.* (*2017*)

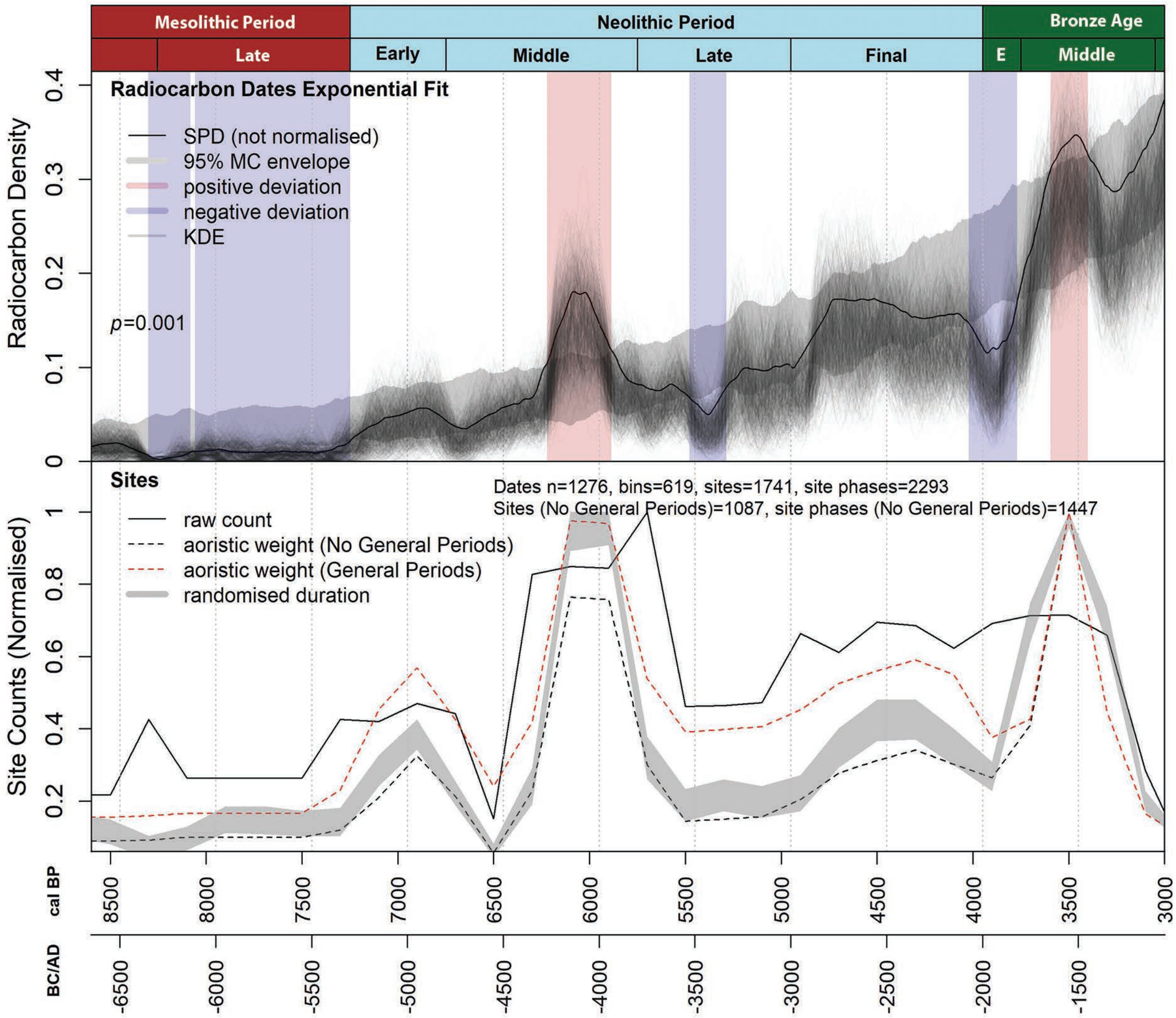

Fig. 4. Top: Exponential null model fitted on the SPD of the Scheldt basin with a multiplot of the KDE overlain. Bottom: Comparison of all site data proxies: raw counts of site phases, aoristic sum of site phases, aoristic sum of the site phases with general periods and randomized duration of site phases. All values have been normalized between 0 and 1.

employ bin sizes of 200 years, Lawrence *et al*. (*2021*) use 100 years. We have chosen to adopt 200-year bins to ensure that each site phase is given equal weight.

MC Methods were used to generate randomized start and end dates for site phases (*Palmisano* et al. *2017*). This approach helps mitigate the uncertainties arising from long archaeological periods. Occupational phases did not likely persist throughout entire archaeological periods continuously. The MC Methods correct for the disparity between the durations of archaeological periods and the realistic duration of the site occupation phases. To achieve this, the duration of the site phase was assumed to be uniformly distributed. Start dates were then randomly sampled from these distributions. The duration itself was randomized, assuming a mean occupation length following a normal distribution of 200 years and a standard deviation of 50 years. This was repeated 1000 times to generate a 95% confidence envelope. A wider envelope indicates greater uncertainty in the reconstruction.

Palmisano *et al*. (*2017; 2019; 2021a; 2021b*) and Lawrence *et al*. (*2021*) use the area of archaeological sites to infer demographic trends alongside the raw and aoristic counts. However, we have chosen not to adopt this approach due to the nature of excavations within our study area, which are primarily conducted through developer-led archaeology. Consequently, these excavations are constrained by project size and funding limitations. Similarly, survey sizes are often determined by the size of a field and do not necessarily represent complete sites or settlements. Using area counts would therefore yield a distorted representation.

Results

Radiocarbon dates

Scheldt basin

The results of the SPD analysis and the null model hypotheses are shown in Figures 2 and 3. The SPD of radiocarbon dates exhibits significant deviations from the null models (p-values<.01). The initial negative deviations between *c.* 6350 and 5300 cal BCE, coinciding with the transition from the Middle to the Late Mesolithic, has already been discussed in previously published research (*Van Maldegem* et al. *2021*). Following this, there is a marginal upturn during the Early Neolithic period (*c.* 5300–4800 cal BCE), although this

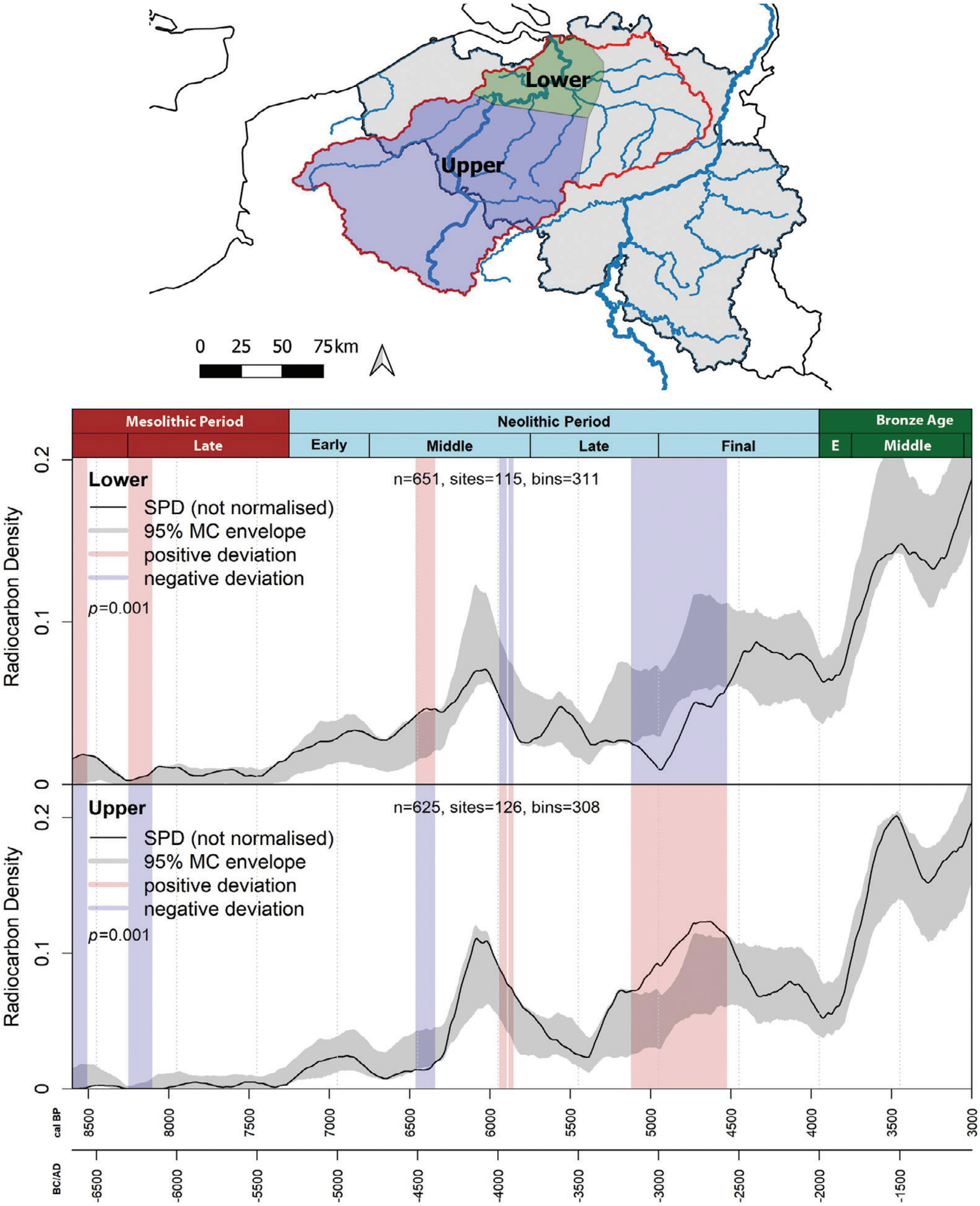

Fig. 5. Top: Map of the study area with the delineation of the upper and lower Scheldt basin. Bottom: Results of the permutation test comparing the SPDs of the upper and lower Scheldt basins.

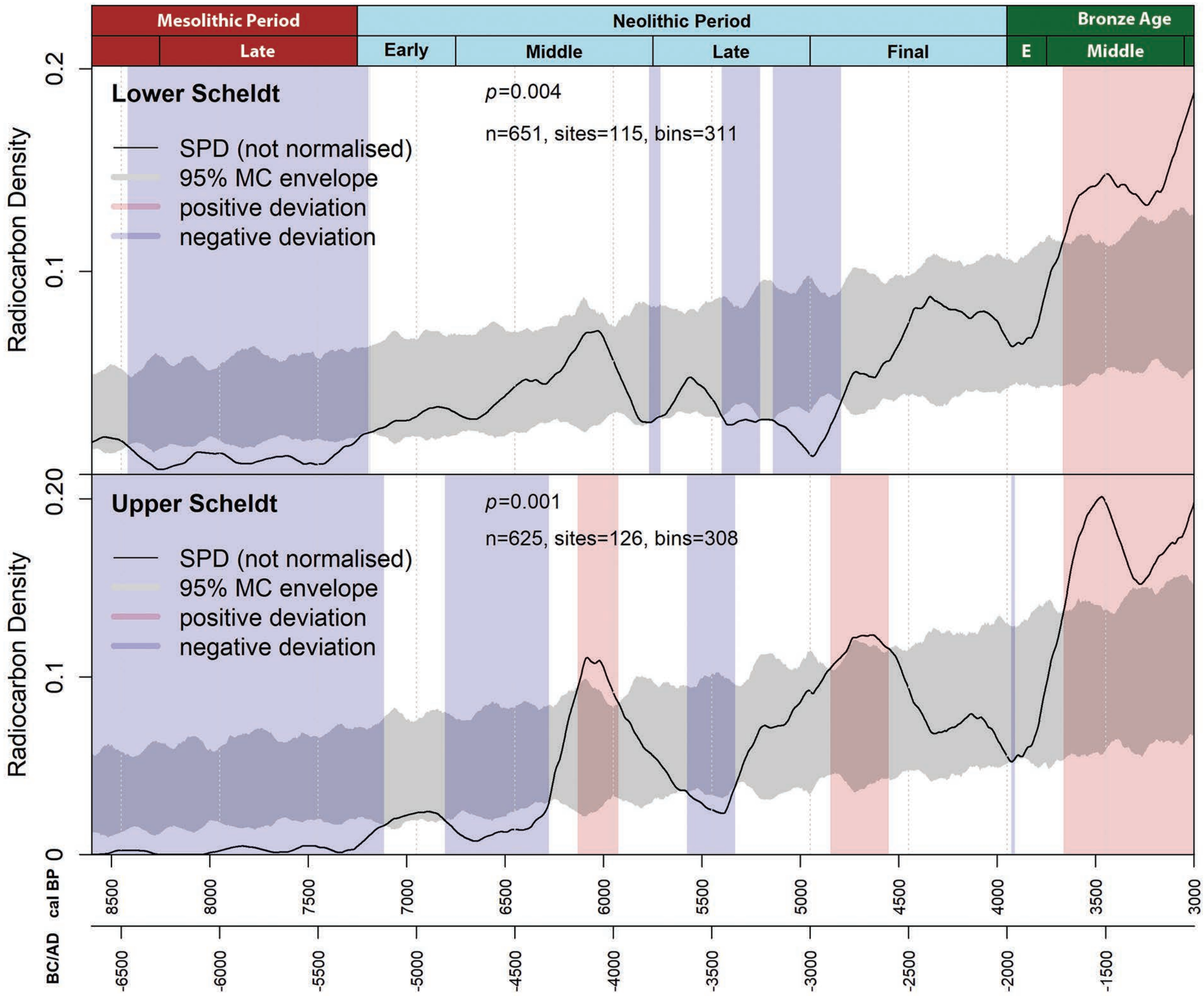

Fig. 6. Top: Exponential null model fitted on the SPD of the lower Scheldt basin. Bottom: Exponential null model fitted on the SPD of the upper Scheldt basin.

is not a significant deviation. However, this peak is short-lived, giving way to a slight decline after 4800 cal BCE, corresponding to the first half of the Middle Neolithic or post-LBK phase.

The second half of the Middle Neolithic sees a steep increase in radiocarbon dates with a larger growth than expected between *c.* 4300 and 3900 cal BCE. At the end of this period, around 3800 cal BCE, there is a reduction in radiocarbon density which culminates in a significant decline between *c.* 3530 and 3330 cal BCE during the Late Neolithic.

During the second half of the Late Neolithic, from *c.* 3350 cal BCE onwards, and particularly the Final Neolithic in the third millennium BCE there is again a slight rise in radiocarbon date densities. Yet again, this does not constitute a significant deviation from the null model. Coinciding with the start of the Early Bronze Age the curve drops significantly below the null model between *c.* 2070 and 1820 cal BCE. After this a steep growth in the curve is evident throughout the first half of the Middle Bronze Age between *c.* 1650 and 1450 cal BCE.

Subregions

The differences between the Upper and Lower Scheldt basins are illustrated in the regional mark permutation tests (Fig. 5) particularly focusing on the Late Mesolithic, the latter half of the Early Neolithic and the latter half of the Late Neolithic.

The results of the SPD analyses of the sub-regions are shown in Figure 6. Although broadly similar, there are notable distinctions between the two sub-regions of the Scheldt basin. In the Upper Scheldt basin, the Late Mesolithic is characterized by sparse dating, with almost no dates recorded between *c.* 6550 and 5240 cal BCE. This is followed by a slight increase during the Early Neolithic, before dropping below the null model

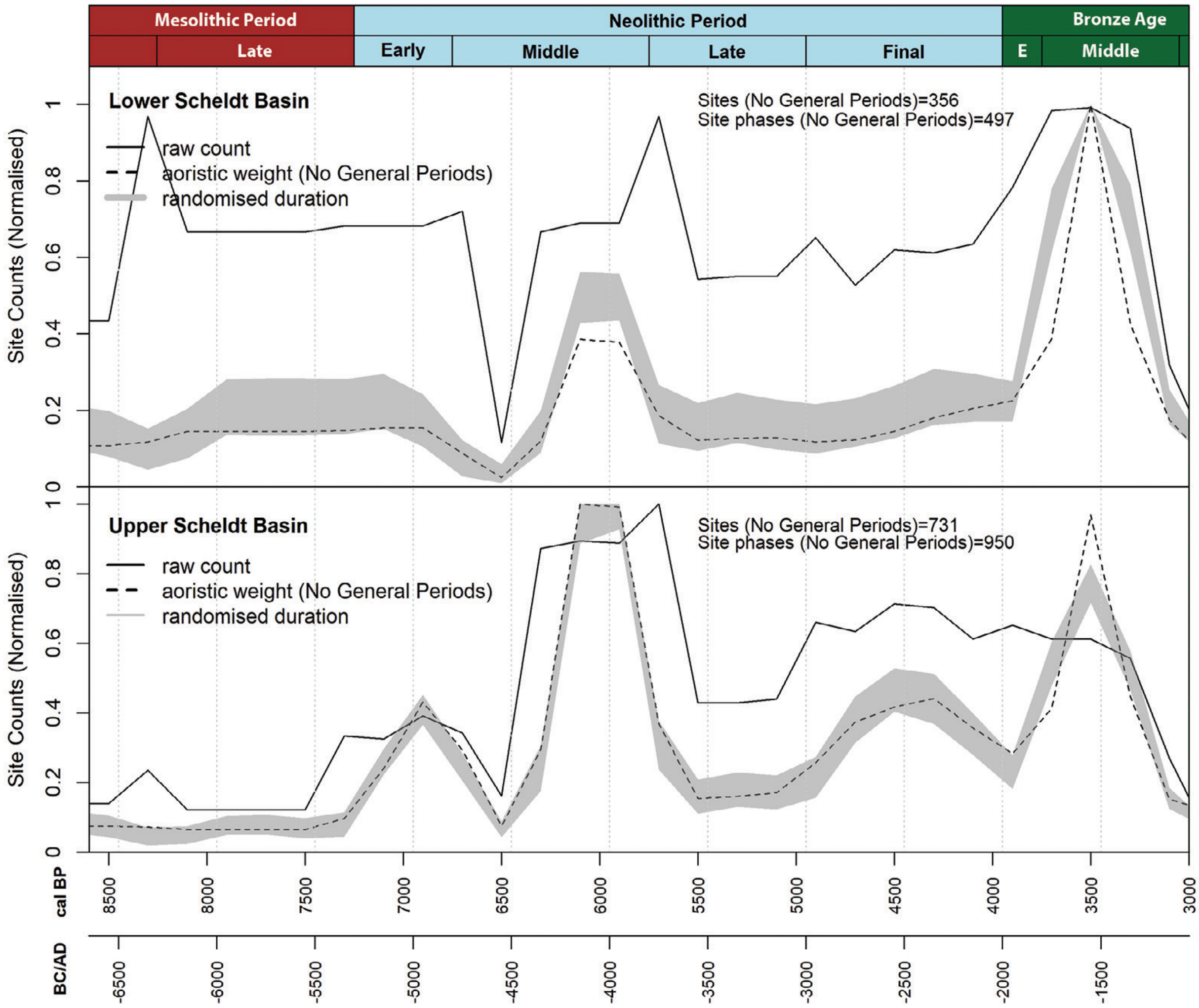

Fig. 7. Comparison of all site data proxies between the two sub-regions. Top: lower Scheldt basin. Bottom: upper Scheldt basin.

again between *c.* 4790 and 4410 cal BCE. Subsequently, the Upper Scheldt basin follows the overall regional trend, falling below the null model between around 3600 and 3400 cal BCE, slightly preceding the Lower Scheldt. During the Final Neolithic the curve significantly exceeds the null model between *c.* 2800 and 2600 cal BCE before reverting to follow the general declining trend.

In contrast, the Lower Scheldt basin exhibits higher densities in the Late Mesolithic. Unlike the Upper Scheldt, there is a gradual increase of dates from *c.* 5500 cal BCE onwards, culminating in a peak between 4305 and 3990 cal BCE, albeit not a significant one. However, this peak initiates slightly earlier than in the Upper Scheldt basin and the entire Scheldt basin, and also concludes slightly earlier. Moreover, the lowest densities of radiocarbon dates occur later than in the Upper Scheldt basin, between *c.* 3175 and 2800 cal BCE, coinciding with a period of growth exceeding the null model in the Upper Scheldt region. During the second half of the Final Neolithic period, while the Scheldt basin and the Upper Scheldt basin exhibit a gentle downward trend, the Lower Scheldt basin experiences a slight rise. At the start of the Early Bronze Age the trend declines in step with both other regions, albeit with a less pronounced trough compared to the Upper Scheldt.

Site counts

Scheldt basin

The results of the site count analyses are shown in Figure 4. The raw counts and aoristic weight differ greatly for the Neolithic Period. This is partly due to poorly refined chronologies during this period, with the subphases spanning longer periods, as well as due to the difficulty in assigning sites to a specific subphase. Sites discovered through field-walking prospections, or smaller sites with fewer distinct cultural markers, are dated more broadly such as 'Middle-Final Neolithic'.

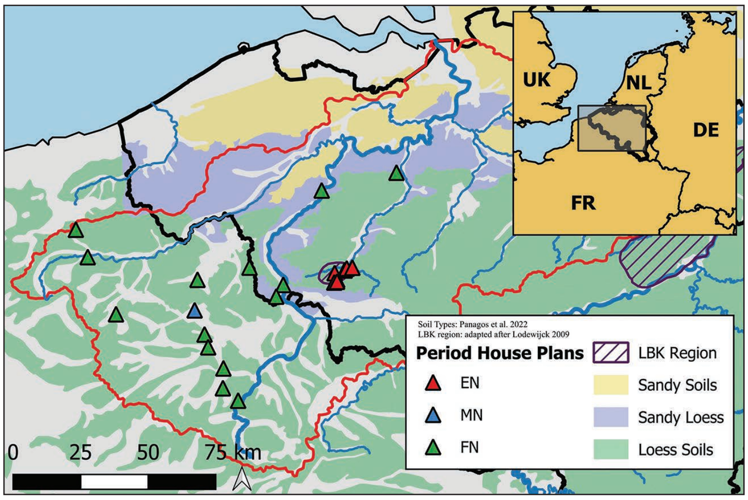

*Fig. 8. Map of the study area with a geographic spread of the archaeological sites displaying radiocarbon dates and archaeological site phases. Dominant soil type (*Panagos et al. 2022*), LKB region (adapted after Lodewijck (*2009*)).*

Raw counts are therefore an overestimation, while aoristic weights likely offer a more accurate representation.

Overall there is a good correspondence between the SPD and the site counts. The latter exhibits four prominent peaks mirroring those observed in the SPD: 1° *c.* 5300–4800 cal BCE; 2° *c.* 4300– 3800 cal BCE; 3° *c.* 2700–2300 cal BCE and 4° *c.* 1600–1400 cal BCE.

Subregions
The results of the site count analyses of the subregions are shown in Figure 7. The curve for the Upper Scheldt region closely resembles that of the entire Scheldt basin, with only minor discrepancies observed. These include a slightly earlier onset of the peak in the Final Neolithic and a more pronounced trough in the latter part of the Final Neolithic and Early Bronze Age.

Conversely, the Lower Scheldt region diverges from both the Upper Scheldt region and the overall study area during several key periods. Notably, the peak in the Early Neolithic, present in the Upper Scheldt, is nearly absent in the Lower Scheldt, and a decline in sites during the initial phase of the Middle Neolithic is evident. Although the peak during the latter part of the Middle Neolithic is less pronounced in the Lower Scheldt region, it is still observable. The trough after this peak aligns with the troughs in the Upper Scheldt, but extends over a longer period, as the peak in the Final Neolithic is absent. Consequently, the trough in the Early Bronze Age is also absent.

Comparison of the different proxies
We used Spearman rank-order correlations to examine the relationship between various datasets (Tabs. 2–6). Several methods exhibit strong correlations, although somewhat less so between SPDs and raw counts, but still significant in the Scheldt and Upper Scheldt basins. As mentioned earlier, this discrepancy is likely attributed to the less refined chronologies and the incorporation of field walking surveys. Aoristic counts therefore seem to be the more robust method for this period.

Discussion

Early Neolithic (5300–4650 cal BCE)
The peak in both site counts and radiocarbon dates during the Early Neolithic, only present in the Upper Scheldt basin, coincides with the arrival of the LBK, and the subsequent BQY (*Van Berg, Hauzeur 2001;*

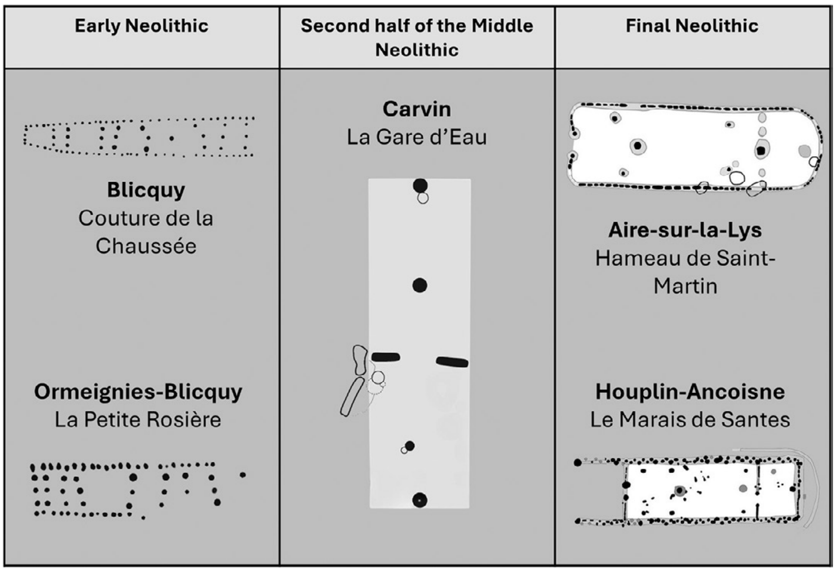

*Fig. 9. Examples for each archaeological period for which house plans are known (adapted from Cahen, Van Berg (*1979*), Claude Constantin, Isabelle Deramaix and Léonce Demarez (*2010*), Frédéric Joseph* et al. *(*2011*), and Cécile Monchablon* et al. *(*2011*)).*

Crombé, *Vanmontfort 2007*). In Belgium, settlements of these first agro-pastoral groups are confined to the loamy areas of the Hainaut and Hesbaye regions (Fig. 8). Only the Hainaut region is included in the study area, and constitutes a small area (*Siedlungskammer*) of *c.* 32km^2 around the source of the Dender river, a tributary of the Scheldt (*Constantin*, *Burnez-Lanotte 2008; Denis 2019*). Within this small cluster 11 LBK sites and eight BQY settlements are known, yielding *c.* 19 houses (Tab. 7, Figs. 8 and 9). In Northern France several sites of the BQY and Villeneuve-Saint-Germain (VSG) cultures have also been discovered, although not yielding clear house plans (*Praud* et al. *2018*). Other finds are often merely single stray finds such as adzes, flint arrowheads or small quantities of pottery (*Jadin*, *Hauzeur 2003*). Outside of the loamy areas, finds of these first farmer-herders are scarce (*Crombé* et al. *2015a*) which could explain the notable lack of Early Neolithic sites in the Lower Scheldt region, as seen in the site counts The paucity of the sandy soils for long-term sustainable agriculture probably is the main reason for the absence of Early Neolithic sites in the sandy lowlands (*Vermeersch 1990; Crombé*, *Vanmontfort 2007; Langohr 2019*).

	Raw Counts	Aoristic Weight	Random	SPD
Raw Counts	1			
Aoristic Weight	**0.86**	1		
Random	**0.83**	**0.98**	1	
SPD	**0.68**	**0.79**	**0.79**	1

Tab. 2. Spearman correlation ρ-values for the Scheldt Basin. The significant correlations (p<.05) are indicated in bold.

	Raw Counts	Aoristic Weight	Random	SPD
Raw Counts	1			
Aoristic Weight	**0.54**	1		
Random	**0.43**	**0.92**	1	
SPD	0.07	**0.60**	**0.54**	1

Tab. 3. Spearman correlation ρ-values for the Lower Scheldt Basin. The significant correlations (p<.05) are indicated in bold.

	Raw Counts	Aoristic Weight	Random	SPD
Raw Counts	1			
Aoristic Weight	**0.83**	1		
Random	**0.78**	**0.97**	1	
SPD	**0.68**	**0.74**	**0.75**	1

Tab. 4. Spearman correlation ρ-values for the Upper Scheldt Basin. The significant correlations (p<.05) are indicated in bold.

	Scheldt SPD	Lower Scheldt SPD	Upper Scheldt SPD
Scheldt SPD	1		
Lower Scheldt SPD	**0.91**	1	
Upper Scheldt SPD	**0.97**	**0.82**	1

Tab. 5. Spearman correlation ρ-values for the SPDs of the subregions. The significant correlations (p<.05) are indicated in bold.

	Scheldt Aoristic	Lower Scheldt Aoristic	Upper Scheldt Aoristic
Scheldt Aoristic	1		
Lower Scheldt Aoristic	**0.75**	1	
Upper Scheldt Aoristic	**0.96**	**0.61**	1

Tab. 6. Spearman correlation ρ-values for the aoristic weights of the subregions. The significant correlations (p<.05) are indicated in bold.

Whether the clear peak in sites and dates in the Early Neolithic of the Upper Scheldt can be linked to a population boost or increase, as claimed in other areas of the LBK territory (*cf. Shennan, Edinborough 2007; Shennan 2009*; *Shennan* et al. *2013*) needs to be questioned. This pattern might be biased to a certain degree by the higher visibility of Early Neolithic settlements compared to hunter-gatherers campsites (*Crombé*, *Robinson 2014*), *e.g.,* due to the presence of numerous deep features such as deep post-holes and foundation trenches belonging to rectangular longhouses and loam extraction pits alongside these houses. In addition, these features provide much better dating opportunities (Tab. 8), as the risk of contamination or misattribution is limited compared to hunter-gatherer sites lacking clear structural features (*Sergant* et al. *2006*). Finally the research focus on the LBK and BQY in particular during the last few decades of the 20th century, involving large-scale excavations (*Jadin 2003; Constantin*, *Burnez-Lanotte 2008*), combined with the lack of research on the Mesolithic in the Upper Scheldt, has certainly influenced the data.

If the introduction of these first farmer-herder migrants would have led to a population increase, the impact most likely would still have been very local given the very small size of the

	EN	1st half MN	2nd half MN	LN	FN	EBA	MBA
Total	19	0	4	0	32	0	33

Tab. 7. Amount of known house plans per period.

Siedlungskammer. Furthermore the size of the group inhabiting these first permanent settlements will not have been much larger than that of a residential hunter-gatherers campsite, as recently demonstrated by a multiproxy spatial analysis of the Mesolithic site of Kerkhove in the Upper Scheldt (*Vandendriessche* et al. *2023*). Most excavated LBK and BQY settlements in the Upper Scheldt yielded between two to three long-houses, exceptionally five (Ormeignies-Blicquy 'La Petite Rosière' and Ath 'Les Haleurs'); using an average of 8.5 inhabitants per house (*Zimmermann, Hilpert, Wendt 2009*), these settlements were occupied by a group of *c.* 15 to 25 people, comparable to the number of occupants of a hunter-gatherer residential camp. Furthermore, detailed analyses of pottery decoration (*Constantin*, *Burnez-Lanotte 2008*) suggest that not all settlements were simultaneously occupied, as at least three phases can be discerned for each cultural phase, reducing the number of potentially synchronic settlements to two, at a maximum three. A population peak is therefore an artefact of the higher visibility of sites. A true population increase in the region does not seem realistic, but a local increase in the Dender region is likely.

First part of the Middle Neolithic (4650–4300 cal BCE)

The BQY groups disappeared around 4650 cal BCE, which coincides with a decline both in radiocarbon density and site counts, particularly in the Upper Scheldt basin. Whilst in neighbouring regions these cultures were replaced by others such as the Cerny (Paris basin) (*Constantin* et al. *1997; Dubouloz*, *Lanchon 1997*) or Rössen (Rhineland) (*Kooijmans 1993; Gehlen*, *Schön 2007*), there seems to be a hiatus in occupation in the Scheldt valley during the ensuing period up until the introduction of the Michelsberg culture around 4300 cal BCE (*Vanmontfort 2004; Crombé*, *Vanmontfort 2007; Constantin*, *Burnez-Lanotte 2008*). A recent study (*Langohr 2019*) pointed out that edaphic factors were likely the cause of the disappearance of the LBK and BQY cultures in the Belgian loess region. Contrary to the fertile Chernozems, Phaeozems and Luvisols soils of Central Europe, which facilitate year-round cultivation, the first farmers in the Atlantic region, including the Upper Scheldt, encountered leached and highly acidic soils characterized by the presence of a fragipan, which constituted a physical barrier to root penetration. Basic shifting cultivation was not sustainable, requiring entire villages to relocate regularly, resembling a 'shifting village' system. Ultimately this pattern would quickly have resulted in the swift abandonment of the Belgian loess area by these initial farmers.

However, potential biasing factors also need to be taken into account. Firstly, changes in building traditions leading to a decrease in site visibility could partially account for the notable decline in archaeological sites and, consequently, in the number of radiocarbon dates obtained (Tab. 8). As already demonstrated in earlier research (*Blouet 2006; Crombé*, *Robinson 2014*) post-LBK settlements are characterized by shallower features, rendering them considerably more susceptible to erosion, and are therefore only sporadically preserved. LBK/BQY timber longhouses, identifiable by deep post holes and extraction pits, for example, are replaced by houses featuring shallow(er) foundation trenches along their exterior walls and the absence of extraction pits (*Giligny*, *Sénépart 2018*) (Fig. 9). Additionally, post-LBK sites, particularly those of the Rössen culture, are difficult to detect in surface finds, because they share similar diagnostic artefacts (triangular arrowheads, flake axes, and so on) with the subsequent Michelsberg culture. Therefore, it is not unlikely that some sites attributed to the Michelsberg culture may actually belong to the Rössen culture. Distinguishing between them relies largely on pottery analysis, although pottery fragments are rarely encountered during field surveys. Similar circumstances apply to the contemporaneous Swifterbant culture, the pottery of which does not survive in the plough-layer. While this indigenous hunter-gatherer culture is to date only known from the Lower Scheldt, it is possible that its territory extended further south including the Upper Scheldt basin. If future research substantiates this hypothesis, it would indicate the continuity of hunter-gatherers communities after the disappearance of the LBK and BQY in the loess area, potentially resulting in the reoccupation of the former territory of the first farmers. This, however, appears rather unlikely given abundance of post-LBK 'contact' artefacts on Swifterbant sites in the Lower Scheldt, including small assemblages of (epi)Rössen pottery (*Crombé* et al. *2015a; Teetaert*, *Crombé 2022*), cereal grains (*Meylemans* et al. *2018*) and domesticated animals (*Crombé* et al. *2020*) indicating the presence of post-LBK/BQY sites in the adjacent loess area, although these could also originate from areas beyond the Upper

Scheldt basin. Consequently, the decline in population immediately following the LBK/BQY remains under discussion.

The above arguments, however, cannot explain the concurrent drop in the number of sites in the Lower Scheldt, an area not inhabited by the LBK nor the BQY. Other potential biasing factors may be in play, including a shift in land-use towards wetland areas, which are less frequently targeted by prospection campaigns and excavations, and would therefore remain largely undiscovered. This corresponds with the settlement pattern observed for the Swifterbant culture sites in the Lower Scheldt valley (*Crombé* et al. *2015b*); the five currently known sites are all located in the Scheldt estuary buried beneath thick layers of peat and tidal deposits. Even if the Swifterbant culture had also utilized adjacent dryland areas, the likelihood of detecting these sites through surface surveys is minimal, given that their material culture closely resembles Late Mesolithic traditions and is nearly indistinguishable from those. Except for the presence of faceted tools (*Halbrucker* et al. *2022*), their assemblages predominantly consist of the same diagnostic artefacts and raw materials as those from the Late Mesolithic period, such as trapezes, Montbani-retouched blades, and the use of Wommersom quartzite (*Messiaen* et al. *2023*). The only five known Swifterbant culture sites within the Lower Scheldt basin are all attributed to this culture solely based on pottery finds, which unfortunately are exclusively recovered during excavations as they do not survive within the plough-layer. Without pottery this culture remains almost invisible.

At first sight the decrease in sites seems contradictory with the slight increase of ^{14}C dates in the SPD of the Lower Scheldt from *c.* 4800 cal BCE. However, this observation is also subject to bias. Extensive dating efforts, particularly in the context of the five Swifterbant culture wetland sites, have yielded over 120 dates (Tab. 8), which could introduce potential biases even after binning.

Second part of the Middle Neolithic (4300–3800 cal BCE)

From approximately 4300 cal BCE onwards, for the first time, both regions of the Scheldt basin show a synchronized distribution pattern in terms of archaeological sites and radiocarbon dates, characterized by a sharp increase lasting for over almost half of a millennium corresponding to the emergence of the Michelsberg culture. Additionally, the peak in the SPDs is the first one which deviates positively from the null model. However, it is essential to acknowledge the presence of potential biasing factors. Firstly the increased visibility and preservation of features, attributed to the (re)appearance of deep structures, such as deep flint extraction mines at sites like Spiennes (*Collet* et al. *2016*), as well as extensive ditch and palisade enclosures observed at locations like Spiere 'De Hel' (*Vanmontfort 2004*), Kemmelberg (*Van Doorselaer* et al. *1974*) and Blicquy 'Couture du Couvent' (*Constantin*, *Demarez 2009*). These features were previously unknown in the Scheldt basin prior to the Michelsberg culture and have been extensively dated at certain sites, thereby constituting the majority (71%) of the total number of dates for this period (Tab. 8). Furthermore, Michelsberg culture sites are more easily identifiable on the surface compared to Swifterbant culture sites, owing to the presence of highly distinctive artefacts including triangular and leaf-shaped arrowheads, polished axes, flake axes and long blades, as well as typical raw materials including high-quality mined flint (*Vanmontfort* et al. *2008; Messiaen* et al. *2023*).

Independent of the question whether the introduction of the Michelsberg culture led to a significant population increase, it is evident that this culture played a major role in expanding the agro-pastoral economy downstream along the Scheldt river into the sandy lowlands of the Lower Scheldt basin. Recent studies examining pottery (*Teetaert*, *Crombé 2021*), stone technologies (*Messiaen* et al. *2023*) and antler tools (*Crombé* et al. *2022a*) have convincingly demonstrated that this was the result of acculturation among indigenous hunter-gatherers through contact and exchanges with southern farmers, rather than further migration of the latter. However the question remains why this occurred during the second half of the 5th millennium, although there is evidence suggesting an earlier onset of local husbandry in the sandy lowlands (*Crombé* et al. *2020; 2022b*).

One possibility is that the spread of the agro-pastoral economy was facilitated by adaptations in cereal cultivation. The transition to the post-LBK/BQY in the French and Belgian loess area is characterized by a significant shift from predominantly emmer (*Triticum dicoccum*) and einkorn (*Triticum monococcum*) to a dominance of bread wheat (*Triticum aestivum s.l./ turgidum s.l.*). Although the reasons for this change are still debated (*Bakels 2008; Bouby* et al. *2018*), it could suggest an adaptation to less fertile or more depleted soils, making cultivation on the sandy soils of the Lower Scheldt basin possible. Even in the loess areas of the Upper Scheldt, Michelsberg culture sites, unlike LBK/BQY sites, are no longer restricted to loess soils, but also frequently occur on outcrops of Tertiary sands, sand dunes and river scroll bars (*Crombé*, *Vanmontfort 2007*). This significant change in land-use may also be linked to the changing importance of agriculture compared to animal husbandry, with the latter becoming more prominent, although this remainscurrently difficult to assess.

The expansion of the agro-pastoral economy along the Scheldt basin in the second half of the 5th millennium reflects a notable economic shift. This expansion possibly occurred in response to prevailing warm conditions attributed to increased summer insolation in the Northern Hemisphere. The expansion from the loess to the sandy lowlands coincided with the Holocene Thermal Maximum (HTM), characterized in NW Europe by elevated summer temperatures, surpassing those of the pre-industrial time (*Kaufman* et al. *2020; Fletcher* et al. *2024*), following a cold collapse associated with pronounced dryness around 4500/4400 cal BCE (*Wanner* et al. *2011; 2014*). This is also supported by the local palaeoecological evidence from the Scheldt basin. Several Swifterbant sites yielded substantial amounts of seeds and charcoal from ivy (*Hedera helix*) and mistletoe (*Viscum album*), two plants considered climate indicators (*Zagwijn 1994*). *Hedera helix* is sensitive to winter frost and thrives in mild winters (mean January temperature >–2°C), whereas *Viscum album* requires warm summers (mean July temperature >15.5°C) (*Iversen 1944; Walas* et al. *2022*).

Late Neolithic (3800–3000 cal BCE)

The onset of the Late Neolithic, around 3800 cal BCE, signifies the start of a serious decline in both sites and radiocarbon densities, persisting for nearly half a millennium in the Upper Scheldt (until *c.* 3400 cal BCE) and for a millennium in the Lower Scheldt basin (until *c.* 2800 cal BCE). Interestingly, the lowest frequencies, denoted by a negative deviation from the null model, do not occur simultaneously in both regions of the basin. While it is situated around 3450 cal BCE and lasts only briefly in the Upper Scheldt, the trough in the Lower Scheldt occurs much later, spanning between approximately 3175 and 2830 cal BCE, enduring for several centuries until the transition to the Final Neolithic. This overarching pattern closely resembles the boom-and-bust pattern observed in various study-areas across NW Europe, including different regions in the UK (*Shennan* et al. *2013; Bevan* et al. *2017*), Central Europe (*Kolář* et al. *2022*) and southern Scandinavia (*Warden* et al. *2017; Nielsen* et al. *2019*), where it is typically interpreted as indicative of a population crash following the initial introduction of agro-pastoral communities. This interpretation may also hold true for the Scheldt basin, despite the fact that the reduced number of sites and ^{14}C dates might simply appear as a decline since deep features, particularly enclosures and deep post holes, are less prevalent. In fact, the majority of dates (*c.* 60%) originate from flint mines and river finds, two categories of contexts not directly associated with settlements (Tab. 8; Fig. 2). Thus far, no Late Neolithic house plans have been identified within the study area (Tab. 7). Similar trends are observed in the surrounding regions occupied by the Seine-Oise-Marne culture in northern France and the Belgian Meuse basin, the Vlaardingen/Stein culture in the Dutch Meuse basin, and even further north with the western Funnel Beaker culture of the northern Netherlands. On dryland locations Late Neolithic settlement sites are limited to a few scattered post holes and pits (*Louwe Kooijmans 1983; Verhart 2000; Raemaekers 2013; Drenth* et al. *2014*), which are often heavily leached and thus difficult to detect (*Verhegge* et al. *2021*). Conversely in wetland areas, better-preserved and occasionally complete sites and house plans are found, such as those in the Dutch Rhine-Meuse delta (*Kleijne*, *Drenth 2019*). The house plans typically feature shallow wall posts combined with deep roof posts, with the latter being more likely to survive in exposed and frequently eroded dryland contexts.

Consequently, the image of the Neolithic population based on Dutch wetland data is one of population continuity or stability rather than a population crash. This interpretation is further supported by the recent findings indicating that the exploitation of the flint mines in the Upper Scheldt continued during the Late and Final Neolithic (*Collet* et al. *2008*) as well as the deposition of antler tools in rivers (*Crombé* et al. *2018*) (Fig. 2). Furthermore, the interpretation is in line with the evidence from the Belgian Meuse valley and the region north of the Rhine/Meuse, where the Late Neolithic is characterized by numerous collective burials, either in caves (*Toussaint* et al. *2010; Toussaint 2013; De Groote* et al. *2022*) or megalithic monuments, specifically *hunebedden* (*Bakker 1992*). Analysis of the SPD for former burials (Fig. 2) reveals an inverse trend, indicating a gradual increase of radiocarbon dates (and thus burials) from the beginning of the 4th to the first half of the 3rd millennium cal BCE, strongly suggestive of population growth during this period. Unfortunately, as burial contexts are undocumented in the Scheldt basin, a similar trend cannot be definitively asserted, but appears highly probable.

Finally there is no obvious explanation for a significant population decline during the 4th millennium cal BCE. In other regions of NW Europe, the observed decline in the SPDs has been attributed to a changing climate and environment, such as prolonged cooling (*Bevan* et al. *2017; Warden* et al. *2017*) and wetter summers (*Bevan* et al. *2017*) from *c.* 3500 cal BCE onwards. Additionally, changes in economic strategies (*Nielsen* et al. *2019; Kolář* et al. *2022*) and social tension (*Kolář* et al. *2022*) have been proposed as contributing factors. Within the Scheldt basin the appearance of yew (*Taxus baccata*) in the pollen spectra during the Subboreal, particularly between *c.* 3500 and 2000 cal BCE (*Deforce*, *Bastiaens 2007*), along with the associated paludification of river floodplains and coastal areas (known as the alder-carr phase) (*Storme* et al. *2017*), suggests increased humidity which may have affected agricultural productivity. However, the extent of its impact on population dynamics is uncertain, as only the lower-lying landscapes (floodplains, coastal regions) would have been affected, constituting a minor portion of the Scheldt basin landscape. Furthermore, speleothem data from the neighbouring Meuse valley (*Allan* et al. *2018*) do not indicate heightened cooling during the 4th millennium cal BCE.

Final Neolithic (3000–2000 cal BCE)

The Final Neolithic exhibits a notable increase in both the number of sites and ^{14}C dates, with the majority concentrated in the Upper Scheldt basin. Out of the 143 Final Neolithic sites identified in the study area, 119 are located within the Upper Scheldt basin. Moreover, this marked rise clearly started much earlier in the Upper Scheldt, culminating in a prominent peak during the first half of the 3rd millennium cal BCE, corresponding to the Dêule-Escaut culture (*Joseph* et al. *2011*). In contrast, the peak in the Lower Scheldt occurs in the second half, coinciding with the emergence of the Bell Beaker culture (*Crombé* et al. *2011*). However, this disparity in timing likely stems from differences in research history and intensity rather than reflecting an accurate prehistoric reality.

In fact, the majority of Dêule-Escaut sites have been uncovered in northern France over the past two decades, largely as a result of large-scale developer-led archaeology, resulting in the identification of at least 18 house plans (*Joseph* et al. *2011*). Prior to this, little was known about the settlement organization of this culture, leading to the assumption that these people occupied lightweight, poorly founded structures that left minimal traces in the soil. In comparison to northern France, large-scale preventive excavations started later in Belgium. Only at present are some areas of the Scheldt basin, in particular the Belgian Upper Scheldt, starting to reveal the first evidence of this culture, *e.g.,* at Ghislenghien (*Deramaix 1997*), Oostkamp (*Demeyere* et al. *2006*) and possibly also at Eine (*Hazen*, *Drenth 2018*). These recent discoveries indicate that further salvage research in the Belgian Scheldt basin will likely lead to more settlements sites and house plans.

Another significant factor contributing to the notable increase in house plans (and consequently the number of sites) is the fundamental shift in building traditions at the beginning of the 3rd millennium cal BCE, which renders sites much more visible and datable (Tab. 8), even in exposed dryland regions. During this period, most

	EN	1st part of the Middle Neolithic	2nd part of the Middle Neolithic	LN	FN	EBA
Sherd		1 (5)	7 (12)		1	
Layer	2 (34)	2 (24)	15 (84)	3 (7)	16	
River	10	6	14	9	16	6
Kiln & Hearth	2	(9)	13 (20)	1	5	1
Circle Ditch		1	2	2	11	12
Mine		2	17	12	15	
Well	1			1	2	
Pit	9		37	1	21	4
Burial		1	4	2	22	3
Posthole	1		2	2	61	2
Ditch			29	3	11	
Total	**25 (57)**	**13 (48)**	**140 (221)**	**36 (40)**	**181**	**28**

Tab. 8. Amount of dates per archaeological context. The dates are presented excluding the dates from Swifterbant sites. The amount including the Swifterbant sites are included between brackets when they occur.

two-aisled houses feature outer walls constructed of posts inserted into deeply excavated foundation trenches – a technique sometimes also employed for interior walls (*Joseph* et al. *2011*) (Fig. 9). In certain instances, the wall posts were even embedded deeper than the foundation trenches. This was combined with a central row of roof posts, some of which could reach very large dimensions. A similar architectural change is observed in the coversand region of the southern Netherlands (*Drenth* et al. *2014*), suggesting that this was not solely a localized development.

Similarly, the discrepancy in SPD between the Upper and Lower Scheldt during the second half of the 3rd millennium BCE is likely skewed by differences in archaeological research. Bell Beaker culture sites are predominantly concentrated in the Lower Scheldt basin, with evidence primarily derived from isolated pottery finds and burials. The latter consisting of burial pits (*Crombé* et al. *2011*) and barrow ditches (*De Reu*, *Bourgeois 2013*). Thus far, none of the known settlement sites have yielded clear settlement structures, such as house plans, which contrasts sharply with the first half of the 3rd millennium cal BCE. Again this has probably to do with changing building traditions rather than indicating a decrease in population. By way of comparison, the scant Bell Beaker house plans identified in the Dutch wetlands (*Arnoldussen*, *Theunissen 2014*) exhibit marked differences from those of the preceding culture; they lack deep foundation trenches, and wall posts are irregularly spaced and frequently are not visible or preserved. Nonetheless, the Dutch wetlands are known to have been extensively inhabited during this period.

Early Bronze Age (2000–1800 cal BCE)

During the transition from the Final Neolithic to the Early Bronze Age, around 2100/2000 cal BCE, a large trough is visible both in radiocarbon dates and site counts. However, when examining the basin subregions individually, a more nuanced picture emerges. It is apparent that in the Lower Scheldt the decrease in dates is less pronounced and of shorter duration compared to the Upper Scheldt, where the decline in dates and sites commenced around *c.* 2300/2200 cal BCE. In our opinion this contrast between the Lower and Upper Scheldt, results from differences in research methodology. The majority of sites dating from the Final Neolithic (Bell Beaker culture) to the Middle Bronze Age consist of barrows, specifically the deep circular ditches surrounding these earth mounds. Most of these monuments were identified through extensive and prolonged surveys utilizing aerial photography, which began in the 1980s and continues to the present (*Ampe* et al. *1996*). These surveys primarily targeted the sandy Lower Scheldt area, whereas the heavier and less well-drained loess soils of the Upper Scheldt received less attention due to their greater distance from airfields and lower detection rates. The rate at which crop marks appear differs fundamentally between sandy and loamy soils, with the latter requiring significantly longer periods of sustained drought for detection. Therefore, the marked decline in the SPD and sites in the Upper Scheldt is likely heavily influenced by the absence of aerial surveys.

Furthermore, the bias in settlement sites observed in the preceding Bell Beaker culture persists into the Early Bronze Age. This is evidenced by the complete absence of house plans in the Scheldt basin, in contrast with the numerous examples from the Middle Bronze age (Tab. 7). Based on the limited number of better-preserved contexts in the Dutch wetlands, it is known that Early Bronze Age houses closely resembled those of the Bell Beaker culture (*de Koning*, *Drenth 2018*). However, the scarcity of early Bronze Age settlement sites in these wetland environments suggests that the transition from the Neolithic to the Bronze Age likely experienced some degree of population decline. Intriguingly, this coincides remarkably with the 4.2kya climate event/IRD3 (*Bond* et al. *1997; 2001; Alley*, *Agustsdottir 2005; Lawrence* et al. *2021*). This abrupt, short-lived event dated from 2250 to 1950 cal BCE (*Weiss 2016; Walker* et al. *2019*) would have led to increased aridity and decreased temperatures, particularly in lower latitude regions such as the Middle East, Southeast Asia, and the Mediterranean region (*deMenocal 2001; Booth* et al. *2005; Geirsdóttir* et al. *2013; Yang* et al. *2015; Weiss 2016; Bini* et al. *2019*). Multiple difficulties and shifts in these regions such as the collapse of the Akkadian empire, the Old Kingdom in Egypt, and so on (*e.g.,* Meller *et al.* (*2015*) versus Sołtysiak and Fernandes (*2021*)), are attributed to this event. In contrast, the impact of this event in the mid and high-latitudes of north(western) Europe appears to be more heterogeneous and less pronounced (*Bradley*, *Bakke 2019*). While there appear to be indications of a decline in yew in the Netherlands, Germany and England (*Bebchuk* et al. *2024*), recent multi-proxy studies in the UK, Ireland (*Roland* et al. *2014*) and Poland (*Pleskot* et al. *2020*) did not uncover compelling evidence for significant changes in terrestrial vegetation or lake ecosystems during this climatic event. Similarly, speleothem studies in the neighbouring Meuse valley of southern Belgium did not reveal evidence of major climatic fluctuations between *c.* 2500 and 1100 cal BCE, but rather suggest stable, temperate conditions (*Allan* et al. *2018*). Therefore, a correlation between the potential population reduction and climate change at the Neolithic-Bronze age transition in the Scheldt basin remains to be established.

Conclusion

The interpretation of fluctuations in radiocarbon dates (dates as data) and sites represents significant challenges when analysing population dynamics. Clearly, these peaks and troughs are influenced by numerous biasing factors, including differences in research methodology and intensity (*e.g.,* large-scale versus small-scale excavations, aerial surveys), soil conditions (wetlands versus drylands) and changes in building traditions throughout the Neolithic. It is notable that most peaks correspond to phases characterized by the presence of deeper features, such as enclosures, mines, barrow ditches and deep-founded buildings. These features enhance visibility and provide greater opportunities for radiocarbon dating.

In contrast to the observed boom-and-bust pattern in other studies within north(western) Europe, our study suggests that Neolithic population dynamics in the Scheldt basin region indicate a trend of gradual population growth. This growth was only temporarily interrupted at the transition towards the Bronze Age, potentially due to a major climatic event that impacted economic productivity. While subtle population fluctuations throughout the Neolithic cannot be entirely dismissed, it remains uncertain whether these fluctuations are discernible through the quantification of radiocarbon dates and archaeological sites alone.

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The uncertain frontier: risks, reversals and interactions in the initial establishment of Neolithic settlement

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ABSTRACT – *Long archaeological debate on the process of Neolithisation across Europe has been resolved at a broad level, thanks to aDNA and other scientific investigations, in favour of significant migrations virtually everywhere. This development has coincided with the establishment of more robust and generally more precise chronologies, and in the long run the historical process of change brought by Neolithic migrants was irreversible. However, the emergent big picture can and should still be examined in much further detail. Some significant implications for the understanding of mobility and migration have been explored, but there is plenty of scope for better integration of archaeological and scientific, especially archaeogenetic, investigations. This can reveal important dimensions of the process of colonisation and the initial establishment of Neolithic settlement, which appears often to have been small-scale at the outset; prone to adjustment, experiment, reversal and even failure; and open to contacts with indigenous people. We support these claims with a series of brief case studies principally from the northern Balkans, the Carpathian basin and northern central Europe to build a simple model of frontier conditions which could have implications for the study of initial Neolithisation across Europe as a whole.*

KEY WORDS – *Neolithisation; aDNA; migration; initial establishment; scale; risk; reversal; failure*

Negotova meja: tveganja, preobrati in interakcije ob ustanavljanju prvih neolitskih neselbin

IZVLEČEK – *Dolga arheološka razprava o procesu neolitizacije Evrope se je, zahvaljujoč raziskavam stare DNK in drugim znanstvenim raziskavam, končala v korist velikih migracij. Vzporedno so bile vzpostavljene bolj robustne in na splošno bolj natančne kronologije. Dolgoročno gledano, je zgodovinski proces sprememb, ki so jih prinesli neolitski migranti, nepovraten. Kljub vsemu se lahko in mora nastajajoča 'velika slika' podrobneje preučiti. Nekatere ključne implikacije za razumevanje mobilnosti in migracij so bile sicer raziskane, vendar pa je še veliko možnosti za boljšo povezavo arheoloških in znanstvenih, predvsem arheogenetskih raziskav. Te lahko razkrijejo nove vidike procesa kolonizacije in ustanavljanja neolitskih naselbin, za katero se zdi, da je bila na začetku majhna; nagnjena k prilagajanju, eksperimentiranju, preobratu in celo propadu; in odprta za stike z domorodnimi skupnostmi. Te možnosti dokazujemo z nizom kratkih študijskih primerov s severnega Balkana, Karpatskega bazena in severne Srednje Evrope. Z njimi želimo oblikovati preprost model 'mejnih razmer', ki bi jih lahko uporabljali pri preučevanju začetkov neolitizacije Evrope.*

KLJUČNE BESEDE – *neolitizacija; stara DNK; migracija; prve ustanovitve; velikost; tveganje; preobrat; propad*

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Neolithisation across Europe: the current big picture

The long archaeological debate about the process of Neolithisation across Europe, which goes back to the later nineteenth century and even earlier, appears now at one level finally to have been settled. The big question has been whether migrants and colonisers were responsible for the introduction into Europe of a new way of life involving agriculture and a more settled existence than practised by hunter-gatherers, or whether this transition was in the hands of indigenous European hunter-gatherers themselves, using knowledge of new techniques and practices diffused from centres of innovation in the Near East. Numerous aDNA studies particularly over the last nine or ten years (froma a much longer list, see *Brandt* et al*. 2014; Szécsényi-Nagy* et al*. 2014; 2015; in press; Lipson* et al. *2017; Reich 2018; Brace* et al. *2019; Nikitin* et al. *2019; Rivollat* et al. *2020; Marchi* et al. *2022; Koptekin* et al. *2024*), supported by even earlier isotopic investigations (for example, *Price* et al. *2001; Schulting, Richards 2002; Schulting 2008*), have at last settled the major outlines of Neolithisation process. Virtually everywhere across Europe, including in regions such as southern Scandinavia (*Allentoft 2024a; 2024b;* and see the references cited above) where previously there were very respectable archaeological arguments in favour of a significant involvement for indigenous people if not indeed a leading role, it now appears that incomers ultimately of Near Eastern genetic ancestry were principally responsible for the introduction of the new way of life.

This decisive shift has broadly coincided with the establishment of a more robust and often more precise chronological framework for early Neolithic sequences than previously available. Many more radiocarbon dates have been achieved, to be interrogated now in many regions in a Bayesian chronological framework, with much more precise regional sequences emerging (*e.g., Jakucs* et al. *2016; Whittle* et al. *2011; Porčić 2024*). That has served to lower some previous informal date estimates for the start of Neolithic activity in given regions, such as the coasts of the west Mediterranean (*Cruz-Berrocal 2012; Szécsényi-Nagy* et al. *2017; Revelles* et al. *2018; Alt* et al. *2020; Leppard 2021*) or central Europe at the time of the earliest LBK (*Jakucs* et al. *2016; Bánffy* et al. *2018;* for a differing view, see *Strien 2017; 2018*), and to unravel and extend a potentially lengthy process in the cases of Britain and Ireland, where debate had previously assumed a single point of change (*Whittle* et al. *2011; McClatchie, Potito 2020; Smyth* et al. *2020*). While there is still plenty of regional detail to be sorted, one can now fairly claim a generally solid and plausible timeframe for the narratives of migration and change (*e.g., Shennan 2018; Whittle 2018; Hofmann* et al. *2024*).

These key twin developments also sit well generally with the previous assertion made by John Robb (*2013*) that the process of Neolithisation across Europe was irreversible; region by region, once Neolithic practices had been introduced, there was in the long run no going back to earlier ways.

By all these means, our understanding of the beginnings of the Neolithic period across Europe has been transformed within the last generation of research, or at an even tighter timescale within the last decade or so. This has served to reset debate in many fundamental ways but the rapidity with which data and interpretations have changed may also explain why, so far, there has been comparatively little further detailed discussion about the implications of these many shifts of perspective. On the one hand, there is a tendency to assume a single, broad or major initial migration in any given region. In contrast, it is clear from wider, comparative discussion of concepts of frontiers, borders and boundaries (see for example, *Green, Perlman 1985; Kopytoff 1987; Parker 2006; Feuer 2016*), that frontiers can often be fluid, unstable and porous. On the other hand, there has been so far rather limited – though very welcome – discussion of how the archaeogenetic data contribute to new understandings of migration and mobility in general and in particular cultural contexts such as the LBK and elsewhere (*Hofmann 2016; 2020; Hofmann* et al. *2022; 2024; Porčić 2024*). We assert that, by contrast, there is still considerable scope for further and better integration of archaeological and archaeogenetic results and for the continuing interrogation of the specific fine detail, region by region, of the emergent big picture described above. We argue that alongside or complementing this big picture this may reveal much about the nature of colonisation and the varying conditions of the initial establishment of Neolithic settlement across Europe. We offer selected brief case studies from the frontiers, principally from the north Balkans and central Europe, and cover further comparative examples from other regions of Europe in our discussion. These may variously illustrate themes of local adjustment, experiment, reversal and even failure, as well as contacts with indigenous people, and they may all help, in our view, to show something of the character and scale of initial Neolithic activity (Fig. 1).

The debate reset: some case studies from the frontiers

Impermanent Körös settlement on the east bank of the Danube

There is reasonable information now about the spread of Neolithic people, things and practices through the Balkans though of course more excavation and more, robust dating would continue to be welcome. A plausible model is the establishment of settlement in the central Balkans by the later seventh millennium cal BC, represented principally by the Starčevo culture, and then in the northern Balkans and into the Carpathian basin, including on to the Great Hungarian Plain and Transdanubia, by the turn of the millennium and into the early sixth millennium cal BC (*Whittle* et al. *2002; Whittle 2007; Oross, Siklósi 2012; Blagojević* et al. *2017; Shennan 2018; Porčić* et al. *2020; 2021*). The settlement at Alsónyék in southernmost Transdanubia represents a Starčevo strand (*Oross* et al. *2016*), while Körös culture sites dominate the Alföld, with Criş sites in Romania (*Kutzián 1944; Kalicz, Raczky 1980-1981; Raczky 1980; Comşa 1959*). While the data are far from perfect, the evidence we have is generally compatible with a picture of steady spread from south to north: in Transdanubia up to Lake Balaton (*Kalicz 1990; Bánffy 2004*), and on the Great Hungarian Plain, as far as up to near its northern limits (*Domboróczki 2010.Fig. 11; Mester, Rácz 2010*). Overall, many of the landscapes with Körös culture sites appear busy and even populous, though well-dated individual sites such as Ecsegfalva 23 are still few and far between (*Whittle 2007;* see *Oross, Siklósi 2012* for a wider summary of the dating of Körös sites), and individual locations may have seen plenty of coming and going; but it remains hard to pin down a sense of settlement density at any one particular time. In Transdanubia, current research suggests that Alsónyék and a few settlements in its immediate vicinity on the south-east edge of the region

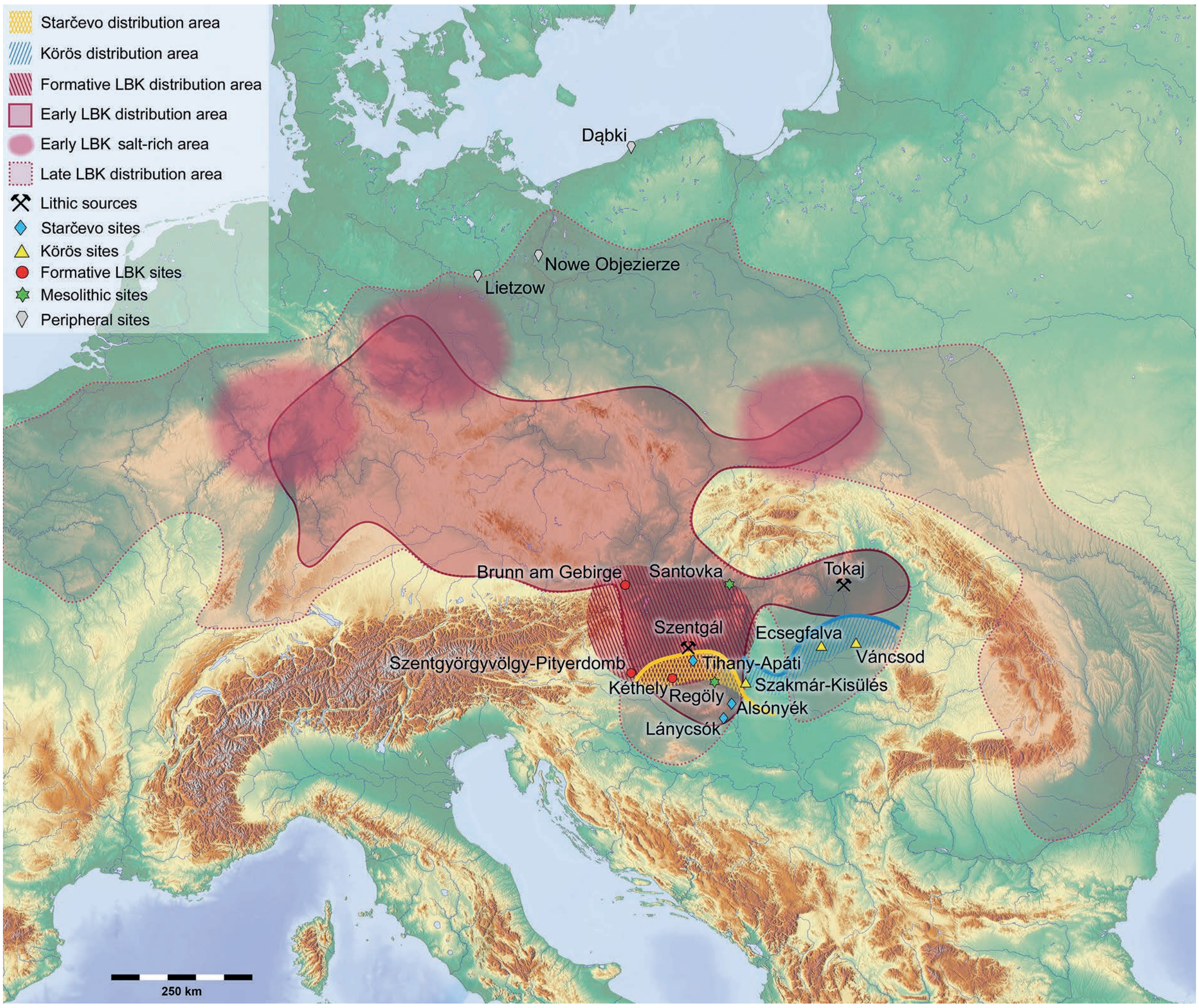

Fig. 1. Map of the core case study areas and key sites discussed in the paper.

stood out for their size and comparative longevity, while other sites further north may have been more scattered, smaller and with less abundant remains, and of short duration (*Kalicz* et al. *1998; Bánffy 2004*).

In this broader context, the example of Körös settlement on the east bank of the Danube can be particularly informative. Research on Körös settlement on the Great Hungarian Plain, east of the Tisza, had started in earnest in the 1930s (*Banner 1937; Kutzián 1944*), though the investigation of a Starčevo presence in south-west Hungary took much longer to get going (*Kalicz 1990*). The subsequent emergence of a notable Körös settlement niche close to the Starčevo sites along the east bank of the Danube came as an absolute surprise that suddenly filled a large blank spot in the Neolithic landscape (*Bánffy 2013.157*). After some sporadic mentions of Körös potsherds in field walking reports, a small excavation at Szakmár took place in 1975, led by Ida Kutzián. Apart from a short report (*Kutzián 1977*), the site and its finds remained unpublished until a later synthesis and two further books dedicated to one of the most distinctive finds (*Bánffy 2013; 2019*). A single, conventional date is available from the excavated site (*Bognár-Kutzián, Csongor 1987; Oross, Siklósi 2012.150*). Precise dating for these settlements remains to be established. Based on the finds compared with well-dated parallels (*Whittle* et al. *2002; Oross, Siklósi 2012*), however, the settlement niche could fall between 5800–5700 and 5650 cal BC (*Bánffy 2012*). Crucially for our wider argument, by the time of the late Körös period, none of the settlements seems to have been inhabited, and there was a gap in settlement approximately four centuries long until Transdanubian LBK groups occupied some of the small elevations in the alluvial area (*Kustár 2013*).

The niche in question, with some 50 known sites, is located where palaeochannels of the Danube led from the Tisza to the Danube: a green corridor for movement north-westwards. In the presumably periodically inundated floodplain, with potentially favourable conditions for garden or other cultivation, the inhabitants probably moved around seeking the drier spots and avoiding temporarily submerged areas; such local instability may explain the high number of sites found within a small area of some 25km^2. A plausible scenario of the outcome is the return of this Danubian Körös group to where it came from: back again to the core distribution region on the Tisza. Overall, the emergence and decline of Körös settlement along the banks of the Danube could be seen as a story of trial and error or failure at the onset of the Neolithic. We do not know the detailed conditions of such a trajectory, but they could be to do with scale and connectivity, neither being sufficient for settlement to be maintained on a sustained basis.

The evidence also highlights an intriguing lack of interaction between the Körös and Starčevo communities in the Sárköz region, despite their close proximity, not more than 15–18km apart in the Danube wetlands. This lack of connection between the Körös and Starčevo communities in the Sárköz region is unexpected (*Bánffy 2013*). While both groups shared similar cultural and economic backgrounds, the differences between the Körös and Starčevo populations may have been expressed more through different practices (*cf. Anthony 2007.104–105*) than in their rather similar material culture. Whatever the reason that the Körös and Starčevo groups avoided contact and cooperation, this circumstance may have contributed to the Sárköz Körös group falling back to the southern Alföld.

Possible long-range but impermanent pioneering in north-west Poland

An early analysis of frontier conditions and the spread of the Neolithic phenomenon across Europe, suggested a 'wave of advance', progressing outward overall but consisting of local movement in all directions (*Ammerman, Cavalli-Sforza 1971; 1973; 1984; cf. Clark 1965; Porčić 2024.3–4*). Subsequently, better dating indicated a less even process, amongst which targeted or leapfrog colonisation was suggested (*van Andel, Runnels 1995*). That helps to give a more nuanced view of some frontier conditions, though it has to stay within the range of chronological and geographical probabilities. It has been invoked in the interpretation of the occupation of Brunn in eastern Austria, where the authors have proposed a leapfrog jump from Starčevo communities some 300km to the south, avoiding Transdanubia (*Stadler, Kotova 2019;* but see *Bánffy 2021*). Leapfrog colonisation could also help to make sense of some of the distribution of earliest LBK communities across central and western Europe, often with considerable gaps between known sites (*Stäuble 2005; Strien 2018*).

Recently, a possible extreme case of long-range pioneering has been proposed (*Czerniak* et al. *2023*), which raises both further questions about frontier conditions and interpretive challenges in equal measure. The scene is north-west Poland in the lower Oder valley, at the very edge of the overall LBK distribution area, and some 90km from the Baltic. The authors present the results of a purely environmental investigation, from a pollen study of a lake core near Nowe Objezierze, focusing on an estimated 140-year-long episode of clearance, cultivation and claimed animal husbandry (their Phase II), from the early 57th century to the mid-56th century cal BC. There follows a hiatus of some 200 years, preceded by signs of climatic downturn at the end of Phase II, and then a second phase (their Phase IV), some 300 years in length, of established clearance and cultivation, starting in the later 54th century cal BC. Although there is a cluster of known LBK sites on either side of the lower Oder (*Czerniak* et al. *2023. Fig. 2*), and in the vicinity one established, late LBK longhouse has been excavated, no archaeological sites contemporary with the Phase II episode have yet been found.

The Phase II episode is defined by increased visibility of Chenopodiaceae, *Artemisia*, *Urtica* and *Plantago major, Rumex acetellum* and *Viola arvensis*; the presence of *Triticum*- and *Hordeum*-type cereal pollen; and an initial decline in the values of oak, hazel and alder and subsequently a marked decrease in pine. There are also signs of burning. This is all taken to represent clearance, cultivation of cereals and perhaps animal husbandry.

Lech Czerniak *et al.* (*2023*) propose that this episode was the result of long-range migration by Neolithic people, not in circumstances of demographic pressure in their area of origin (*cf. Shennan* et al. *2013; Silva, Vander Linden 2017*) – the available evidence for Formative LBK and earliest LBK settlement hardly speaks to crowded landscapes (*Jakucs* et al. *2016*) – but, in their view, perhaps as an outcome of ethnic diversity or of competition for prestige and access to resources among pioneering colonisers. The episode played out some fully 700km north of the area of the Formative LBK, and ignoring the spaces in between.

At face value, there do not seem to be interruptions to or anomalies in the accumulation of lake sediment. The documented sequence has a coherent trajectory, with Phase IV corresponding broadly with our understanding of the chronology of established LBK settlement in the north of Poland (*cf. Marciniak* et al. *2022*). There are of course problems in the identification of cereal pollen (*Behre 2007*), so that the claim for cereal cultivation in a context of probably limited interference with local woodlands might be challenged, but a uniform method was applied to both Phases II and IV, and the presence of cereal cultivation in Phase IV is hardly controversial.

The authors ascribe this 'infiltration phase' to the activity of Neolithic people, without quite specifying their possible identity. They refer to what has been claimed by the excavator of Brunn (*Stadler, Kotova 2019*) as a 300km 'flying' jump or leapfrog from Starčevo communities in northern Croatia to found Brunn. One might also support the general argument of Czerniak *et al.* (*2023*) by reference to more general models of the prevalence and importance of movement in the LBK tradition as a whole (*Hofmann 2020*), although Daniela Hofmann speaks about micro-mobility, back and forth, rather than on wider scales. There is the specific difficulty here that the activity in question begins before the emergence of the Formative LBK as represented by Szentgyörgyvölgy-Pityerdomb in western Hungary and Brunn in eastern Austria, if we follow the formal date estimates of János Jakucs *et al.* (*2016*) and reject the 'high' start date for Brunn proposed by the authors (*Stadler, Kotova 2019*). The appeals to ethnic diversity and competition are rather vague, though preeminent clans or lineages have been envisaged as a powerful force in the spread of earliest LBK communities (*Frirdich 2005*).

Another possibility to be thought about, though rejected by Czerniak *et al.* (*2023*), is of an episode of experimentation by local hunter-gatherers. We know of the long-distance movement of materials and objects in Mesolithic Europe as a whole (*Gronenborn 2010a*). Putting this activity in the hands of far-ranging Mesolithic people might make it easier to explain the impermanence of the episode. In the end, time will tell whether similar instances can be documented beyond the frontier or leading edge of Neolithic settlement in the first half of the 6th millennium cal BC, and whether matching local archaeology can be located and documented.

Whichever interpretation is preferred, this episode can be seen as an important further clue to unstable frontier conditions in the very early stages of the Neolithic, and we note other possible comparisons in the discussion below. Once again – especially in the version promoted by Czerniak *et al.* (*2023*) – not only is there the possibility of fission and long-range movement, but failure was the end result, as the activity described came to an end after probably some 140 years. Czerniak *et al.* (*O.c.14*) refer to probable indications of climatic downturn at the very end of their Phase II, strongly implying that that was the cause of abandonment. As with the Körös example discussed above, speculatively the limited scale of settlement, isolation and poor connectivity might also have been responsible for abandonment.

Other impermanent settlement and interaction close to the Baltic

Following the probably 54th-century cal BC rapid expansion of the earliest LBK (*Jakucs* et al. *2016; Bánffy* et al. *2018; Bánffy, Whittle 2022*) that took agricultural colonisers far west and north, there was further infill of the loess-dominated river basins in the established LBK. There are also signs of further spread beyond the fertile loess areas. LBK groups have been found farther down the Vistula and Oder rivers on the north European Plain, some fairly close to the Baltic (*Bogucki 1979; 1982; cf. Czerniak* et al. *2017; Marciniak* et al. *2022; Czerniak* et al*. 2023.Fig. 2*).

Such LBK groups faced the challenge of creating a subsistence strategy in a post-glacial landscape without obviously fertile soils. Possible advantages included large empty spaces for settling and herding, rich wild game and plant resources, and perhaps good communication routes (probably also with hunters and fishers living in the coastal area: *Kabaciński, Terberger 2009*). The earliest, arguably temporary settlements known so far are small, consisting of a few pits with potsherds and food remnants (*Grygiel 1976*). Demographic pressures may not have played a crucial role in this move since many of the loess-covered regions to the south remained unoccupied. One characterisation of these numerous, scattered early sites has been as a group of tactical pioneers in search of finding and developing resources other than arable land (*Bogucki 1979.242*).

The Baltic coastal and palaeo-lakeside settlement of Dąbki, Sławno County, West Pomerania, initially a forager (Ertebølle) site, offers an important case study with a long tradition of cultural exchange and adaptation. Its inhabitants are believed to have encountered LBK farmers and subsequently incorporated some elements of the Neolithic lifestyle (*Zvelebil 1998*). Since 2004, extensive fieldwork and analysis have been carried out, providing numerous details about the mixed foraging and sedentary lifestyle. There are a large amount of final Mesolithic material finds, including locally made pointed-bottom vessels, animal bones and plant remains indicating a coastal hunting and fishing lifestyle (*Czekaj-Zastawny* et al. *2013; Kabaciński, Terberger 2009; Kabaciński* et al. *2015*). The earliest evidence for agriculture gained from cereal pollen grains is dated to no earlier than the final phase of the settlement, *c.* 3700–3600 cal BC. Its earliest dates (though not entirely unproblematic) appear to underline the dynamic nature of this cultural transition (*Kotula* et al. *2015.119,133*).

In the neighbouring area to the west, in north-east Germany, similar dates have been published for the earliest Neolithic sites in northern Brandenburg and in western Pomerania (*Cziesla 2008.409*). Several publications have investigated the appearance and disappearance of LBK groups in this northern periphery (*Cziesla 2008*). A new summary of the site of Lietzow 10, Havelland, Brandenburg, located on a ground moraine plateau, covers enclaves of agricultural life amidst the settlement zone of forager groups (*Kirleis* et al. *2024*). The site yielded features containing late LBK pottery fragments, from which a settlement site with two farmsteads could be reconstructed, which was inhabited for two or three generations, around 5100 to 5000 cal BC. Despite its peripheral location, the pottery finds, and raw material provenance for tools attest to long-distance contacts. Domesticated cattle and emmer are well documented, with pigs and small ruminants also present, as well as evidence for extensive gathering. A wide range of game species is represented but hunting was probably not very important overall.

These sites did not have abundant material remains and probably disappeared by the early 5th millennium cal BC. In these northerly areas, to which the later Neolithic Lengyel orbit did not extend, the following culture group to occupy the northerly margins was the Funnel Beaker culture (*Midgley 1992;* see also *Marciniak* et al. *2020; Czerniak* et al. *2017*). The one-and-a-half millennia-long hiatus between the two settlement periods is telling and meaningful; the LBK attempt to settle in northern post-glacial landscapes appears to have been unsuccessful. Speculatively again, perhaps scale and connectivity were insurmountable challenges, apart from the difficulties set for the LBK subsistence system by the surroundings. Plausibly, these groups in the Polish and German cases that failed to thrive probably moved back to their core areas of settlement, as we suggested above was probably the case in the Danube-bank Körös case, to the regular LBK zones to the south.

Another facet of the frontier: contact with indigenous groups

Interbreeding at Brunn and pre-Neolithic pottery in Slovakia

Recent aDNA results right across Europe (see, for example, the references cited above) have tended to suggest a rather modest contribution at best from indigenous hunter-gatherers to Neolithic genetic signatures. The picture is varied region by region and we do not have the space here to go into all the detail. The great majority of LBK samples come from established phases of that culture. The example of Brunn near Vienna (*Nikitin* et al. *2019*), however, can remind us of the potential variability in frontier contexts. Here in the Formative LBK at Brunn am Gebirge site 2, one of three analysed individuals had a genetic ancestry descended from Anatolian Neolithic farmers. The other two, however, had a mixture of Western Hunter-Gatherer-related and Anatolian Neolithic Farmer-related ancestry, one of them with approximately 50% of each. Strontium isotope analysis also showed that the latter individual with mixed, balanced ancestry was non-local to the Brunn 2 area (*Nikitin* et al. *2019*). Stable carbon and nitrogen isotope ratios for all three individuals indicated a broadly Neolithic diet. Though the sample is very small, the report on the autosomal analysis reveals descent from a potentially large number of ancestors (*cf. Mathieson* et al. *2015; Booth 2019*) and highlights interbreeding between incoming farmers and indigenous hunter-gatherers, and the 'integrative nature and composition of the early LBK communities' (*Nikitin* et al. *2019.1*).

Whether or not LBK lithic production was strongly influenced by Mesolithic traditions (*Mateiciucová 2008; Kozłowski 2004*), we know that raw materials from areas occupied by hunter-gatherers were coming down into early Neolithic settlements, obsidian from north-east Hungary to Körös settlements on the Great Hungarian Plain (*e.g., Szeverényi, Priskin 2021*), and radiolarite from north of Lake Balaton into Starčevo and Formative LBK contexts (*Biró 2005; Mateiciucová 2008*).

Further evidence of possible contact across a fluid frontier between early farmers and hunter-gatherers, thus providing more information about the conditions of early Neolithic settlement, comes from a recent study in Slovakia (*Tóth* et al. *2023*). During palaeoecological research in calcareous lake sediments at Santovka, in the Slovakian Danube basin, so far without corresponding settlement traces, sherds of grass-tempered vessels were found. Stylistically these sherds do not match LBK styles, normally considered as the first Neolithic pottery north of Lake Balaton. The study faced considerable challenges in attempting the radiocarbon dating of this Santovka pottery. A novel method of bulk separation of organic content from the grass-tempered pottery was used, producing a coherent series of dates, from the 58th to 55th centuries cal BC, and in line with the chronostratigraphic Bayesian model for the coring site. However, dates on lipids extracted from the same sherds were divergent by up to 400–600 years.

If the dating of the organic content of the grass-tempered pottery is robust, reliable and correct, ceramics predating the Formative LBK phase have been found, and the authors conclude that Mesolithic groups must have experimented with pottery-making prior to the arrival of farming in the region (*Tóth* et al. *2023*). Santovka, just north of the Danube, is under 200km from known concentrations of early Neolithic, Starčevo settlement to the south, making a contact and connections plausible.

Local copies of Starčevo and Formative LBK objects

People who experimented with tempered pottery-making probably also tried their hand at other facets of Neolithic things and practices, further informing us of frontier conditions. Given an overlap between the end of the late Mesolithic and the start of early farming settlement in Transdanubia, this may have been the case among the many sites found near each other between the Regöly Mesolithic settlement (*Marton* et al. *2021*) and the large oldest, Starčevo phase of Alsónyék. In the first half of the 6th millennium cal BC, the Starčevo culture occupied the region involving the whole of Lake Balaton, at least sporadically including its northern side (for example at Tihany-Apáti: *Regenye 2010*). As already noted, there is proven contact between the Transdanubian Starčevo and the hunter-gatherers inhabiting the forested upland north of them since the Starčevo groups were also users of the north Transdanubian red radiolarite. Accessing the sources was presumably only possible via forager contacts. Speculatively, some domesticates and pottery know-how may have gone in the other direction. A synchronicity between the latest phase of the Starčevo and the Formative LBK has also been documented by radiocarbon dates (*Kalicz* et al. *2002; Jakucs* et al. *2016; Oross* et al. *2023*) as well as by archaeological analyses, with the ubiquitous use of the red radiolarite raw material by Formative LBK communities (*Bánffy 2004; Biró 2005; Bánffy, Whittle 2022*). This evidence implies that the forager groups must have been in contact with people from both major Neolithic cultural formations. During these long-standing encounters, there are further signs of the foragers' intention to adapt to the Neolithic lifestyle and perhaps also adopt some of the farmers' material practices.

Among the figural finds from the Formative LBK site of Szentgyörgyvölgy-Pityerdomb, in westernmost Transdanubia (*Bánffy 2004*), a fragment of a carefully modelled vessel, resting on a human foot, indicates a direct south-east European Starčevo origin. Another fragment found at the nearby site of Balatonszentgyörgy comes from a similar vessel, although it was less carefully made and is of vastly inferior quality (*Bánffy 2004*). This footed vessel is a fragment of a pot which is arguably a copy of late Starčevo and Formative LBK representations. Speculatively, and setting out from the Mesolithic traces in the region (*Duffy* et al. *2023*), the copy was made by local foragers.

The well-known animal (or human)-headed Starčevo altar from Lánycsók, in southern Transdanubia (*Kalicz 1990*), with a hint of its female character, may have been the model for a similar object of which only a fragment remains. This is the head from Kéthely, also not so far away in southern Transdanubia (*Sági, Törőcsik 1991*) (Fig. 1). This looks like an imitation – a local copy – of the same type as Lánycsók, albeit it is a vastly inferior, poorly fired variant of the 'original'. The Kéthely fragment has a further interesting detail. Its eyes were formed by cereal grains (*Triticum dicoccum*), a phenomenon that can perhaps be taken as a symbol indicating that the indigenous groups related positively to Neolithic innovations and made efforts to adopt cereal cultivation.

Thus, arguably, some Balkan early Neolithic cult paraphernalia like clay figural representations were adopted and used by the Formative LBK communities, while others (like pintaderas and small clay house models) were discarded. We could posit that certain elements of the Balkan cult inventory were adopted or copied for prestige reasons, as in the case of other Neolithic innovations such as some domesticated plants, perhaps reflecting some kind of incipient, modest social ranking among these indigenous communities, in the 56th–55th centuries cal BC.

However, this kind of motivation seems to decrease at the time of the LBK spread in the 54th century cal BC. There is a very high number of clay figural images from late Starčevo sites from the southern Carpathian basin, part of the north Balkan abundance of clay objects in general, while just a few years ago the total number of LBK figurines was 267 over its entire occupation area across Europe, and through its entire duration (*Becker 2011*). Moreover, this fading away matches the spatial and temporal distribution process of LBK spread, since most of the relatively low number of LBK clay images concentrate in the regions closest to the original zone of the Formative LBK. Bottlenecks, with features or objects fading away during the spread of Neolithic lifestyle from its Anatolian source, occur several times. While the reasons are not fully understood, the decline in clay figurine making is potentially connected to two main factors. One might be a scarcity of suitable clay raw material due to environmental factors, and the other would be the increasing influence of a different ontology of cult and ritual of local, forager population groups (*Bánffy 2019*).

Discussion: implications for our detailed understanding of colonisation and initial establishment

We have given examples of varied situations and processes at what we have called the frontier of Neolithisation in central Europe. An important general examination of frontiers and borderland processes has called for "*cross-disciplinary supra-regional comparison of frontier dynamics*" (*Parker 2006*, 77) but our principal aim has been the examination of specific contexts in central Europe. Two examples, from the margins of the Körös and LBK cultures, on the east bank of the Danube and in Pomerania respectively, the latter including the site of Lietzow 10, show settlement established for a while – or in the case of Lietzow just for a generation or two – but then being abandoned. A recent, controversial claim for early, long-range pioneering into northern Poland in the earlier sixth millennium cal BC has been discussed. Some of the evidence for contact and interaction between incoming farmers and indigenous hunter-gatherers has been reviewed, including aDNA evidence from Brunn 2 for interbreeding in the Formative LBK phase, adoption of new practices at Dąbki, and material evidence from Transdanubia in the form of figural representations in the Formative LBK phase, suggestive of potential local copying and the adoption of Neolithic things and practices by indigenous people, seen also in the experiment at Santovka in Slovakia with the making of grass-tempered pottery probably before the arrival of Neolithic people and other new practices. These varied case studies suggest to us that we need to make more allowance for fluid, unstable, frontier conditions in the initial stages of Neolithisation than has normally been the case in the recent archaeological literature, though we note the 'continuum of boundary dynamics' proposed by Bradley J. Parker (*2006*). We can profitably think more about instability, risk, reversals and even failures, paying attention to specific contexts and relying less on generalising or universalising models. Further reference to the development of the archaeological literature underlines this claim.

The difficult conditions for pioneers of the initial establishment of Neolithic settlement were perhaps first imagined in detail long ago by Humphrey Case (*1969*), in a far-sighted essay about the beginning of the Neolithic in Britain and Ireland. In the era of processualism and post-processualism, at least in what we can call the Anglo-American literature, there was a subsequent shift in favour of indigenous explanations, and it took two essays by David Anthony (*1990*; *1997*) among others (note, for example, *Gronenborn 1999; 2007; Sheridan 2003; Rowley-Conwy 2004; 2011*) to remind the discipline of the realities and practicalities of migration and colonisation. As noted in our introduction, that perspective has been dramatically underscored for studies of Neolithisation by the results of aDNA analysis, particularly over the last decade or so. So far, so good: but we argue that an over-generalising approach has been employed in ongoing modelling of the processes of Neolithisation. Targeted or leapfrog colonisation has usefully been recognised (*van Andel, Runnels 1995*), as noted in our introduction, and is regularly included in continuing discussions (for example, *Porčić* et al. *2020; LaPolice 2024*), but the evident favourite frame of reference remains the wave of advance model (*Ammerman, Cavalli-Sforza 1971; 1973; 1984*). That in turn encourages a general model of population growth and demographic pressure as the generative motor of Neolithisation across Europe (*Shennan 2013; 2024; Blagojević* et al. *2017; Silva, Vander Linden 2017; Porčić* et al. *2020; Porčić 2024. 3–4*). Refinements of this approach are to be found in the literature, such as a study of the central Balkans, based on summing of radiocarbon dates which suggests, plausibly enough, high fertility and 'scalar stress',or the tendency for communities to fission and disperse further before reaching sizes of 50–100 people, to avoid social tensions (*Porčić* et al. *2021;* with slight revisions in *Porčić 2024*). Predominantly within-group mating has been proposed, and fresh calculations have been made about the 'front speed' of the wave of advance (*LaPolice* et al. *2024*). Reference has also been made to competition (*Czerniak* et al. *2023; cf. Frirdich 2005; Shennan 2018; Porčić 2024.12*).

Though many of the details and methods used can be debated – the summing of radiocarbon dates, for example, remains a flawed method, on the open admission of one of its exponents (*Crema 2022*) – the emphasis on a wave of advance and on demographic growth and pressure seems to fit well the big-picture narrative of Neolithisation provided now by aDNA analysis. What we want to emphasise, however, is the over-general character of this perspective, especially for the early stages of Neolithisation in Europe. Admittedly in the era immediately preceding the aDNA revolution, a strong reminder was given of the potential variability and complexity of frontier conditions (*Barker 2006.378–379*), and in his many publications the late Marek Zvelebil patiently explored the possibilities for fusion models involving both incomers and indigenous people (*Zvelebil 1996; 1998; 2004; Zvelebil, Rowley-Conwy 2004; Zvelebil* et al. *2010;* see also *Porčić 2024.8*). These ideas seem largely to have been forgotten in the recent literature, though they seem still relevant to us. Even if the contribution of indigenous hunter-gatherers to Neolithic genetic signatures was generally low – and there is no space here to go into all the regional detail – that still leaves open the possibility that indigenous knowledge of landscapes and resources was of major importance in the colonisation process (*Bánffy 2004; Whittle forthcoming a; forthcoming b*). And hunter-gatherers did not all go away, as pockets of survival and the later re-emergence of U-haplotypes testify (*Bollongino* et al. *2013; Szécsényi-Nagy et al. 2015; in press; Lipson* et al. *2017; Bánffy 2023)*. Much of the aDNA sampling for early Neolithic populations has been within established phases of settlement, and as we have emphasised above in relation to Brunn 2, where a demonstrably very early situation has been investigated (in an admittedly tiny sample), interbreeding has been demonstrated.

Thus, without wishing to subvert the big picture which we have sketched earlier, we think we should be refining elements of a model for frontier conditions in the initial stages of Neolithisation. These appear to us to have been often fluid and unstable. There seem to have been variations in the rate of the spread of Neolithic people, things and practices across mainland Europe (for reasons of space, we here leave the Mediterranean aside (see *Leppard 2021*), though the same claim may well apply). It has been argued that the rate of spread in the central Balkans was faster than the continental average (*Porčić* et al. *2020)*, with a detectable slowing down north of the Sava and Drava (*Porčić 2024.7*): significant differences in the context of our discussion, since they bring variability. Moreover, summing of radiocarbon dates offers a possible bust or decline at the very end of the 6th millennium cal BC (*O.c.4*): yet another instance of possible reversal. What we further need to understand better are whether faster spread equated to greater or lesser density of settlement, and the duration of individual occupations, few of which have been precisely dated and modelled. We have suggested above that the scale of initial, pioneering settlement may regularly have been small and the gaps between pioneer occupations potentially considerable, even though wave of advance modelling, of for example a kilometre of advance or more per year (*LaPolice* et al. *2024; cf. Porčić 2024.6*), implies a much more regular setting up of the Neolithic presence. There may have been all manner of reasons for the abandonment, indeed failure, of settlement in given circumstances. Unfavourable climatic conditions are often summoned, for example at the end of the LBK in general (*e.g., Gronenborn 2010b*) and have been used in the interpretation of the end of the Phase II episode at Nowe Objezierze (*Czerniak* et al. *2023*); social tensions and disease are other main suspects, as discussed briefly above. We have also suggested, however, that low social connectivity, related in turn to small scale, is another potential suspect in processes of abandonment, especially in marginal situations. We should also fully incorporate leapfrog moves into a more nuanced model of frontier conditions, and not see these as just sporadic (*Porčić* et al. *2020.10*). These may have had varied motivations: to create space, to build prestige (*cf. Frirdich 2005*), or to avoid social tensions (*Porčić* et al. *2021*). And we could make allowance too for genuinely targeted colonisation. During their initial spread across central into western Europe, probably in the 54th century cal BC, farming groups of the earliest LBK reached out to three regions which were specifically rich in desirable salt water: the salt region of the Wetterau in north-west Germany, the Middle Elbe-Saale region in central Germany and the Cracow-Wieliczka salt region in south-east (Lesser) Poland (*Bánffy 2015*). A final element of a nuanced model for frontier conditions is interaction with indigenous population. Even though the contribution of local hunter-gatherers to genetic signatures is now shown by aDNA analysis to have been modest in the early stages of the Neolithic, nonetheless the people already there should still be accorded agency and influence. In the long term, we can note further changes. Whereas in the early Neolithic Starčevo and Körös culture-associated samples the U haplogroups were much rarer than in the hunter-gatherer populations, the frequencies of subvariants of U in Neolithic populations gradually increased in the LBK, and reached some 10–12% (especially of U5b) by the late LBK and in the succeeding Tisza and Lengyel phases of the earlier fifth millennium cal BC (*Szécsényi-Nagy* et al. *in press*).

Our aim in sketching a simple model of this kind is to reinforce the importance of local circumstance, and to make full allowance for variability from context to context. And while the wider literature can be seen as often too prone to over-generalisation if not universalising (*cf. Whittle 2023*), we can also reflect that risk, reversal and even failure have regularly been underplayed. Risk has often been seen as lying principally in unfavourable environmental or climatic conditions (*e.g.*, for the LBK, *Bogucki 1988; Gronenborn 2010b*), but social risk, for example in undertaking feats of construction under the gaze of a watching, critical public (*Richards 2004*), should also be kept in mind; pioneering as much as monument building can be thought of as risky. Likewise, when risk leads to bad outcomes, failure results, but probably too much attention has been given to major failures and collapses, like the fall of great empires (*Morrison 2006*), and not enough to ones on a smaller scale (*Price, Yaffe 2023*).

Finally, we believe that our call for a more nuanced view of the Neolithic frontier and the conditions of initial settlement could be useful in the detailed region-by-region interpretation of the spread of the Neolithic. Clearly this requires longer treatment than we have space for here, but an indication of its potential can be seen by brief, initial reference to some other situations across mainland Europe. Around the Aegean, including in Greece, for example, there seem to have been multiple strands in the process of initial Neolithisation (*e.g., Furholt 2016; Douka* et al. *2017; Özdoğan 2024; cf. Koptekin* et al. *2024*). Perhaps that set the tone, as it were, for the continuing colonisation of the Balkans. We have already noted the significant claim for a faster wave of advance in the central Balkans (*Porčić* et al. *2020*). There is still much to understand better about the timing and tempo of the spread of the earliest LBK (*cf. Lenneis, Lüning 2001; Jakucs* et al. *2016*) but the rapid nature of its spread, the patchy nature of its distribution and the often sizeable gaps between sites or clusters of settlement are striking. It is plausible that at least some of the spread was conditioned by existing connections created by the movement of raw materials by indigenous hunter-gatherers (*Mateiciucová 2008*). Seriation of pottery decoration in the west allows for finer phase estimates (*Strien 2017; 2018*), compatible in our view with continuing migration streams (*cf. Anthony 1990; 1997*). Jumping further west to the lower river valleys, coastal wetlands and estuaries of the Netherlands, a recent review of Neolithisation in the later fifth millennium cal BC stresses that "*there is no reason to assume that early farming appeared in the same way at the same time everywhere in northern Europe*" (*Brusgaard* et al. *2024.666*) and "*sweeping narratives should be reassessed to focus more on local trajectories and regional processes*" (*Brusgaard* et al. *2024. 667; cf. Whittle, Cummings 2007*). The appearance of the first sedentary settlements post-dates the initial appearance of domestic resources in the context of a mobile wetland economy, by around a millennium (*Amkreutz 2013; Dusseldorp, Amkreutz 2020. 124*). Lastly, there are several competing models for the start of the Neolithic in Britain and Ireland (full references in *Whittle forthcoming a; forthcoming b*). The wave of advance model has never been formally applied to Britain and Ireland, though informal representation of possible, time-transgressive processes of spread have been speculatively mapped on the basis of formal chronological modelling (*Whittle* et al. *2011. Figs. 14.177, 15.8*); those are now in need of revision. The possibility of successive migration events or streams has been suggested (*Thomas 2022; Whittle forthcoming a*), compatible with the aDNA evidence as it stands (*Brace, Booth 2023; Booth forthcoming*). Small-scale and low-key beginnings have been mooted (*Thomas 2022*), perhaps from the 41st to 39th centuries cal BC, but whether those excluded cereal cultivation in the initial stages (*Griffiths 2018*) remains debateable. There are controversial claims, on the basis of pollen analysis, for local experimentation with cereal cultivation in northern England, in the later fifth millennium cal BC (*Albert, Innes 2020; Innes* et al. *2024*). In Ireland, Neolithic settlement is much better documented from ENII, probably from the 38th century cal BC onwards, with earlier activity in ENI (back to *c.* 4000 cal BC) minimal (*Smyth* et al. *2020*). The aDNA evidence suggests the dominant presence of incoming farmers, though with some local interbreeding, for example in western Scotland (*Brace, Booth 2023; Booth forthcoming; Cassidy 2023*).

Conclusion

Ancient DNA analyses and robust chronological modelling have had a profound impact in recent years on wider narratives for the Neolithisation of Europe. There is, however, still considerable scope for the further integration of archaeogenetic and archaeological evidence and for working at varied scales. Our paper has suggested that a more nuanced approach to frontier conditions, early settlement and initial contacts with indigenous people is one important way ahead, making allowance in thinking about pioneering conditions and initial Neolithisation for fluidity, instability, variations in scale, duration and connectivity, and some interaction between incoming farmers and indigenous population. Risk and even failure should be taken into account. A simple model incorporating these kinds of factors serves to unpick some of the familiar generalisations of the dominant conceptualisations of an irresistible wave of advance, unrelenting demographic pressure and ubiquitous Neolithic success. Though generated by selected examples principally from the northern Balkans, the Carpathian basin and northern central Europe, such a model could have wider usefulness.

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Kinship questions: three sketches from the Neolithic of Britain and Ireland

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ABSTRACT - *Kinship, diverse webs of relationship generated by people in their social practice, has long been analysed and debated by anthropologists, from an earlier dominance of lineage theory to the current, much more fluid emphasis on relatedness. Since the days of processualism, archaeologists have given more attention to kinship than in the early years of the discipline, but in rather limited and general ways until very recently. With the advent of successful aDNA investigations, and with some prompt from posthumanist theory, that interest has been renewed recently. I discuss some inconsistencies between the accounts of kinship by anthropologists and archaeologists, notably the emphasis by the former on diversity, relatedness, the possibilities and implications of bilateral descent, and the uncertain relationship between biology and kinship. To begin to investigate how this might all work out in archaeology, I sketch three scenarios from successive parts of the Neolithic in Britain and Ireland, across the fourth to third millennia cal BC, attempting specific rather than generalised models and indicating the outlines of a possible trajectory through time.*

KEY WORDS – *kinship; relatedness; diversity; trajectory; Neolithic; Britain and Ireland*

Vprašanja sorodstva: tri skice iz britanskega in irskega neolitika

IZVLEČEK – *Antropologi že dolgo analizirajo in razpravljajo o sorodstvu in raznolikih spletih odnosov, ki jih ustvarijo ljudje v svojih družbenih praksah. Razprave segajo od nekdanje prevladujoče teorije rodu do sedanjega bolj fluidnega poudarjanja sorodnosti. Arheologi so od časov procesualizma sorodstvu posvečali več pozornosti kot v zgodnjih letih razvoja discipline, vendar do nedavnega na precej omejen in splošen način. Z uspešnimi raziskavami stare DNK in nekaj spodbude iz posthumanistične teorije pa se je zanimanje v zadnjem času povečalo. Razpravljam o nekaterih nedoslednostih pojasnjevanja sorodstva pri antropologih in arheologih; predvsem poudarjanja raznovrstnosti, sorodnosti, možnosti in posledicah bilateralnega potomstva ter negotovega razmerja med biologijo in sorodstvom pri prvih. Da bi začel raziskovati, kako bi vse to lahko delovalo v arheologiji, sem skiciral tri scenarije v zaporednih fazah neolitika v Britaniji in na Irskem, v četrtem in tretjem tisočletju pr. n. št.; pri tem poskušam oblikovati specifične in ne posplošene modele ter nakazujem obrise možne trajektorije skozi čas.*

KLJUČNE BESEDE – *sorodstvo; sorodnost; raznovrstnost; trajektorija; neolitik; Britanija; Irska*

Introduction

Over the years, anthropologists and archaeologists have treated kinship in very different ways. Intensely observed and debated since as far back as the 1860s and 1870s, anthropological views of kinship – perhaps the still best overall definition is given by Edmund Leach (*1982.107*; emphasis in the original) as "*a widely ramifying pattern of* named *relationships which link together the individual members of a social system*

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in a network ... The naming of relationships marks the beginning of moral sanctions" – have gone through a long series of changes of perspective: successively evolutionist, structural-functionalist and symbolist (*Parkin, Stone 2004.ix*). In the latter part of the twentieth century, following the work of David Schneider (*1968; 1984*), there was a revision of the significance of what had previously been regarded as at the heart of the discipline of anthropology (*Leach 1982.134*), with a shift to looser notions of 'relatedness' and care for others (*Carsten 2000a; 2004; Sahlins 2013*). Debate continues (*e.g., Shapiro 2016; Bamford 2019a; Kuper 2018; 2019a; Papadaki* et al. *2019; Ingold 2022.350–352; Miller n.d.*), as sketched further below.

By contrast, many archaeologists have long paid mere lip-service to anthropological notions of kinship. With the advent of processualism in the late 1960s and 1970s, the topic came more to the fore (*e.g., Edmonds 2019.19*), in the belief that kinship was a fundamental constituent of tribal and other non-western social existence and with renewed interest in schemes of social evolution or development (*Sahlins 1968; cf. Flannery, Marcus 2012*). On the whole, however, very little detail was suggested until very recently, other than vague reference to lineages, at a time when anthropologists had already moved on from lineage theory (in which stable, enduring descent groups were seen as the basic unit in stateless societies). In recent times, of course, the advent of successful aDNA analyses (*Reich 2018*), extending from population studies to the first detailed examinations of specific mortuary contexts, collective and other, has changed the game, and kinship, starting from biological relatedness amenable to investigation by aDNA analysis but also going beyond those limitations, is very much to the fore (*Fowler 2022*). Chris Fowler (*2022*), in the wake of the successful and thought-provoking aDNA-based study of the collective mortuary deposit at the Hazleton North long cairn in central-southern England (*Fowler* et al. *2022;* elaborated in *Cummings, Fowler 2023*), has given the best archaeological overview so far of kinship as diverse social practice in the Neolithic of Britain. This has coincided with further prompting from posthumanist theory, arguing for more fluid, creative, relational notions of kinship (*Johnston 2020; Crellin, Harris 2020; Crellin 2021*).

Nonetheless, in seeking to complement Fowler's and others' recent studies, there are further aspects to draw out: to emphasise the differing histories of the study of kinship in anthropology and archaeology; to underscore the diversity observed and debated by anthropologists and to consider the implications of such diversity, including the role of cognatic and bilateral systems; to look further at the role of biology in kinship; and to contemplate and speculate about possible differences through time, at least through the prism of changes in the Neolithic trajectory of Britain and Ireland. At stake are detailed questions about the possible character of small-scale social groupings and categorisations, allowing us potentially to move beyond so far often very general notions of 'community' and 'society'. This could obviously have significance for the wider study of the Neolithic as a whole.

Kinship: the anthropologists' and archaeologists' accounts

What archaeologists have to say about kinship is largely couched in the terminology derived from anthropology (and we may come to want to review that relationship in due course). I want to give a more historical or historiographical sense of how limited archaeological accounts have been until very recently. I am not attempting a full history of the development of thought in both disciplines, an impossible task in a short paper, but in making rather compressed comparisons I do want to try to bring out important differences, and some of the key remaining challenges for archaeology. There have of course been important periodic reviews of both disciplines, where the reader can find much more detail and many times more references than I have space to cite here (for anthropology, see *Leach 1982; Kuper 1999; Carsten 2000a; 2004; Parkin, Stone 2004; Eller 2013.chapter 8; Engelke 2017; Ingold 2018; 2022; Bamford 2019a*; for archaeology, see *Trigger 2006; Harris, Cipolla 2017; Chapman 2023*).

When the first detailed studies of kinship appeared in the 1860s and 1870s (*Maine 1861; Morgan 1871; 1877*), establishing an evolutionary interest in patterns of descent and affinity, and the terminology of patrilines and matrilines which is still in use, there is no sign that these were being read by early archaeologists. John Thurnam (*1869.177*), for example, in his examination of the remains from long barrows and long cairns, makes passing references to "*great chieftains or heads of some British clan*", and 'family tombs' used in 'successive generations' (*O.c. 224*), but goes no further than that. Jump over fifty years forward, and the pages of Childe (*1925; 1929*), for example in his *Dawn* and *Danube*, whose principal concern was to begin to make sense of the growing mass of archaeological evidence for the Neolithic and Copper Age (and Bronze Age) across Europe, are disappointingly thin on social interpretation, with the occasional reference to peasants and chiefs giving no idea of the by then much more detailed studies emerging from anthropologists like Bronisław Malinowski, William H. R. Rivers, Franz Boas and many others (*Leach 1982; Kuper 1999*). The more discursive *Man makes himself* from the 1930s (*Childe 1936*) offers little more, with only brief mention of clans (including 'totemic clans' in the early Nile valley, *O.c. 101*), kings and slaves. Likewise, the era of social anthropology in the middle part of the twentieth century of dominant British structural-functionalist models of lineages, especially unilateral descent groups, as a key constituent of acephalous societies as exemplified in studies of the Nuer, Tallensi and Tiv in east and west Africa (*Fortes, Evans-Pritchard 1940; Evans-Pritchard 1940; 1951; Bohannan 1952; Radcliffe-Brown 1952; Leach 1982.45–47*) found little or no direct echo in contemporary archaeological interpretation. The same fate befell the alternative 'alliance' theory of Claude Lévi-Strauss (*1949*), though this was belatedly to receive much more discussion through the idea of 'house societies' (see briefly further below). In the 1950s into the 1960s in Britain, for example, much debate centred on the difficulty of achieving reliable social interpretation at all (*Bradley 1984*, with references); *Ancient societies*, by two giants of the establishment of British prehistory, Grahame Clark and Stuart Piggott (*1965*), has practically no specific social interpretations at all, far less any reference to the anthropological literature of its time.

With the advent of processualism in the late 1960s and 1970s, and on into the post-processualist era from the early 1980s onwards, as already noted, the topic of kinship did receive more attention (*Edmonds 2019.19*). There were some attempts to provide more detailed and sophisticated models of social difference and change rooted in anthropological understanding (*e.g., Friedman, Rowlands 1977*). There were frequent appeals in the literature to generalised ancestors, for example as a source of legitimacy for emergent social factions (*e.g., Shanks, Tilley 1982*) or the inspiration for specific feats of construction, as at Stonehenge (*Parker Pearson, Ramilisonina 1998; cf. Parker Pearson 2023*), but this led in due course to severe criticism, albeit without detailed plausible alternatives for the Neolithic period itself (*Whitley 2002*). Mark Edmonds (*1999.98–103,109–129*) made perceptive suggestions about the possible role of kin groups in the planning and implementation of causewayed enclosures, though without any detail of their possible composition. An important general potential link with cattle in terms of fictive relatedness and descent was proposed (*Ray, Thomas 2003;* see also *Ray, Thomas 2018.295–297*).

There were other, now rather striking, gaps in these processual and post-processual phases. Although the processual era ushered in a much more explicit interest in models of social development, in Britain exemplified by Colin Renfrew (*1973; 1979*) but drawing on a longer trail of comparative studies in the American tradition, going back to Elman R. Service, Morton Fried and Marshall Sahlins, and before them to Julian Steward and Leslie White, and other predecessors (see *Trigger 2006; Flannery, Marcus 2012* for references), specific references to the role of kinship, descent and affinity remained surprisingly scarce. The narrowing of focus in post-processual approaches seems to have been one culprit (there is more to say on this, but space precludes it here), though the lack of awareness in processual interpretation is more puzzling. The diversity of situations by then being explored by anthropologists (so often the leitmotif of overviews of social anthropology (*e.g., Leach 1982.123; Engelke 2017.314; Ingold 2018.27; 2022.1)* does not seem to be reflected in archaeological models of the time. That African lineages did not seem to fit observations of highland communities in Papua New Guinea (*Barnes 1962*; and see further below) passed archaeologists by, as did the devastating critique of lineage theory (*Kuper 1982; 1988; 1999*), perhaps best summed up in Adam Kuper's (*1982.84*) striking judgment that "*the Nuer are not like* The Nuer". Kuper's account is complex but emphasises how a particular model worked more as an abstraction for anthropologists than as a robust description of diverse situations on the ground, involving among other things lack of permanence, considerable variability, liability to change, and other dimensions of local and territorial groupings. He concluded that "*there do not appear to be any societies in which vital political or economic activities are organized by a repetitive series of descent groups*" (*O.c. 92*). Further, it has long been emphasised that 'cognatic' systems of kinship, in which common ancestry is traced through both male and female links' are just as common as those dominated by unilineal descent (*Leach 1982.167;* see also *Freeman 1961; Sahlins 1968.54–55*). Finally, I can find no reference in the archaeological literature of the time (but I make no claim to an encyclopaedic search) to the major critique of kinship studies as whole by David Schneider (*1968; 1984*), which argued that previous interpretations had falsely imposed a western, specifically American, model of a biological basis to kinship on other parts of the world. That led to kinship generally falling out of anthropological focus (but note *Strathern 1992*) for a generation or so, until revived by Janet Carsten (*2000a; 2004*) and others, but the archaeological literature of the time seems silent on these great shifts.

A slow convergence of sorts has been taking place since. From the turn of the millennium, the anthropological study of kinship was revived (*Carsten 2000a; 2004*). At one level, Janet Carsten's *After kinship* simply constituted renewed, further studies of kinship (*Carsten 2004; Bamford 2019a; Hirsch, Rollason 2019.16*), but since that time kinship has no longer been the defining trope of anthropology (*Moore 2010.20.footnote 9; Ingold 2018.98*). Instead, the much looser and freer notion of relatedness has taken over, "*to convey ... a move away from a pre-given analytic opposition between the biological and the social on which much anthropological study of kinship has been based*" (*Carsten 2000b.4*). With "*the boundaries between the biological and the social ... distinctly blurred, if visible at all*", issues of gender, the body and personhood come much more to the fore (*Carsten 2000b.3*). Much of Carsten's own work has covered case studies such as gender assignment, adoption, surrogacy, artificial insemination and blood and organ donation (*Carsten 2004*, covered also quite extensively in chapters in *Bamford 2019a,* including *Carsten 2019*), but she has also looked at the relevance of more fluid notions of kinship for migration studies (*Carsten 2020*). She contrasts two anthropological models of kinship, centred on static notions of being and descent versus doing, becoming and performance (*O.c. 321–322*). The emphasis on performance has also been strongly asserted elsewhere (*Engelke 2017. 6; Ingold 2018.100, Fig. 4 caption; Bamford 2019b*).

The issue of biology has been explored in recent times most extensively by Marshall Sahlins (*2013*). His short book is full of examples of the social construction of kinship, whose essence he defines as a 'mutuality of being', with repeated examples worldwide of how the facts of generation and birth are not the defining features of how people go on to be classified and treated in life. From the very start, in the opening sentences of his preface, he insists that "*kinsfolk are persons who participate intrinsically in each other's existence; they are members of one another*" (*O.c. i*). Reviewing the book enthusiastically, Carsten (*2013.249*) notes nonetheless the enduring 'sticky paradox' of the biological-social divide; "*the more one tries to dispense with the dichotomy, the more one seems to end up reiterating it*". Just as the notion of relatedness may prompt endless questions of definition (*Miller n.d.*), so too may Sahlins' definition make it very difficult to draw distinctions between kin, neighbours, allies and others, but his contribution should at the least serve to make archaeologists much more aware of the challenge. Tim Ingold (*2022.350–352*), as part of a wider, generalising discourse on philosophical and anthropological approaches to life, has referred to notions of filiation ("*the fundamental human bond between parent and child*", *O.c. 350*), going back to Meyer Fortes; "*filiation – and the kinship it engenders – is supremely rhizomatic; its lines do not connect but are themselves lines of life that carry on alongside one another, answering or responding to one another – or literally corresponding – as they go*" (*O.c. 351*). On a different note, Warren Shapiro (*2016*) has challenged the performative account of kinship championed by Sahlins and Carsten, and before them Schneider, reasserting the significance of indigenous kinship categories. Kuper (*1982; 1988*), who as noted above helped to demolish the previously perceived importance of lineage theory and was further another, earlier severe critic of Schneider (*Kuper 1999; cf. Feeley-Harnik 2019*), has comparatively recently called for fresh attention to be paid to kinship (*Kuper 2018*). And other anthropologists go on with the task of investigating changing attitudes to kinship in particular contexts (*e.g., Papadaki* et al. *2019*; *Firth 2019.97; Goddard 2019.231; Eriksen, MacCarthy 2019.354*).

Signs of change in the archaeological literature came with a series of case studies through the Neolithic sequence of Greece, drawing attention to the neglect of kinship in social archaeology (*Souvatzi 2017*). An encouraging general statement frames things – "*Kinship is about much more than just blood ties. It is a domain of social relations; a framework of action, rules, and rights; a powerful means to stretch identities across space and time; and a mode of structuring time, history, and memory*" (*O.c. 172*) – and ways of weaving kinship into narratives of settlement and landscape are explored, but the theoretical and historiographical background is largely passed over and few suggestions are made about specific kinship relations. It is also worth mentioning the critique of patrilocality as the dominant mode for the European Neolithic, which combines isotopic, aDNA and archaeological analyses (*Ensor 2021*).

Meanwhile, the diversity of turn-of-the-millennium theoretical and interpretive approaches in archaeology shifted gradually to the relational, ontological or material turn. There are clearly many strands to this (*Harris, Cipolla 2017; Harris 2021*) but interest in themes of gender (see also *Robb, Harris 2018*), body, identity, flow, affect, vibrancy and others rather obviously overlap with the wider remit of anthropological relatedness. But in the search for material agency in a complex world, there is no sign until very recently of special attention being given to kinship (absent, for example, from the index of *Harris 2021*; see further below). Other less theoretically driven recent archaeological syntheses for Neolithic Britain and Ireland also still make very restrained use of notions of kinship and descent, especially still that of lineage (*e.g., Bradley 2019*). Vicki Cummings (*2017.137, 188–189*) has been more explicit than many others, even if very brief, while Keith Ray and Julian Thomas (*2018. 47,119,172*) have perhaps been the most explicit of all; their notion of 'invested lineages' (*O.c. 113,171,312–314*) underpins their interpretation of both houses and tombs in the early Neolithic of Britain, though they do not spell out further just what kinds of descent and relationships they envisage in this concept. There has been one exception to this reticence, in the form of the idea of house societies, derived from models of kinship by Lévi-Strauss (*Borić 2008; Thomas 2015; Richards, Jones 2016; Ray, Thomas 2018*). This is also discussed by Fowler (*2022.3–4*). The notion is not in itself a form of kinship, and it has been applied to so many diverse situations that it is often hard to understand its specific force. Interesting though it is, there is not space to pursue it further here.

As already indicated in the introduction, in the wake of the recent successful development of aDNA analysis, there have been important investigations of collective and other mortuary contexts, which have enabled close examination of particular situations beyond the initial attention given to population-level studies (*e.g.,* among others *Sánchez-Quinto* et al. *2019*; *Cassidy* et al. *2020*; *Cheronet* et al. *2022*; *Rivollat* et al. *2023;* see also *Meller* et al. *2023*). Those include the ground-breaking analysis of the human contents of the Hazleton North long cairn in the Cotswolds of central-southern England (*Fowler* et al. *2022*; *Saville 1990*). Fowler's further reflections on whether it is possible to see patterns of kinship in the varying architecture of early Neolithic tombs, cairns and barrows (*Fowler* et al. *2022*) are the first sustained and detailed attempt that I know of in Neolithic studies to align archaeological with anthropological interpretation of kinship. He strongly emphasises process and performance, as underlined above in discussion of the anthropological literature post-Schneider, and correctly underscores the fact that aDNA analysis is the investigation of biological relatedness. His account of the history of archaeological research into kinship, however, is quite brief and compressed, which why I have given a more extended historiographical review above, and whether the potential diversity of performed kinship arrangements is to be easily read from the varying plans of tombs and monuments is perhaps more open to question in principle than he allows. He and Vicki Cummings have elaborated their interpretation of Hazleton North and its context (*Cummings, Fowler 2023*), which I discuss further in detail below.

Other posthumanist approaches to kinship have been made very recently. The most extensive, book-length, treatment is by Robert Johnston (*2020*), primarily applied to the Bronze Age in Britain and Ireland, but with obvious relevance to Neolithic and other studies as well (and cited on that basis by *Fowler 2022*). In setting out his inspiring stall, seemingly with a principal reliance on Sahlins (*2013*), Johnston (*2020.15–18*) pronounces five main features of kinship as he perceives it: its ability to create personhood and collective belonging; its association of people with nonhuman beings, things and landscapes; its historical situatedness; its making through the sharing of substances and what are called presences; and its creative, performative and political nature. In a similar spirit, a perceived diversity of kin relations has been emphasised, in an attempt to underscore relationality and avoid binary opposition between nature and culture (*Crellin, Harris 2020; Brück 2021; Crellin 2021*). It is interesting to reflect on the theoretical sources here. Several of these themes overlap with the more recent, more fluid anthropological emphasis on relatedness. Some, however, are so broadly framed that it is often hard to see (as noted above with reference to *Sahlins 2013*) what is specifically to do with kinship, rather than with a general model of sociality (for example, including 'relational work', *Bandelj 2020*), of a mostly warm and positive kind (as opposed to anything more negative, as noted importantly by both *Carsten 2013,* and *Bamford 2019b*). Thus, disappointingly, though Robert Johnston (*2020*) asserts the ubiquity of 'kinwork' and 'kinfolk' right from the beginning of his book, he never attempts to differentiate or further characterise kin relationships; it seems inherently improbable that these were uniform and unchanging throughout the span of the Bronze Age in Britain and Ireland. The dominant citations from the literature are to the broad ontological literature (for critique, see *Whittle 2018*), and the details of and historical shifts in anthropological models as such are not given.

So plenty of questions remain to be debated. I see getting to grips with diversity, specific contexts, finding plausible ways to account for changes through time, and the ever-troubling relation between kinship and biology as particularly significant challenges. How can we follow patterns of kinship rather than broader trends in sociality?

The performance of kinship: three sketches from the Neolithic of Britain and Ireland

To offer a first start at addressing these questions, I give three brief sketches from the Neolithic of Britain and Ireland. The fullest is of the Early Neolithic, but I hope the other two may serve to point to ways of thinking about change through time. I will obviously make use of recent aDNA results, but hope fully to engage the archaeological evidence as well. My account is deliberately speculative.

Early Neolithic

I am not attempting complete coverage of the Early Neolithic from the late fifth to past the middle of the fourth millennium cal BC. I simply pick things up at the point probably around 3800 cal BC when monuments start to become more prominent. One of the most striking developments in recent times has been enhanced evidence for biological relatedness – or its absence – through aDNA analysis of mortuary assemblages.

Completed aDNA studies of this kind are still comparatively rare. The general picture for early monuments seems to be one of diversity. Patrilines have been suggested as the dominant arrangement found in megaliths in western Europe (*Sánchez-Quinto* et al. *2019*), but differences in fact are also documented. Studies in western France indicate a mixture of related and non-related people being deposited (*Cheronet* et al. *2022*). In Ireland, there were also diverse arrangements, as seen in the relatively small sample of sites so far available. There was a lack of close biological relations in both the early portal tomb at Poulnabrone (from *c.* 3800 cal BC onwards) and the probably slightly later court tomb at Parknabinnia, leading the investigators to "*exclude small family groups as their sole proprietors and interpret our findings as the result of broader social differentiation with an emphasis on patrilineal descent*" (*Cassidy* et al. *2020.387*). Is it kinship as opposed to alliance or other relationships which is being expressed here? (It is also worth noting the apparent father-daughter relationship found in analysis of the remains from Primrose Grange (*O.c.; Cassidy 2023*).) There was also a network of distant relatives in the passage tombs examined so far, some of which may go back to earlier centuries of the Neolithic (*Cassidy* et al. *2020; Cassidy 2023*). If Chris Fowler's (*2022*) point is accepted that chamber architecture is related to kinship arrangements (though that claim is not unproblematic, given the instances above where close biological relations do *not* predominate), then we should expect further diversity. Perhaps that is characteristic of pre-Indo-European societies, with Indo-European societies (perhaps from the late fourth or third millennia cal BC onwards) being said to be predominantly patrilocal and patrilineal (*Pronk 2023*).

Penywyrlod, in inland south-east Wales, probably dating from the 38th century cal BC onwards and arguably one of the earliest constructions in its local area (*Britnell, Whittle 2022*), raises similar questions, though here without the benefit of aDNA because of poor preservation. Its large stone cairn probably contains several small lateral chambers, the investigated examples of which so far excavated have yielded varying, fragmented and small assemblages of human bone. Strontium isotopic evidence suggests a comparatively wide-ranging population, at a lifetime scale. We cannot therefore be certain in this and many other cases, but it is plausible on the basis of these isotopic analyses that Penywyrlod served a wider population, perhaps with multiple kinds of biological and social relationships, as seen in the diverse representation of age and sex groupings in the small assemblages of human bone excavated so far (*Wysocki 2022*), in a context of initial, pioneering inland settlement.

The most stunning aDNA case study for the early Neolithic in Britain and Ireland so far has been that of the Hazleton North, Gloucestershire, long cairn. Here in the two opposed lateral chambers and passages (*Saville 1990*) were the remains of 41 people; it was possible to obtain high-quality genetic information from 35 of these, 27 of whom proved to be close biological relatives (*Fowler* et al. *2022*). The main picture is well published (*O.c.; Cummings, Fowler 2023*). Thus, over five generations in the earlier and middle part of the 37^{th} century cal BC, deposition of the dead was carried out in parallel in both chambers, that on the north side interrupted and partly curtailed by the collapse of the northern passage. In the first generation, a man deposited in the innermost part of the north chamber had reproduced with four women, the remains of three of whom were recovered, two on the north side and one on the south side; the existence of the fourth is inferred from her descendants placed on the south side. Subsequent generations could trace relationships through the male line. There was a general lack of young adult females and indeed a total absence of any adult females born into the social group represented. Isotopic and other analysis had also already suggested a pattern of mid-range mobility at a lifetime scale and a diet rich in animal protein and including dairy products. In addition, there is strong evidence for the importance of maternal sub-lineages, with dominant continuity in those represented on the south side and also strong though not as complete continuity on the north side (*Fowler* et al. *2022.586*). Women were also important in that offspring from unions from other fathers not represented in the monument were also deposited, which could evoke adoption and 'adoptive kinship' (*O.c. 587*). There were also "*eight individuals without evidence of close biological relationships or reproductive partnerships with others in the pedigree*" (*O.c. 586*).

From these and other observations a possible model of "*patrilineal descent, virilocality, polygyny and cattle husbandry*" was aired (*O.c. 586*). There is little reason to doubt these features, but an equally strong impression is of the diversity of the situation. The women in the first generation must also have been significant individuals, and it may be telling that one of them is absent, though that woman could have died before the monument was conceived (*Cummings, Fowler 2023.10–11*); there are of course many other such tombs in the Cotswolds, including the unexcavated Hazleton South close by. Their descendants in the respective maternal sub-lineages are also prominent.

It is also possible to examine the diachronic and chronological situation in a little more detail (for which there was hardly space in the original *Nature* publication, supplementary information notwithstanding, but now made fully good in *Cummings, Fowler 2023*). The genetic analysis showed five generations, whereas the initial Bayesian modelling of the radiocarbon chronology of the monument had suggested probably three (*Meadows* et al. *2007*). Clearly, further modelling will be desirable, with both more radiocarbon dates to come and genetic relationships acting as further powerful priors in future modelling (Chris Fowler, Alex Bayliss, *pers. comm.*). It is possible nonetheless to offer some preliminary analysis of the generational pattern of succession as it stands (it is also worth noting the arguments of *Cummings, Fowler 2023.10* for probable generational overlap). We do not know if the first generation was itself responsible for the construction of the monument, or whether that was in fact the work of the second generation (*Cummings, Fowler 2023.7*); but if the latter, the case for lineage expansion in the first two generations (*O.c. 10*) is perhaps harder to support. That second generation is dominated by the adult sons of the women in the first generation (NC4, NE1, NE2 in various locations on the north side, plus an infant boy, NC5; and SC2, SC3 and SP1 on the south side, along with an infant boy who is a candidate for adoption from another union not otherwise represented). By the third generation, there is a strong emphasis on younger members, grandchildren of the first generation, which shows particularly on the north side (the side of the initial reproductive male); perhaps this represents an emphasis on continuity, though it has also been discussed in terms already of waning and decline (*O.c. 12*). In the fourth generation, there is a mix of ages and sexes; one adult male, NC9, is again placed at the back of the north chamber adjacent to the 'founder' male (though Chris Fowler notes (*pers. comm.*) that locational information is imprecise). The fifth generation is found only on the south side, perhaps a reflection of the north passage collapse or perhaps a final indication of the successful continuity of the south-side maternal sub-lineages. These relationships may of course alter in detail with further chronological modelling (and see *Cummings, Fowler 2023* for further valuable detail), but overall what is striking so far is the combination of both stable and unstable arrangements and relationships. It may be unwise to construct any rigid model of a fixed, closed, unaltering patriline, since the maternal sub-lineages were clearly important, and some kind of bilateral descent could have been in question; there is the further dimension of the bilateral layout of the two opposed chambers (and their relationship to place in terms of placing relative to the pre-existing midden). It has been noted elsewhere in the vast global literature (see above) on kinship arrangements how bilateral systems tend to have a finite, relatively short span (*Foxhall 2000; Forbes 2007*). There is a tendency perhaps in the case of Hazleton and many other instances to seek more or less precise analogies with ethnographically documented systems. Such matching may be an historical chimera, but an alternative approach for Hazleton (since the account in *Cummings, Fowler 2023.2, 3, 13–14* is still very much in the language of lineages) might be to think in terms of Melanesian big men, bolstered by an agnatic core but needing the support of many others including matrilateral kin and affines, and usually destined for a brief floruit (*Barnes 1962.98–101; Sahlins 1968, 88–89; Martin 2019.375*).

It is important to underline the probable construction date of Hazleton North, in the earlier part of the 37th century cal BC (*Meadows* et al. *2007; cf. Cummings, Fowler 2023.13–14*). Not far away from Hazleton North is the rather similar long cairn at Ascott-under-Wychwood, also with opposed sets of lateral chambers or cists, containing a mortuary population not dissimilar to that in Hazleton North; Ascott, however, dates probably to the second part of the 38th century cal BC (*Bayliss* et al. *2007a; Benson, Whittle 2007*), and so far, aDNA analysis of its human remains has not been carried out, though that would now be highly desirable for better understanding of sequence and development.

By the earlier 37th century cal BC, the Cotswolds may have been occupied for a couple of centuries (subject to the remodelling underway for *Gathering Time*). The latest revised models suggest that enclosures probably still appeared around the turn of the 38th century cal BC, but with a broader initial distribution than the previously suggested east–west spread (*Whittle* et al. *2011; 2022; forthcoming*). Enclosures became more numerous through the course of the 37th century cal BC, and reached the peak of their use in the 36th century (*Whittle* et al. *2022*). A few more enclosures have been discovered in eastern Ireland (*Whittle* et al. *forthcoming*).

These developments were a radical transformation of the physical and social landscape. Enclosures may reflect a more numerous population, a plausible enough claim after three centuries or more of early Neolithic settlement. The idea of these constructions was surely based on knowledge and memory of enclosures on the adjacent continent, but it was activated in Britain and Ireland long after continental practice had begun (*Whittle* et al. *2011; 2022; forthcoming*). We have argued that enclosures both reflect and create a more competitive social milieu; some of the evidence for that can be seen in the occurrence of violent attacks and burnings, though that is not found in every case (*Whittle* et al. *2011; 2022*). These three observations may be linked. It has also been claimed that enclosures can show the whole community at work, perhaps 'the largest cooperating social unit' of the time (*Shennan 2018.101–103; cf. Pechtl 2009; Guilaine 2018; Vondrovský* et al. *2022*). Depending on the size of the enclosures in question and the temporality of phases and scales of construction, that might not always be the case, but there is no doubt that many of these undertakings, both in terms of the labour involved in building and of the people and things coming from afar to use these places, did represent a more intense order of social interaction (*cf. Cummings, Fowler 2023.15–16*). The question then remains of who drove such an innovation in the first place, before the phenomenon achieved its own momentum and dynamic of emulation, tradition and history.

Such a question has tended to be overlooked in the literature, with an unstated assumption that things would develop naturally on a trajectory from simple and more fragmented to complex and more integrated. At the same time, there have long been social inferences from the characteristically segmented ditch layouts of the involvement of multiple groupings (*Oswald* et al. *2001*), and general speculation about the possible role of kinship groups (*e.g., Edmonds 1999.98–103,109–129*). In the proposed shifting social scenario it is plausible that more self-conscious and self-defining social groupings such as seen at Hazleton North by the earlier 37th century should have emerged. We can now therefore think in more concrete terms about the possible role of more rather than less tightly defined or self-defining kinship groupings, perhaps lineages or kindreds or both, in the adoption, practice and elaboration of the enclosure idea. Actual evidence of biological relatedness at enclosures themselves remains sparse in southern Britain; there are the disarticulated remains of three maternally related 1st-degree relatives at Whitehawk (*Brace, Booth 2023.140*) and one of these had distant biological relatives in Normandy (*Booth forthcoming*) – and so far, tantalisingly, that is about all we have to go on directly. If the trail of the enclosure idea, however, leads back to continental sources, it is plausible that this could have happened along lines of ancestral connection (*cf. Anthony 1990; Carsten 2020*). Even if enclosures represent a wider community at work than seen previously in other constructions and activity, there is the question of mobilisation. More or less self-defining but open lineages or kindreds could have been one contemporary kind of social grouping that could have risked innovation and motivated others to contribute to bigger shared enterprises. The modelled histories of the neighbouring Windmill Hill enclosure and the West Kennet long barrow, with the construction of the long barrow woven in between the building of the inner and outer circuits on the one hand and that of the middle one on the other (*Whittle* et al. *2011.chapters 3,14*), strongly suggest that enclosure building and kin groupings were actively contemporary ideas, and thus arguably interacting. There are signs that the earliest enclosures in southern Britain may have been relatively simple in terms of layout and labour (*Whittle* et al. *2022*) and thus feasible for smaller social groupings working on their own. Almost all the many individual activities seen at enclosures (*Whittle 2014; 2022*) could be broken down to be within the reach and scope of lineages or similar social groupings. The diversity of the situation at Hazleton North, stressed above, is potentially important in this regard, as adoptive kin and others associated but not biologically related would have served significantly to extend the network of connections and alliances that may have been necessary initially to bring enclosures into existence.

Middle Neolithic

My last two examples are much briefer. For the Middle Neolithic, from the later fourth into the earlier third millennia cal BC, I want to draw attention to both probable diversity and possible signs that kinship may not always have been a benign strand in society.

One element in mortuary practice from the latter part of the Early Neolithic and on into the Middle Neolithic is the development of more individualised burials (*Whittle* et al. *2011.724*). I follow Keith Ray and Julian Thomas (*2018.159–161, 221*) in seeing a "*growing preoccupation with particular lines of descent*". In the unusual case of Duggleby Howe, Yorkshire (*Gibson, Bayliss 2009*), funerary activity began in the 36th or 35th century cal BC – at a time when enclosures were still in use further south – with a deep grave shaft being used for the burial of four individuals, predominantly adult men, two with marks of trauma or violence (a fifth individual is represented by the severed head of a woman). After a probable gap of one to three centuries, the funeral around 3000 cal BC was that of a mature man (Burial C), in an adjacent shallow grave. Isotopic analysis indicates that none of these individuals were local, and that some lived far away, even perhaps on the Continent. Burial C was accompanied by worked flints, a bone pin, two beaver incisors and 12 boars' tusks. A small mound was subsequently raised over these graves, containing further burials, and later, possibly around 2800 cal BC (*O.c.*), over 50 deposits of cremated human bone were inserted into an enlargement of the mound. So far, no aDNA analysis is available for this sequence (but it is underway, Tom Booth, *pers. comm.*), but we could speculate that it represents, at least down to the early third millennium, a series of named ancestors or forebears, with the gaps between funerals not too great to be covered by living memory. Though I am again wary of precise analogies from ethnography, perhaps something akin now to the all-important counting back through the generations of lineages among the Tiv (*Bohannan 1952*) could be involved here. Descent may be becoming a weapon in power relations.

In the different context of Orkney in the late fourth millennium cal BC and around the turn of the millennium, collective burials in a variety of styles of tomb were still the norm (*Edmonds 2019; Bayliss* et al. *2017*). Kin groupings are plausible. Comparatively little aDNA analysis is so far available, and there was a lack of close biological relatives in small samples from Isbister and Holm of Papa Westray North (*Armit* et al*. 2016*; *Olalde* et al. *2018; Sheridan* et al*. 2019*); recent discovery of a Maeshowe-style chambered tomb with preserved human remains at Blomuir (*Current Archaeology 2024*) may soon expand the range of sampling. At the major settlement of Ness of Brodgar, a series of impressive, large stone-built houses in existence around and just after the turn of the millennium (*Card* et al. *2017; 2020*) could be seen, from their individual characteristics, to represent separate communities or something like clans (*Edmonds 2019.263*) or kindreds, brought together in this dominant focus in the landscape. Among the monuments of this broad horizon, probably from the 32nd century cal BC, people were building large, impressive passage grave monuments, including nearby Maeshowe, whose architecture, decoration and contents evoke important connections with the developed passage tombs of eastern Ireland.

That brings in another stunning recent discovery, thanks to aDNA analysis, of the adult son of a first-order incestuous union (between either parent and offspring or perhaps siblings) in a central position in the chamber – in the most elaborate recess – of the major passage tomb at Newgrange in the Boyne valley (*Cassidy* et al. *2020*). This probably dates to the late fourth millennium cal BC, the apogee, with Knowth and Dowth in the same Boyne group, of the Irish passage tomb tradition and notable for its scale, architectural sophistication and the range from which constituent materials were brought in (*Hensey 2015; Schulting* et al. *2017; cf. Lynch* et al. *2014*). Incest of this kind is seen as rare, and comparisons are said to have been documented almost exclusively among 'politico-religious elites', specifically within "*polygynous and patrilineal royal families that are headed by god-kings*" (*Cassidy* et al. *2020.384*), examples being cited from Hawai'i, the Incas and ancient Egypt (*O.c. 385; cf. Flannery, Marcus 2012*). Fairly distant biological relatives are also detected in both Carrowkeel and Carrowmore out to the west (*Cassidy* et al. *2020.386*). As far as I know, we do not have further information from other individuals in Newgrange or neighbouring Knowth. Cassidy *et al.* (*2020.385*) see such 'dynastic incest' as part of the 'deification of political leaders', and as "*a means of intensifying hierarchy and legitimizing power*", "*alongside tactics such as extravagant monumental architecture and public ritual*"; speculate that such practices may have extended to Wales, Orkney and Brittany, because of the link of shared architecture; and even talk in terms of "*early states and their precursors*" (*O.c. 386,387*).

This needs a bit of unpicking. I think that the reference to early states is unhelpful, since so much else characteristic of early states is missing from the Middle Neolithic record in Ireland and Britain. The Breton exemplars which have prompted speculation about Neolithic kings (*e.g., Jeunesse 2017*) are much earlier, and the claim for a much wider set of practices is open to discussion. It has also to be noted that incest does not universally incur the same level of taboo, historical and ethnographic counter-examples being given by both Robin Fox (*1967.63*) and Edmund R. Leach (*1982.51,115,233*). Nonetheless, the examples of dynastic incest are compelling (*Cassidy* et al. *2020.385*, citing *Wolf 2014*), and the isolation of the Newgrange example perhaps clinches that kind of explanation (though this is controversial). If so, here is a case of kinship being potentially part of unequal social relations and even coercive practices, and it may be telling that the apogee of the passage tomb tradition appears to have been quite short-lived.

Late Neolithic

My last example is even briefer and largely speculative, but develops the themes of extreme differentiation just discussed. At the end of the Late Neolithic, there was a flurry, not to say a frenzy, of major construction projects, before and perhaps overlapping with the arrival of Beaker practices and people, around 2400 cal BC. At least some of these undertakings appear to have been carried out swiftly, as at Mount Pleasant, Dorset, in the generations either side of 2500 cal BC (*Greaney* et al. *2020.219, Fig. 12;* see also *Marshall* et al. *2024*). The two largest heroic feats of assembly and building, Stonehenge and Silbury Hill, are very different in conception (*Parker Pearson 2012; 2023; Parker Pearson* et al. *2020; 2021*; *Whittle 1997a; 1997b; Leary* et al. *2013*) but similar in outrageous scale. The current consensus view is probably that the major sarsen phase (Stage 2) at Stonehenge preceded the building of Silbury Hill, these taking place perhaps a century or so apart at *c.* 2500 and *c.* 2400 cal BC respectively (*Darvill* et al. *2012; Parker Pearson* et al. *2022; Parker Pearson 2023.14; Leary* et al. *2013*), though in my view there may still be unresolved questions of detail about the currently available chronology of Stonehenge (*Bayliss* et al. *2007b*) and these two constructions might be closer in time, offering rival, more or less contemporary, conceptions of the origin of the cosmos (*Whittle 1997a; 1997b*).

Though great strides have been made in recent years in the understanding of Stonehenge and its wider context (*Parker Pearson* et al*. 2020; 2022; Parker Pearson 2023*), there is much still that we do not easily comprehend. Our knowledge of mortuary practice at this time, which had shifted to dominant cremation rites, is limited, though small cremation cemeteries could be consistent with all manner of kinship arrangements in line with practice earlier in the Neolithic (*Willis 2021*). Likewise, our knowledge of settlement and landscape at this time is decidedly uneven, with the broad exception of Orkney in the north. It is striking, however, in a recent review of Grooved Ware pottery across Britain and Ireland how a whole series of regional studies emphasise the shifting and comparatively slight evidence for settlement in the last stages of the Neolithic in southern Britain, better seen now in the context of often large-scale investigations in advance of development (*Barclay 2024; Brook 2024; Cleal, Pollard 2024; Evans* et al. *2024; Garwood 2024; Jones, Quinnell 2024*). While there is still much more to be done with the fine grain of settlement, this surely raises the question of how the major constructions of the end of the Late Neolithic, and especially those of Stonehenge and Silbury Hill, were actually brought about in a context of potentially patchy population levels (*Armit, Reich 2021; Booth forthcoming*), albeit one with evidence for extensive movement of both people and animals (*Snoeck* et al. *2018; Madgwick* et al. *2019*). Paul Garwood (*2024. 241*) has suggested authoritarian ideologies and fundamentalist mythologies as driving monument building at this time. Could all this have been effected through the calling in of scattered kinship connections and obligations, by elites again (as in Middle Neolithic Ireland) claiming kinship with the divine? And was the ensuing "*fragmentation, disillusion, rejection and rebellion*" (*O.c. 241*) made all the more inevitable because of the irresistible attractions of more normal, intimate kinship arrangements among Beaker people, a return to the named relationships and moral code with which people had been familiar over the longer term?

Conclusion

I have tried to show in more detail than commonly attempted in the archaeological literature how until very recently archaeological interpretations of kinship have lagged far behind those of anthropology. In catching up with current looser anthropological definitions of kinship as relatedness, practice and performance, archaeologists nonetheless risk blurring, in generalised models of sociality and mutuality, principally of a benign kind, what could be distinctive about kinship. The issue of the role of biology in kinship remains problematic; we have learnt to be suspicious of it, but some of the most instructive case studies of kinship in recent times, enabled by aDNA analysis, are founded on the genetic identification of biological relatedness. I have also argued that specific models are needed. Through examples taken at intervals across the sequence of the Neolithic in Britain and Ireland, I have suggested the outlines of a possible trajectory, from fluid arrangements among pioneers and early communities, to more self-defining groupings and namings at the time of established tomb building and enclosure construction, through to diverse practice in the later fourth millennium, including the incestuous union at Newgrange, suggestive of elite differentiation, and perhaps some kind of lineage at Duggleby Howe. Finally, I have speculated briefly on whether the drivers of massive constructions at the end of the Late Neolithic also made use of appeals to kinship with the divine, before a return to more grounded, familiar and acceptable notions in the Beaker period.

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Tracing social inequalities in the Early Iron Age. A multiproxy approach from Punta de Muros (NW Iberia, Spain)

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ABSTRACT - *The excavation of the settlement of Punta de Muros was a breakthrough in our knowledge of the Early Iron Age of the Iberian Peninsula. The development of new multidisciplinary research has broadened our understanding of the site and clarified several facts about the emergence of fortified landscapes. This paper synthesizes these advances and focuses on the development of social inequality trends within a non-hierarchical society between the 6th and the 4th centuries BC. The reflection of these changes in the archaeological record will be addressed, focusing on what forces triggered these internal transformations and to what extent we can define the emergence of social inequality.*

KEY WORDS – *Early Iron Age; NW Iberia; Europe; Prehistory; social change*

Na sledi družbenim neenakostim v starejši železni dobi. Večplastni pristop v naselbini Punta de Muros (SZ Iberskega polotoka, Španija)

IZVLEČEK – *Izkopavanje naselbine Punta de Muros predstavlja prelom v poznavanju starejše železne dobe na Iberskem polotoku. Razvoj novih meddisciplinarnih raziskav je razširil naše razumevanje najdišča in razjasnil več dejstev o nastanku utrjenih krajin. Članek povzema ta napredek in se osredotoča na razvoj družbene neenakosti znotraj nehierarhične družbe med 6. in 4. stoletjem pr. n. št. Obravnavali bomo odsev teh sprememb v arheološkem zapisu, s poudarkom na tem, katere sile so sprožile notranje spremembe in kako obsežna je bila na začetku družbena neenakost.*

KLJUČNE BESEDE – *starejša železna doba; SZ Iberskega polotoka; Evropa; prazgodovina; družbene spremembe*

Introduction

Punta de Muros (Arteixo, A Coruña) is an Early Iron Age (hereinafter, EIA) settlement located on the Atlantic façade. The site was entirely excavated in 2005 due to the construction of the Outer Port of A Coruña (*Cano Pan 2012*), which also entailed its subsequent demolition. Despite this unfortunate end, the huge amount of information that was collected provides an excellent framework for challenging our understanding of this period. This paper explores new research advances and proposes a diachronic review of the site, focused on the emergence of social inequalities between the 6th and 4th centuries BC.

As in other European territories, the social landscape of the northwest of the Iberian Peninsula underwent a profound change at the beginning of the Iron Age (850–400 BC). This process marked the transition to a fortified and sedentary habitat, which was the only

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strategy of occupation for almost a millennium in NW Iberia (*González-Ruibal 2006–2007.160*). Here, the EIA is defined as a fortified landscape that prioritizes the occupation of conspicuous and prominent places with high visibility, with small settlements (*Parcero-Oubiña 2000.86–87*) structuring a deeply fragmented and potentially conflictive context (*Fábrega Álvarez 2005*).

This model of occupation brought a remarkable break with the dynamics of the Late Bronze Age (hereinafter, LBA). The LBA (1200–850 BC) was based on a semi-nomadic way of life, with non-fortified open settlements close to the valley bottoms and a high degree of mobility, as reflected in the wide circulation of bronze objects on a large scale (*Armada, Martinón-Torres 2016*). At the same time, different strategies of social inequality emerged (*Parcero-Oubiña* et al. *2020.156*). LBA societies were probably focused on encouraging warrior values and promoting the role of the 'champion' within the community (*González García 2009.63*). It is necessary to underline the emergence of personal leadership focused on certain collectives, perhaps with the typical strategies of 'Big Men' societies (*Armada 2012*). In this context, the accumulation of objects and prestige goods, the increase of which is highlighted in this period (*Comendador Rey 1999*), would have fostered these social differences, and legitimized a value system that glorified predominant collectives, such as warriors.

The process of 'fortified sedentarization' during the EIA brought about a significant change in LBA ways of life. In the social sphere, the system of prominent leaders collapsed in favour of the strengthening of a more 'egalitarian' *ethos* (*González García* et al. *2011*), rejecting unequal values (and the symbols that underpinned them), in favour of a more collective worldview (*Nión-Álvarez 2023a.258).* This is reflected in the disappearance of the main cultural patterns of the LBA, such as a progressive abandonment of several prestige goods and iconographic representations, as well as an abrupt rejection of mobility and foreign goods (*González-Ruibal 2006–2007.242).* In line with this, the EIA settlements represent a marked rejection of the dynamics of inequality, expressing different mechanisms of resistance to hierarchization and social change (*Parcero-Oubiña, Criado-Boado 2013*).

Punta de Muros: methods and results

The present study is based on different investigations which have carried out an effective multidisciplinary study of the site. As a brief review, the archaeological works involved the complete excavation of the settlement, as well as 53 archaeological surveys in the surrounding area (*Cano Pan 2012.788*). Several underwater surveys and a morphostatistical analysis of the related ceramic production were also carried out, as well as malacological, anthracological, palynological and archaeometallurgical analyses (*Cano Pan 2012.10–12*). Subsequently, the knowledge of the settlement was strengthened by architectural (*Ayán-Vila 2012*), socio-metallurgical (*Nión-Álvarez, González García 2023*), chrono-statistical (*Nión-Álvarez 2023b*) and paleodemographic studies (*Nión-Álvarez 2023c*), among others.

All these data make Punta de Muros one of the sites with a larger volume of scientific information in the northwest Iberian Peninsula. However, some problems affecting the study area should be point-ed out, such as the high acidity of the soils (*Fernández Marcos* et al. *1994*), which prevents the effective conservation of materials such as wood, bones or metal (especially iron) or the lack of identification of phenomena such as burials (*Nión-Álvarez 2023d*). This situation has fuelled other fields of study, such as architectural or chrono-statistical analysis, aiming to exploit the possibilities of the available evidence.

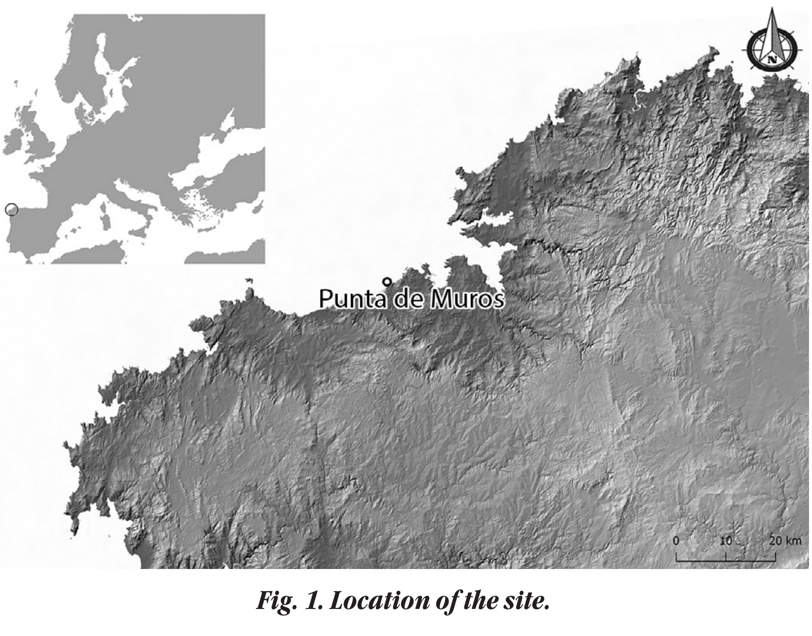

Fig. 1. Location of the site.

Punta de Muros is a fortified settlement of barely one hectare in size, based on a small peninsula. The origin of the settlement dates back to the mid-9th century BC (*Nión-Álvarez 2023c.9).* During this period, Punta de Muros had a simple and non-organized layout, with a few dwellings scattered across the fortified enclosure. This rampart defines the boundaries of the dwelling area, as it is common in this period and region (*Ayán-Vila 2012.403*). It is interesting to note that this is the only building that shows evidence of collective work and symbolic activities during this period, a fact that hints at its value as a community symbol (*Haber 2011.26–28*).

The dwellings are characterized by being simple and uniform across the settlement. They are all small (none of them cover an area of more than 35m^2) and have no internal divisions or spaces dedicated to productive activities (*Nión-Álvarez 2023a.258*). Even a significant activity such as metallurgy (*Cano Pan, Gómez Filgueiras de Brage 2010*), does not have specialized areas detached from the domestic sphere. The case of Structure III is quite meaningful: it has a furnace for the reduction of copper ore in the same place where cooking and resting activities were carried out, as it can be traced by the presence of tools and pottery for cooking and everyday activities (*Nión-Álvarez, González García 2023.59*). This simplicity is evidenced by the absence of restricted space inside the dwellings and the straightforwardness of their accessibility (*Cano Pan 2012. 690*).

Fig. 2. Aerial image of Punta de Muros (from* Cano Pan 2012.102*).

This phase can be dated to between the mid-9th century BC and the end of the 6th century BC (*Nión-Álvarez 2023b. 10*). However, a difference should be noted between the first period (Phase 1A), which lasted until the middle of the 8th century BC, and a second (Phase 1B), which lasted until the end of the 6th century BC. There is hardly any archaeological difference between the phases: the most relevant difference relies on a gradual (albeit significant) demographic increase, according to radiocarbon dating and paleodemographic studies. Several calculations based on the inhabited area suggest an annual growth rate of around 0.30%. Even with the most conservative calculations, this implies that the population of the village had doubled at the end of Phase 1 (*Nión-Álvarez, 2023c.8*). However, we should remain cautious about these numbers, as the radiocarbon data are affected by the Hallstatt Plateau, which significantly affects the accuracy of samples dated in this period (*Hamilton* et al. *2015.2–3*). In this sense, it cannot even be ruled out that this progressive demographic increase was part of a whole dynamic that dates back to the beginning of the settlement's occupation.

However, Punta de Muros underwent a significant change between the end of the 6th century BC and the beginning of the 4th century BC (*Nión-Álvarez 2023b.9*). The most remarkable change is an extensive process of the concentration of family units in new dwellings of greater size and complexity. This involved both the concentration of old, previously built domestic units (*e.g.,* Structures XII-XVI) and the creation of large dwellings from scratch (*e.g.,* Structure XXIII), creating houses three or four times larger than in previous periods.

All these examples of domestic complexity are chronologically related to Phase 2 (*Nión-Álvarez 2023b.10*). The case of Structures X and XI is particularly representative of this process, as it relates archaeological and architectural contexts with the whole occupational sequence of the settlement. Structure XI was built in Phase 1A (PEC 8407, see Table 1) as a simple dwelling of small dimensions (27.5m^2). Later, in Phase 1B (PEC 8425), Structure X was built nearby with similar characteristics (21.8m^2). However, both units were merged to create a single domestic unit in Phase 2 (PEC

9647), reusing the western wall of Structure XI for internal compartmentalization (*Cano Pan 2012.325*). This process can be hinted in other examples (*e.g.* Structures XII-XVI or XVII-XVIII-XIX-XIV) and also coexists with much simpler domestic units, similar to those from earlier phases (*e.g.,* Structure XXVIII).

This array of domestic changes is also reflected in accessibility and mobility strategies, creating more complex transit patterns (*Cano Pan 2012.697*).

Changes in the domestic space are related to three key issues: a division and individualization of the

CODE	Nº	DATE (BP)	CAL BC (95% confidence)	PHASE	SAMPLE LOCATION	LOCATION DETAIL	MATERIAL DATED	PLANT SPECIES
PEC 8343	2	2150 ±35	231-52 BC		Structure VI	Collapse level	Charcoal	*Fabaceae*
PEC 8345	3	2480 ±35	700-547 BC	1B	Structure VI	Hearth	Charcoal	*Quercus sp.*
PEC 8347	4	2550 ±35	796-547 BC	1B	South Access	Isolated charcoal	Charcoal	Unknown
PEC 8353	5	2495 ±35	771-544 BC	1B	Rampart (external area)	Hearth	Charcoal	Unknown
PEC 8354	6	2485 ±35	699-548 BC	1B	Rampart (external area)	Hearth	Charcoal	Unknown
PEC 8407	7	2620 ±40	830-774 BC	1A	Structure XI-b	Hearth	Charcoal	Unknown
PEC 8425	8	2500 ±35	773-544 BC	1B	Structure X	Hearth	Charcoal	Unknown
PEC 8429	9	2710 ±40	879-793 BC	1A	Structure XIV	Hearth	Charcoal	*Fabaceae*
PEC 8432	10	2485 ±40	773-537 BC	1B	Structure IX	Hearth	Charcoal	*Fabaceae*
PEC 8433	11	2460 ±40	766-519 BC	1B	Structure IX	Hearth	Charcoal	Unknown
PEC 8441	12	2010 ±40	103 BC-121 AD		Structure VII	Isolated charcoal	Charcoal	Unknown
PEC 8444	13	2620 ±35	827-777 BC	1A	Rampart (external area)	Isolated charcoal	Charcoal	Unknown
PEC 8446	14	1035 ±30	955-1045 AD		Rampart (internal area)	Isolated charcoal	Charcoal	Unknown
PEC 8447	15	2480 ±35	700-547 BC	1B	Structure XVI	Hearth	Charcoal	*Quercus sp.*
PEC 8451	16	2375 ±35	538-402 BC	2	Rampart (external reinforcement)	Isolated charcoal	Charcoal	Unknown
PEC 8455	17	2555 ±35	797-548 BC	1B	External area of the settlement	Isolated charcoal	Charcoal	Unknown
PEC 8486	18	2660 ±35	887-783 BC	1A	Structure XIX	Stratum below the hearth	Charcoal	Unknown
PEC 8496	19	2425 ±35	542-412 BC	2	Structure XXV	Isolated charcoal	Charcoal	*Quercus sp.*
PEC 8498	20	2375 ±35	538-402 BC	2	Structure XXIII	Hearth	Charcoal	*Fabaceae*
PEC 8513	21	2480 ±35	700-547 BC	1B	Structure XIb	Stratum below the hearth	Charcoal	*Quercus sp.*
PEC 8529	22	2510 ±35	778-544 BC	1B	Structure XXX	Hearth	Charcoal	*Fabaceae*
PEC 8532	23	2385 ±35	539-406 BC	2	Structure XXXII	Hearth (second level of use)	Charcoal	*Fabaceae*
PEC 8536	24	2480 ±35	701-547 BC	1B	Structure XXXII	Hearth (first level of use)	Charcoal	*Quercus sp.*
PEC 9647	25	2395 ±35	540-407 BC	2	Structure XIa	Hearth	Charcoal	Unknown

Tab. 1. Radiocarbon dates of Punta de Muros (from* Nión-Álvarez 2023b.12*).

Fig. 3. Structures from Punta de Muros (numbered).

space, the creation of specific productive areas and an increase in the capacity to store goods. Intra-domestic compartmentalization embodied a different way of conceiving the dwelling, shifting from simple, multifunctional units to specialized and individualized ones. This process expresses the specialization of certain tasks and their separation from the activities of resting, cooking and consumption. Metallurgy may be a representative example: metalworking activities were removed from the domestic environment during Phase 2 (*Nión-Álvarez, González García 2023.62*), finding new spaces outside the dwelling (*e.g.,* Structure XXXIII) or specialized, individualized areas (*e.g.,* Structure XXIII). Other evidence of specialization, related to craftsmanship or processing raw materials (see Structures XIII and XV, *Cano Pan 2012.355,586*), as well as new environment for storing goods (*e.g.,* Structure XXIII), also separated from domestic activities, have also appeared within these new compounds. These shifts in domestic space came along with an increase in the percentage of large storage vessels. The dwellings of Phase 2 show a significant increase in storage pottery (see Table 2): while they represent about a 10% of the pottery found on Phase 1 houses, they surpass 30% in the large dwellings of Phase 2 (even exceeding 60% in some cases: *Nión-Álvarez 2023a.259*).

Structure XXIII provides an insightful example about these changes. Built during Phase 2 and in use between 5th and 4th centuries BC, it was the largest building in the settlement ($130m^2$). Its architecture illustrates the aforementioned task specialisation, setting apart different areas for cooking, resting, storing goods or performing metalworking activities (see Fig. 8). Metalworking, indeed, shows a significant change: it acquired a specific and specialised place, separate from the rest of the activities, marking a clear difference with the domestic environment of Phase 1, in which metalworking and domestic activities shared the same location.

With regard to consumption strategies, the uniformity of NW Iberian EIA pottery (*González-Ruibal 2006–2007.228*) hinders a comprehensive functional analysis. However, there was a progressive reduction in the percentage of kitchen and tableware ceramics between Phases 1 and 2 (from 10.1% to 4.1%), parallel to the increase in storage vessels. In this regard, the emergence of new specialized activities and storage areas within the household led to new needs in terms of pottery production, and therefore to a change in the materiality of the domestic units. Finally, a significant absence of imported goods might also be noted (*Nión-Álvarez, González García 2023.59*), an issue that will be discussed below.

These profound changes in domestic space reflect a paradigmatic shift in the settlement, as strategies of town planning (*Ayán-Vila 2012.399*) and specialized buildings began to appear. In addition to productive structures (such as metalworking areas like Structure XXXII), the most outstanding example is Structure XX. It is a round building with an area of around $6m^2$, probably with a cultic/religious purpose. This structure was surrounded by a continuous bench running along the entire length of its inner wall, excluding a small 'niche' carved to host an outsized monolith (*Cano Pan 2012.431*). There is evidence of intentional deposits in some parts of the atrium, as well as of bonfires inside it (*Cano Pan 2012.755*). To the south, there is an open courtyard bounded by two walls, occupying an area of

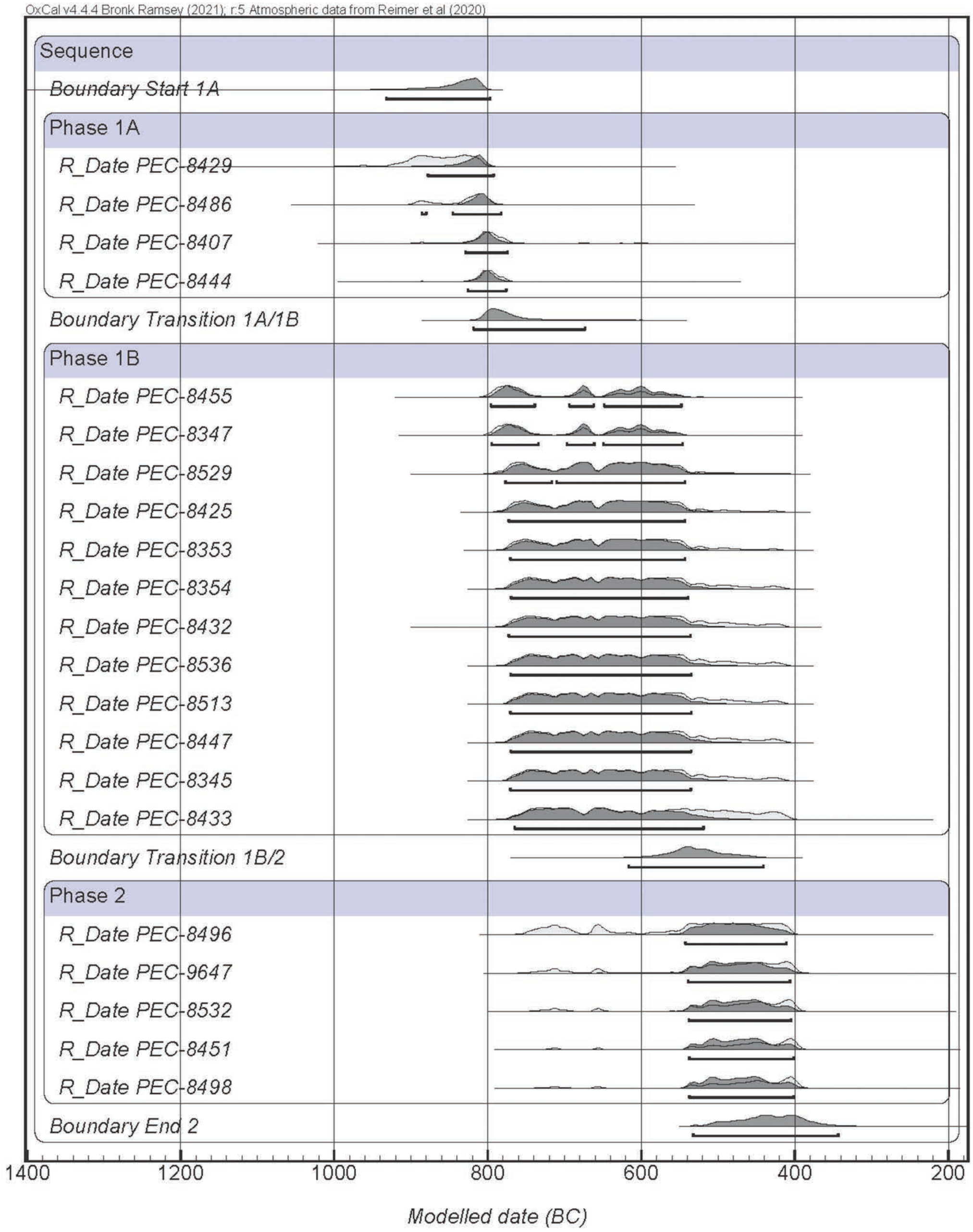

Fig. 4. Modelled radiocarbon dates (from* Nión-Álvarez 2023b*).

about 150m². Structure XX has some elements which are representative of a religious context, such as the continuous bench (*González-Ruibal 2006–2007.596*) and which embody an architectural model that would be replicated during the following centuries (*Nión-Álvarez 2023a.269*).

Tracing the emergence of inequalities

In the following section, the archaeological context of Punta de Muros from the point of view of societal organization will be examined. Logically, this topic will touch on concepts such as 'social inequality', 'hierarchy', or 'social difference', some keywords whose significance will come to mind just as quickly as their intrinsic problems. Therefore, throughout this reflection on Punta de Muros' societies, a brief depiction of how we understand these concepts will be provided when appropriate.

One of the key questions about Punta de Muros' social transformations is to define to what extent the changes in Phase II implied a shift towards models of social inequality. In some ways, archaeology may not tackle this issue fully and effectively. This is not only due to the usual problems arising from archaeological contexts, but also to the application and influence of some narrow perspectives that constrain the emer-

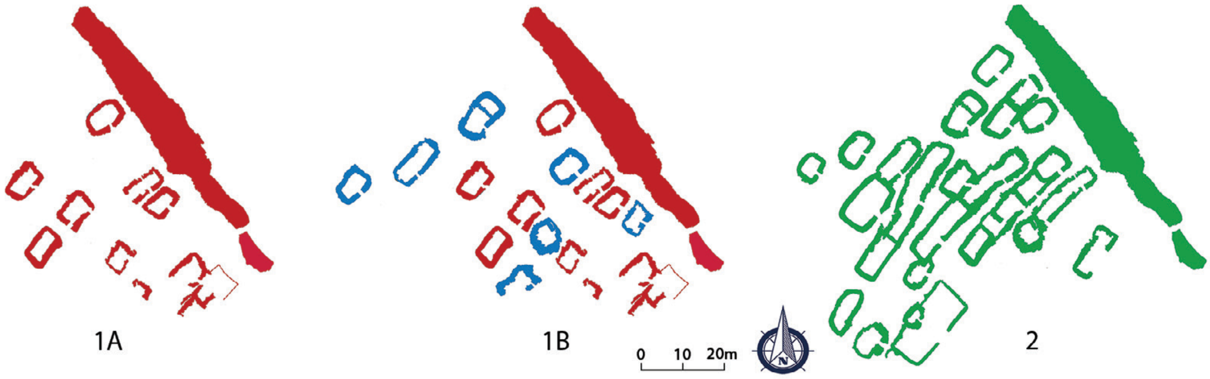

Fig. 5. Phases of occupation.

gence of inequalities to concepts such as coercion or a transactional economy (*McGuire 2022.491*). The emergence of inequalities in ancient societies should not be understood as one specific phenomenon, especially if it is mostly referred to present rather than past contexts. On the other hand, as Kenneth Ames (*2010.20–23*) suggested, it is particularly difficult to identify any community without any kind of social disparity, as almost all communities show a system of status and internal organization.

In my personal opinion, the works of Pierre Clastres may be helpful with regard to understanding egalitarianism and inequality, at least at a theoretical level. Clastres' works have been already used to analyse different kinds of human societies (*Demoule 1999; Parcero-Oubiña, Criado-Boado 2013; González García 2017*), and have proven to be highly valuable for societal analysis, since they suggest a key factor to pay attention to in order to define unequal societies. It is undoubtedly true that criteria such as gender, age or origin are prone to generate intra-communitarian differences, regardless of the degree of social inequality. However, what is defined as social inequality stems from how the relations between individuals in each community are structured. Egalitarian communities are defined as such because they are composed of equal individuals who ignore what inequality means (*Clastres 1981.122–123*), and thus the life of any individual is not worth more or less than that of another – it is neither inferior nor superior. It may be possible that some people can acquire a higher social status according to certain circumstances based on prestige, but always to a degree that is far smaller than that seen in hierarchical systems. If there is a chief in an egalitarian community, then they do not exercise power because they are worth 'more' than another member of the community, but because the community allows and empowers their position. The relations of power are equitable, and the ruler is not detached from the social body but must justify their power in front of the community, based on the idea of 'social debt' (*Heusch 1987*). Victor Turner (*1980.103–109*) defines this subordination of the chief's privileges to their community as a 'slave in power'. In this kind of society, the government is 'perpetually indebted' to its community, as its position and prestige depend on the fulfilment of its prerogatives and responsibilities (*Clastres 1981.139,147*). Pierre Clastres (*1978*) described such societies as 'undivided' and 'against-the-state', but others have applied other definitions, such as 'deep rural' (*Jedrej 1995*) or, in more economic-based approaches, 'transegalitarian' (*Hayden 1995*). While these positions have explored different views, both identify forms of social organization in which the ruler irrevocably depends on communitarian decisions, even though the inner degree of inequality may vary. In any case, the community is the only political decision-making unit, with several centrifugal mechanisms to preserve social cohesion.

Returning to Punta de Muros, and as discussed above, there are two clearly differentiated phases of occupation. Phase 1 is consistent with both the current knowledge of the EIA and the previously noted social issues. There is a lack of signs of social hierarchy or inequality, and the settlement seems to be the basic unit of political organization: there is no evidence of other agents capable of structurally imposing their decisions on the rest of the community (*Nión-Álvarez, González García 2023.57*). In this sense, we can consider them as 'undivided' from a Clastrian point of view: everything points that relations were established among equals that ignored inequality.

However, the transformations of Phase 2 paint a different picture. In contrast to a static, immobile and change-resistant EIA (*González García* et al. *2011*),

Domestic Unit	Area (in m²)	% of storage vessels In overall pottery record	Has dedicated storage space	% of cooking vessels in overall pottery record	Radiocarbon Dating
Phase 1A/1B					
III	28.1	21.5		5.8	
VI	18.1	7.1		3.0	700-547 BC (PEC 8345)
IX	25.2	5.1		11.1	699-548 BC (PEC 8432) 704-546 BC (PEC 8433)
X	21.8	_		0.7	697-546 BC (PEC 8425)
XI(b)	27.5	_		_	829-780 BC (PEC 8407)
XII	20.9	0.0		10.5	
XIV	27.7	_		_	853-796 BC (PEC 8429)
XVI	26.9	33.2		11.8	700-547 BC (PEC 8447)
XXIV	23.4	8.6		1.3	
XXV	28.0	0.0		18.5	
XXVIII	36.8	29.3		0.0	
XXX	34.2	17.7		0.0	654-549 BC (PEC 8529)
XXXII	19.8	5.8		47.8	701-547 BC (PEC 8536)
Mean	**26.0**	**12.4**		**10.1**	
Phase 2					
X-XI	68.8	37.5	Yes	1.6	518-401 BC (PEC 9647)
XII-XVI	114.3	27.7	Yes	16.6	
XVII-XVIII-XIX-XXIV	154.2	27.3	Yes	5.6	
XXII	25.8	_		_	
XXIII	130.5	58.4	Yes	0.7	517-399 BC (PEC 8498)
XXVIII	36.8	29.3		0.0	
XXIX-XXX	108.8	14.8		0.0	
Mean	**91,3**	**32,5**		**4.1**	

Tab. 2. Dwellings of Phases 1A, 1B and 2 (according to **Nión-Álvarez 2023a.260*).***

these changes hint at a breakdown of the non-hierarchical values. Perhaps the most meaningful argument is the process of aggregation, division and specialization of the domestic sphere, an illustrative proxy for increasing social complexity (*Steadman 2015*). The appearance of large household groups implied a substantial change in family relationships and community strategies. The emergence of specialized activities in some houses, as well as houses with dissimilar sizes, marks a clear break from the uniformity of Phase 1 dwellings. The necessity to distinguish the individuality of domestic spaces usually represents a fracture of the collective *ethos* (*Gerritsen 2007*).

In view of these approaches, it is worth considering to what extent the relationship between equals traced back to Phase 1 broke down in Phase 2. Pierre Clastres (*1978.175*) established a dichotomy: societies can be "*for the state or against the state*". It might be worth mentioning that Clastres considered as 'the state' any kind of political subjugation by some individuals towards others, an intentionally broad and polemical definition that intended to undermine ideas based on Marxist and ecological-liberal ideology, as well as to detach social division from modern perceptions of statalized power (*Clastres 1981.165–180*). In this regard, we need to reflect to what extent it is possible to suggest a breakdown in egalitarian relations and, at the same time, to what extent it is useful to use contingent categories to interpret these changes. Transformations in Punta de Muros' domestic architecture have been related to the appearance of different lineages/collectives with greater or lesser influence (*Nión-Álvarez, González García 2023.65*). In contrast to the previous uniform context, this points to the emergence of new social agents with greater agency in the village's decision-making. Aspects such as the different capacity to store or obtain goods, as well as specialization in certain activities, may indicate a further step towards a process of greater social fragmentation and inequality. In addition, it should be noted that these transformations have an eminently local root. In spite of some proposals that have suggested the relevance of the trade and production of objects (*Cano Pan, Gómez Filgueiras de Brage 2010.52–54; Cano Pan 2012.773*), no material evidence of foreign contacts has been found (*Nión-Álvarez 2021.185*). For instance, there was no evidence of early Punic productions (*García Fernández 2020*), and the common ware shows evidence of a geological composition from local deposits.

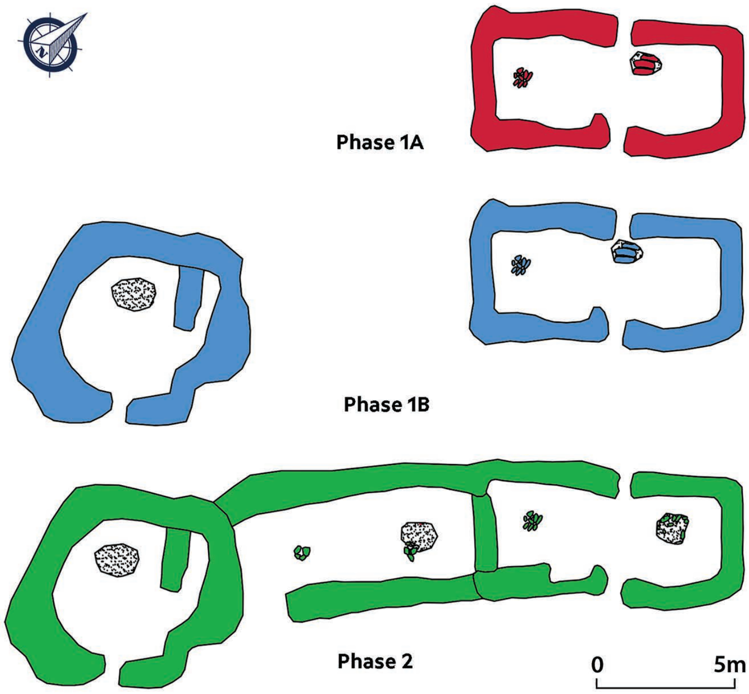

Fig. 6. Changes in Structure X and XI across different phases (modified from* Nión-Álvarez 2023b.9*).

The archaeological record points to a significant shift between Phases 1 and 2. However, and regardless of the issues on archaeological diachronic analysis (*Feinman 2023.350–351*), there exist two substantial difficulties in societal analysis: identifying the emergence and consolidation of social inequality and how we can define it. In this regard, it may be necessary to reflect on the differences between inequality and hierarchy. Naturally, any process of hierarchization entails inequality, but not all inequality can be labelled as hierarchy. Social hierarchization may be considered as the existence of a structural collective that holds certain privileges by its very nature, implying a potentially inheritable structural inequality (*Nión-Álvarez 2024.65*). However, stable inequalities can arise without inheritance systems and class differentiation. If we move further away from materialistic and economistic views, it is possible to trace alternative societal forms of organization. Inequalities do not usually emerge from wealth or land control: there are different kinds of 'capital' to accumulate and waste in order to express inner differences (*Bourdieu 1992. 111–113*). Indeed, the rise of differences usually came from social prestige, which could be obtained in many different ways. This fact links up with Sahlins' (*1963*) idea of Big Men and later reinterpretations. The Big Men proposals aimed to fill the gap between egalitarian and hierarchical models, but, in my personal opinion, I find it a bit narrow to categorize social dynamics. This is indeed an issue with any kind of categorization (*Feinman 2023.349*), as any explanation of change cannot set a univocal formula (*Giddens 1995.270–271*). In any case, it may be more appropriate to define these kinds of societies as 'potentially unequal', rather than to apply Big Men models, as there are different factors that can trigger a change in social strategies. In fact, the emergence of internal inequalities does not only rely on the appearance of Big Men, as it is not unusual for lineages or families that achieved great prestige to reinforce status differences in contexts without class differences. In these cases, status and prestige rely on customary laws and inter-familial honour (*Jamous 1981.181–188*). In addition to this, even in some Big Man contexts there is not only one Big Man, but many: they are defined by their success in prestigious tasks and, therefore, they achieve a higher social position (*Godelier 1986.167–168*).

According to Clastres, it is not clear that these contexts reflect a 'debt inversion', but it may reflect the beginning of social division. Following Hayden (*1995.56*), about 70% of the Big Men of New Guinea were descendants of other Big Men. This fact highlights the potential of such contexts to perpetuate and legitimize privileged positions. In this regard, a fracture of horizontal relations can be observed, but there is still no group with a structural class predominance.

In Phase 2 of Punta de Muros, evidence suggests the emergence of several individuals with greater agency in the village's decision-making. Aspects such as the different capacity to store or obtain goods, as well as specialization in certain activities, indicate a further step towards complexity from relations of reciprocity and dependence to a process of greater social fragmentation and inequality. These contexts point towards a 'potentially unequal' society, in which different agents acquired more power than others and, therefore, may retain a greater weight in decision-making. As discussed above, defining different degrees of inequality is not easy, especially from a strictly archaeological point of view. In this regard, it is difficult to identify if it is the beginning of an unequal society or even the onset of a process of social hierarchization. In this case, it is perhaps enough to identify a path towards social inequality that may have culminated, some centuries afterwards, in a process of social hierarchization, as has been argued (*Nión-Álvarez 2023c.266–267*).

It seems interesting to link these changes with demography and the environment. Palaeodemographic studies do not indicate any correlation between the appearance of complex domestic units and a demographic increase, ruling out this factor as a trigger for social change. In fact, it has been highlighted that the growth rate was very similar in all periods, being even slightly lower in Phase 2 (*Nión-Álvarez 2023c.8–9*). In this sense, the increase in the size of the living space in each dwelling does not necessarily imply a demographic increase: extended family models allow for more members in each unit, but with a lower density of occupation than in nuclear families (*Flannery 2002. 424*). Along these lines, paleoenvironmental studies also seem to suggest that demographic pressure on the landscape did not imply any abrupt changes in the surrounding vegetation. Pollen studies show a low presence of forest species, following the usual trends of coastal environments (*Gómez-Orellana, Ramil Rego 2012.1019*). The expansive presence of shrubby species such as *Fabaceae* (*Martín Seijo 2012.936*) does not stem from a process of deforestation resulting from the demographic pressure, but as part of a gradual demographic dynamic (*Gómez-Orellana, Ramil Rego 2012.1018*) consistent with palaeodemographic studies. In addition, it is likely that this strong presence of *Fabaceae* was encouraged by the inhabitants of the settlement, as it was commonly used as firewood in the Iron Age (*Figueiral, Bettencourt 2004).*

The changes in the patterns of settlement organization are also significant in terms of societal analysis. During Phase 2, a new set of criteria led to a complete reconfiguration of the layout. Among other changes, the emergence of religious buildings marked a profound shift with respect to cult areas and expressions of earlier phases, which were exclusively focused on the defensive systems. In Phase 2, however, cultic activities shifted from the walls towards new buildings constructed under hierarchical and restrictive criteria. In Structure XX, the courtyard seems to be accessible to the public, but the inner part of the building is invisible from the outside and its access seems to have been reserved to a small number of individuals (*Cano Pan 2012.755*). In this sense, the value of religion in structuring unequal models has recently been emphasized in Iron Age studies (*López-Mondéjar 2014; Fernández-Götz, Roymans 2015; Stegmaier 2017*). Religion operates as a binding element of collective identities, promoting the reformulation of cultural schemes under identitarian frameworks linked to power collectives (*Assmann 2011.123–138*). This makes religion an 'enabler' in cases in which social dynamics shifted toward inequality (*Aldenderfer 2010.8792*), building environments in which collective participation is essential, but in which some rituals are restricted from the whole community.

Finally, changes in household units and social structure may have also triggered changes in kinship relations. In other Iberian Iron Age contexts where larger domestic units have emerged, the dwellings were usually defined by several structures around a courtyard or corridor (*Grau-Mira 2013.63–64*). This type of dwelling is often associated with patrilocal residence patterns and patrilineal descendancy (*Blanco-González 2020.126*). However, the complex houses of Punta de Muros were structured differently: they were built on a single building, with internal divisions and housing different hearths with cooking and resting areas, in addition to storage and production spaces. The construction of these large dwellings (with more than 50–60m^2 of living space, *Porčić 2010.406–407*) tend to relate to matrilocal residence patterns in 85–90% of cases, according to kinship studies (*Ember, 1973; Divale 1974*). Recent phylogenetic studies have confirmed the statistical validity of these approaches (*Hrnčić* et al. *2020*), although there are some exceptions that may pose problems, especially in non-agricultural contexts (*Porčić 2019*). These interesting hints, however, should be taken with some caution, given the impossibility of carrying out genetic or isotopic analyses on skeletal remains.

Discussion and conclusions

Phase 2 of Punta de Muros has shown a remarkable transformation of the settlement. Between the 6th and the 4th centuries BC there was a dynamic of social fragmentation in the domestic sphere, a higher degree of specialization in certain tasks, a new planning strategy on the settlement's layout or a shift in religious expressions towards more hierarchical forms of worship. All these changes seem to have brought a dramatic transformation in the social *ethos* of the settlement. In our opinion, there are some aspects that point to the emergence of internal inequalities, showing the appearance of several powerful groups with enough potential to influence the decision-making process. Accordingly, this is no longer a relational system established 'between equals', but a context in which different individuals retain a privileged position according to their lineage or occupation. The coexistence of very different domestic units suggests a context of 'stable inequality' which, according to the radiocarbon dates, lasted only a few generations, which prevents asserting the emergence of a truly hierarchical system.

It is also worth considering whether this possible social imbalance is based on belonging to a family affiliation (such as the *iqar'iyen* of north Africa, *Jamous 1981*) or whether it depends on certain collectives whose occupation gives them a predominant, non-structural position (as with the Baruya of New Guinea, *Godelier 2014*). The possibility that the knowledge of metalworking may have been a key factor in the social rise of certain groups has recently been proposed (*Nión-Álvarez, González García 2023*), and it is true that the production of metal acquired a certain degree of specialization, controlled by some of the most outstanding households (*Nión-Álvarez, González García 2023. 66*). However, not all large dwellings produce metal, so this response can only emphasize metalworking as an activity that enhances the prestige of those who know and perform it, but not as a main driving force of social inequality. In other words, the metalworkers of Punta de Muros may have resembled the Big Men, but they had to share their prestigious position with other collectives with similar recognition.

Perhaps we have to consider other phenomena from a more long-term perspective. I would like to put the spotlight on some changes in the social value of objects. As mentioned above, the LBA has been defined by the accumulation of goods and the ostentation of certain prestige objects. However, the processes of sedentarization and fortification completely changed the rationality patterns of the northwest communities: the value of the old prestige goods began to decline and the possession and ownership of land (probably, in a communal sense) acquired a new meaning. Instead of being semi-nomadic, holding and preserving the same land across generations became essential for community cohesion and sustainability. This is clearly evident in the structuring of domestic space: EIA houses, even those built with perishable materials, maintain and preserve its location after several renovations, although it would have been easier to rebuild them elsewhere (*Blanco-González 2011*). In this sense, it is possible that the change in the ways of inhabiting the landscape brought about an unstoppable long-term change in the patterns of these societies. As argued by some scholars (*González García* et al. *2011*), the EIA may have started as a rejection of social inequalities, focusing on new patterns of rationality oriented towards community cohesion and heterarchical systems. However, it is possible that this new model planted the seed of a new social system, in which housing, kinship and land became future forces of inequality.

The emergence of the dynamics of social inequality during the EIA are unknown in the NW Iberian Peninsula, as also seems to be the case in most of the Spanish Northern Plateau. Landscape fragmentation, resistance to change and egalitarian *ethos* remained as

Fig. 7. Structure XX: detailed view of the inside (from **Cano Pan 2012.434*****).***

a social constant on the Atlantic façade until the 5th and 4th centuries BC (*Marín Suárez 2011.350; Moore, González-Álvarez 2021.142*). However, other European regions have acknowledged dynamics of inequality. One example are the *Fürstensitze*: central places in Baden-Wüttenberg, Rhineland-Palatinate and Alsace-Lorraine regions, characterized by very marked social hierarchies (*Fernández-Götz 2017.120–124*). A similar case (although in a wider time span) occurs with the *stelae* temples of southeast Gaul, which became central sites in the urbanism of a new model of social hierarchization (*Golosetti 2014*). This emergence of new central sites is also a common feature on the nearby Iberian Northeast (*Sanmartí 2004.20–22*), although it is not a widespread process, being mostly traced in contexts of social instability (*García, Rubert* et al. *2011.450*), as may have happened in Punta de Muros. In other locations, such as the Meuse-Demer-Scheldt (MDS) region, the social landscape underwent a profound change during this period: old, fortified habitats and community landmarks were abandoned in favour of a new settlement pattern based on the predominance of the house as a representative element of kinship and family unity (*Gerritsen 2007.161*). Finally, a similar domestic transformation to that in Punta de Muros, albeit on a greater scale, has been observed in the Mediterranean Gaul, pointing to a shift from unspecialized, undivided houses to more specialized spaces (*Py 2012.166–170*).

As in Punta de Muros, these processes of change occurred abruptly in a similar brief period (6th–5th century BC). Usually known as the 'Crisis of the 400s' (*González-Ruibal 2006–7.269*), this is understood as a widespread context of social instability throughout temperate Europe (*Fernández-Götz 2014.149*). As happened in most of Europe, this process was brief and sharply interrupted. In Punta de Muros, chronostatistical studies have highlighted a rapid and uniform abandonment process in the early 4th century BC (*Nión-Álvarez 2023b.9*). The same happened with most of NW Iberian hillforts, which were abandoned during these decades in favour of new habitats closer to the valleys and natural communication routes (*Parcero-Oubiña 2003.287–288*). This marks a clear difference with other areas of the Iberian Peninsula, where the processes of social hierarchization effectively began in the 4th century BC and continued until the Phoenician colonization (*Grau-Mira 2019.158*). However, this 'Crisis of the 400s' had a very different outcome in the northwest: there was no evidence of significant social hierarchization until the 2nd–1st centuries BC, as part of a completely different processes that only emerged in specific regional contexts (*Álvarez González* et al. *2018; Nión-Álvarez 2023a*). In this regard, it has more similarities with other European contexts than with the most part of the Iberian Peninsula.

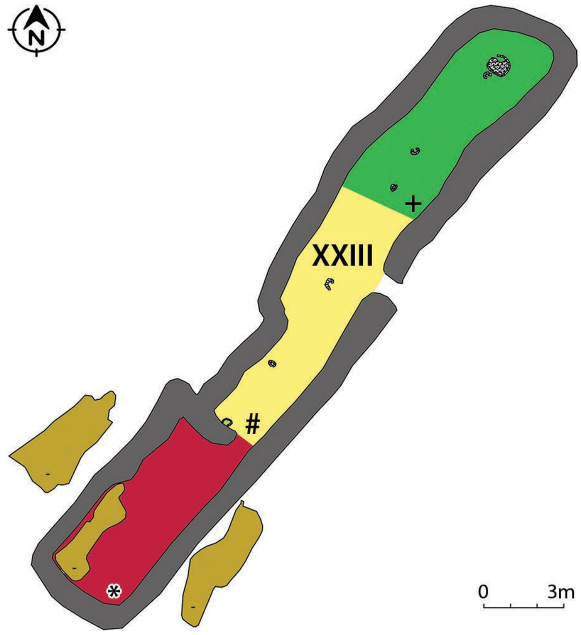

Fig. 8. Complex household with metalworking activities (Structure XXIII: domestic activity in green (+), metalworking in red (*), rest and storing areas in yellow (#) (redrawn from **Nión-Álvarez 2022.496*).***

In social terms, we may reflect on how the 'egalitarian' community of Punta de Muros underwent a radical shift towards an antagonistic social model. Perhaps we can bring up the possible shift towards a matrilocal residence pattern, as previously mentioned. It should be borne in mind that matrilocality is not particularly common (about a 10%, according to *Murdock* et al. *1999*), and tends to appear in contexts favoured by situations of social instability, usually due to external conflicts (due to men's prolonged absences) (*Ember, Ember 1971.588–590*) or in contexts of migration (*Divale 1974.79–80*). Matrilocality, especially in war-influenced contexts, emerges as an efficient adaptive response that breaks ties between men and dilutes potential internal conflicts, channelling them towards external warfare with neighbouring communities (*Divale 1984*). It is also possible that this led to a matrilineal descent system, as Bradley E. Ensor (*2013.25*) stated.

Although the degree of influence of war and migrations must be correlated with other factors (*Moravec* et al.

2019), it can be assumed that there is a link between social instability and the emergence of matrilocal residence patterns. In Punta de Muros, either war or migration may be on the table, as this region is noted for a warlike and conflictive context (*González García 2009*), but there are also some (written, not archaeological) sources that suggested the presence of migrations during this period (the most representative example is the Ora Maritima by Avienius, *Suárez Piñeiro 2002*). In any case, both could have fuelled the rise of these significant transformations at Punta de Muros. On the other hand, if there was a pattern of matrilocal residence it was not necessarily related to the emergence of inequalities. An extensive cross-cultural study by Alexandra Surowiec *et al.* (*2019*) did not find any pattern linking inequality with matrilocality or matrilineality. Matrilocality may have not been a cause but a consequence of the social and political instability of that context.

In conclusion, regardless of the causal factor, this situation may have led to the emergence of powerful new groups and a greater degree of social inequality. In this regard, it may be interesting to consider the capacity to accumulate prestige. Some familiar units, and perhaps also some collectives, managed to achieve a higher social position in terms of cultural capital (*Bourdieu 1985*), controlling prestigious activities (warfare, metalworking, religion) and holding a predominant position in the community. This can be seen through some differences in the domestic record: although diffuse in material terms, the increase in storage capacity and the exclusive control of activities such as metalworking by some specific households may point in this direction. This predominant position may have been favoured (or perhaps promoted) by a context of social instability, perhaps warlike, perhaps migratory, in which matrilocality was chosen as a new pattern of post-marital residence. Following this hypothetical approach, matrilocal patterns may have persisted over the following centuries. More than 70% of post-marital residence patterns result in matrilineal descent systems (*Surowiec* et al. *2019.6*–7), in which women can inherit land and assets through the maternal line (*Mattison 2011.70*), even though men retain political power (*Mutolib* et al. *2016*). It is interesting to note that classical authors such as Strabo have emphasized the power of women in NW Iberian, and it has been pointed out that women were the ones who worked and inherited the land, while men were only focused on war and looting (*Llinares García 1997.163*). Although it cannot be considered more than a mere hypothesis, this has great potential for future research.

To sum up, the development of new archaeological research has helped to contextualize the transformations that took place in the EIA of northwest Iberia, leading the acknowledgement of a profound change in terms of households and architecture, an emergence of social inequality and a possible shift towards different kinship strategies. We hope that this work will encourage further research to delve deeper into the outstanding context of Punta de Muros.

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New insights into the funeral practices of the Vučedol culture from the example of Grave no. 5, Vučedol – Cornfield Streim site

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ABSTRACT - *Recent archaeological excavations of the Vučedol site at the Cornfield Streim were carried out in the period from 2012 to 2021. Most of the excavated objects belong to the settlement of the Classical phase (2900–2630 BC) of the Vučedol culture. The focus of this paper is on the analysis of Grave 5 within the Vučedol settlement complex and its role and meaning in the life and funeral practices of the Vučedol culture. Anthropological analysis will show the biological features of the Vučedol population and of the sample found only at the Vučedol site.*

KEY WORDS – *Eneolithic; Vučedol culture; settlement burials; graves; ritual practice*

Nova spoznanja o pogrebnih praksah v vučedolski kulturi na primeru groba št. 5, najdišče Vučedol – Koruzno polje Streim

IZVLEČEK – *Nedavna arheološka izkopavanja na najdišču Vučedol – Koruzno polje Streim so bila izvedena med letoma 2012 in 2021. Večina izkopanih predmetov pripada poselitvi klasične faze vučedolske kulture (2900–2630 pr. n. št.). Poudarek našega prispevka je na analizi groba 5 v vučedolskem naselbinskem kompleksu in njegovi vlogi ter pomenu v življenju in pogrebnih praksah vučedolske kulture. Antropološka analiza je pokazala biološke značilnosti vučedolske populacije in značilnosti vzorca, najdenega le na najdišču Vučedol.*

KLJUČNE BESEDE – *eneolitik; vučedolska kultura; pokopi v naselju; grobovi; pogrebne prakse*

Introduction – the state of excavation and the organization of the settlement on Vučedol

The Vučedol site is the most famous and certainly the longest systematically excavated settlement of the Vučedol culture. From the first excavations by Josip Brunšmid in 1897, the first larger excavations by Robert Rudolf Schmidt in 1938, smaller trial excavations by Stojan Dimitrijević in 1966 and 1967, to the first systematic archaeological excavations in the 1980s initiated by Aleksandar Durman, and a recent excavation that continues today, a large amount of findings and data from the site were collected and analysed. However, these were only partially published, so there is a lack of complete and systematic publication of the units investi-

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gated to date (*Hoernes 1903.263–289; Schmidt 1945; Dorn 1965; Dimitrijević 1966.22–23; 1977/78.3–4; 1979.268–271; Durman 1982; 1984; 1985; 1987; 1987a; Težak-Gregl 1986; Durman, Forenbaher 1989; Durman* et al. *2003; 2013; 2014; 2015; 2016; 2017; Balen 2004; 2006; 2007; 2008; 2009; Durman, Balen 2005; Durman, Hutinec 2011; 2019; Hutinec 2011; 2012; 2012a; Hutinec, Šuljug 2018; Miloglav 2018; Solter 2017; Hutinec* et al. *2021*).

Until the 1980s, the site was partially explored through smaller test probes and trenches, which did not yield significant data on the size and appearance of the settlement. Most of the data was collected during 16 years of systematic excavation (1984–1990, 2001–2011) of the location of the Vineyard Streim, where a part of the northern edge of the plateau with a total area of about 1800m^2 was investigated. Four archaeological trenches (V 84, V 85, V 87, V 04) were excavated, and cultural layers whose depth varies and is approximately up to three meters deep were found that belong to the Baden, Kostolac, Vučedol and Belegiš cultures, as well as sporadic finds of the Starčevo culture and the Early Bronze Age Vinkovci culture[1] (*Forenbaher 1995; Miloglav 2018*). Most of the layers in that position can be distinguished very clearly, although the upper layers were destroyed by ploughing and drilling for the vineyard. The layers of settlements of the Vučedol culture, which according to radiocarbon dates are dated 3080–3060 cal BC to 2580–2450 cal BC, stand out in particular (*Benko* et al. *1989; Horvatinčić* et al. *1990; Balen 2010; Miloglav 2018*). Although the absolute dates from this location speak of the Preclassical phase (A phase) of Vučedol settlement and then through the Classical to the Late phases (B and C phases), the mobile finds speak only in favour of the classical stage (B1 and B2 phases) of the Vučedol culture (*Dimitrijević 1979.272*). In this position, the relationship between the settlement layers of the Baden and Kostolac cultures and their relationship with the Vučedol culture is also interesting (*Durman 1984; Težak-Gregl 1985; Durman, Balen 2005; Balen 2004; 2010; 2011; 2018; Đukić 2018*).

Recent systematic excavations of the Vučedol settlement were carried out during ten years of excavation on the southern edge of the plateau of the Cornfield Streim (2012–2022). Cultural layers with a relative depth of up to 2.5m were found, belonging to the Lasinja, Baden, Kostolac, Vučedol, Vinkovci, Belegiš II cultures and the late Middle Ages. The fully preserved youngest layer of the Late Classic Vučedol culture (B2) and its link, *i.e.* stratigraphic relations, with the layers of the Vinkovci culture as well as relations with the older Kostolac culture were clearly defined (*Durman* et al. *2014; 2016; 2017; Hutinec, Šuljug 2018; Durman, Hutinec 2019*). Absolute dates from this position also indicate a very wide time period, ranging from 2910 to 2630 BC (*Hutinec* et al. *2021.15*).

The Vučedol settlement of the tell type, according to the data known so far, is spread over several positions (Vineyard Streim, Vineyard Karasović, Cornfield Streim and Gradac) on the higher loess plateau on the right bank of the Danube, which is up to 30 meters high and forms a natural barrier and protection in a narrower sense, it includes three excavated sites, the total assumed area of which is about 3ha; however, it should be kept in mind that the largest part of the site is completely unexplored, and the total area in a broader sense should be much more, over 8 ha (Fig. 1). Excavations at the Vineyard Streim position from 1984 to 2011 (trenches V 84, V 85, V 87, V 04) on the edge of the northern plateau established the residential part of the Vučedol settlement, *i.e.* above-ground and pit objects (houses, storerooms and other), and individual and group graves within the settlement grid (*Forenbaher 1995.17–25*). The Gradac position was mostly explored in 1938, and completely by rescue excavation in 2009, during the levelling of the ground for the construction of the 'Copper Caster's Megaron' building within the Vučedol Archaeological Park (*Schmidt 1945; Hutinec 2011.94–96*). The layers of the Neolithic (Starčevo) culture, Eneolithic cultures (Baden, Kostolac and Vučedol cultures), Iron Age cultures, and from the early and late Middle Ages are defined. The most represented is the Baden and Classical Vučedol culture layer with above-ground buildings, pits and graves that are defined as special purpose objects, and the entire plateau, which was physically separated from the rest of the settlement by a trench or some kind of palisade, is colloquially defined as a kind of sacral-metallurgical centre called the 'Copper Caster's Megaron' (*Schmidt 1945; Dimitrijević 1979.332; Durman 1988.15*).

1 The first excavation of Vučedol site, at the Vineyard Streim, were conducted by Brunšmid in 1897, then director of National Museum, when he probed the southeastern edge of the plateau and found 15 skeleton graves which he attributed to a necropolis of Vučedol culture. Recent analyses of several whole and several fragmented skulls from his excavations date these graves to the Early Bronze age, most likely Somogyvár-Vinkovci period (*Hoffiller 1933; Solter 2017.161–163; Zavodny* et al. *2021*).

At the position of Cornfield Streim, recent rescue excavations of trenches V 12/V 17 on the edge of the eastern part of the Vučedol settlement, on an area of about 1200m^2, recorded 72 above-ground buildings with associated infrastructure and the existence of five construction phases of the settlement, Classic Vučedol phase (B1 and B2), and an earlier, sixth Kostolac-Vučedol construction phase, represented by several smaller, poorly preserved above-ground buildings (Fig. 1). The duration of individual construction phases can be roughly estimated because the stratigraphy shows sudden demolitions, upgrades, repairs and conversions of space, so it can be noticed that some phases lasted longer than others. The relationships between individual objects and entities are very clear, but some remain without concrete explanations. What can already be preliminarily concluded by observing Vučedol architecture from the position of the Cornfield Streim is that it differs greatly in its construction elements and techniques from other investigated buildings in the rest of the settlement (*Forenbaher 1995; Miloglav 2018.113–145; Roksandić Vukadin 2021.12–17*). The buildings are larger in size, have an open space floor plan and are innovative in construction technologies. This especially applies to the use of new construction materials, such as loess dolls and recycled pottery fragments that have been used for the foundations of houses and levelling of floors, fireplaces and furnaces. The grouping of some objects is noticed, which indicates their related function. The objects are located near each other, with regular repeating orientations, formed into special units separated by corridors, *i.e.* passageways, so one gets the impression of planning, *i.e.* a well-thought-out organization of space, and a survey of the floor plan of the buildings. Obviously, the function of the buildings in these positions is different from the others (Vineyard Streim and Gradac) and it is most likely a part of the settlement with a pronounced workshop, *i.e.* craft activity. This is indicated by the organization of the interior of certain buildings and certain structures within them, such as, for example, spaces with dome furnaces and waste pits with a large amount of workshop waste, as well as numerous findings that point to work activities. This should not be so surpris-

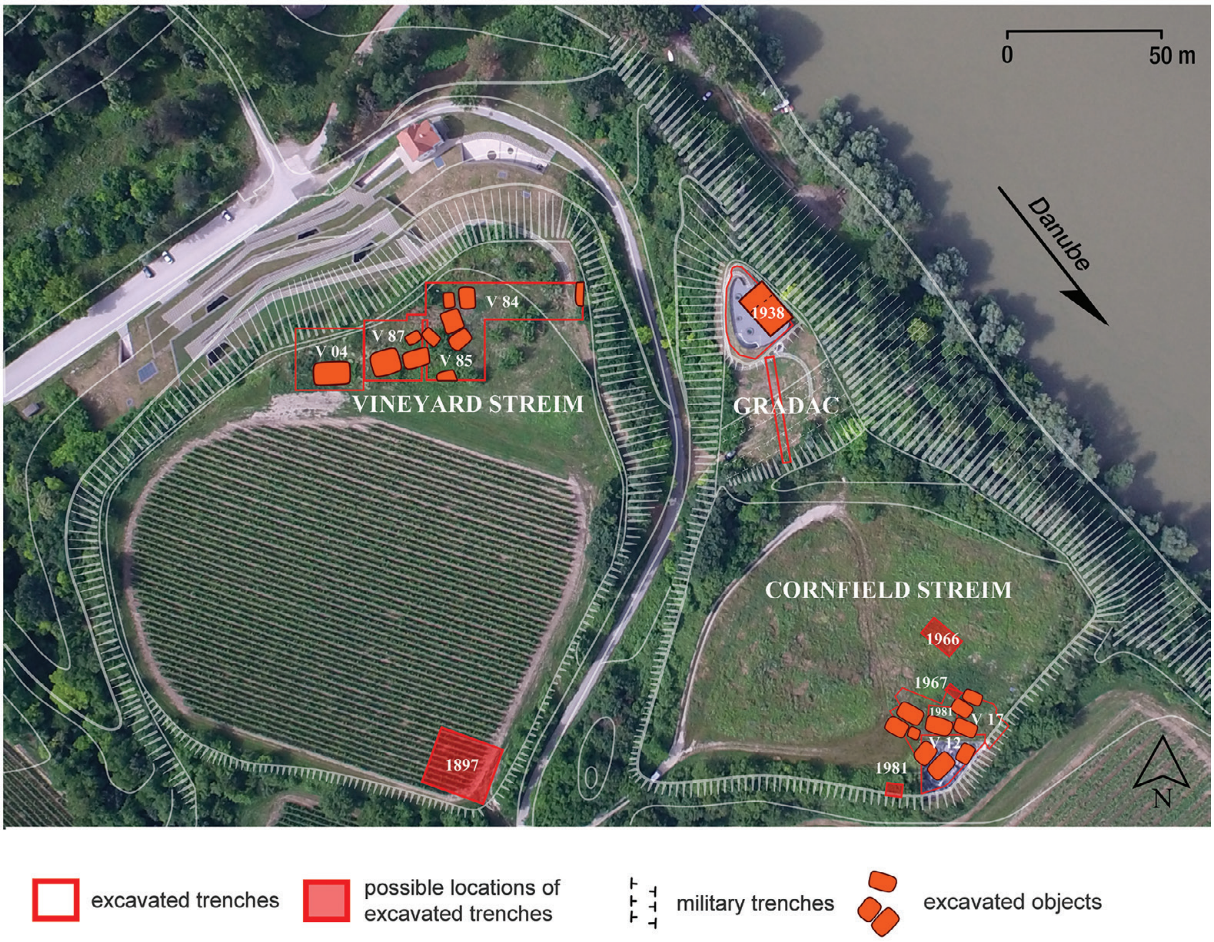


Fig. 1. Positions of excavated archaeological trenches at Vučedol site (authors S. Bošnjak and D. Roksandić Vukadin).

ing considering the peripheral location within the settlement and the proximity of the sacral-metallurgical complex Gradac. Grave burials in pits between residential and workshop buildings and their mutual relationships show a similar pattern in the organization of the settlement as in the mentioned position of the Vineyard Streim.

Considering the relatively small percentage of the excavated area of the entire Vučedol site (about 15%), it is difficult to create a complete picture of the organization and functioning of the Vučedol settlement in certain phases. Nevertheless, within certain microlocations in the current phase of excavation, some architectural and functional elements can be concretely reconstructed and they tell us about the psychology of the settlement of the Vučedol site. The innovations that stand out in the new elements of architecture and construction techniques speak of a high standard and changes in technological development and give us possible solutions in the reconstruction of the organization of the settlement in the Vučedol site (*Durman* et al. *2013; 2014; 2015; 2016; Miloglav 2018.119–125; Roksandić Vukadin 2021.12–17*).

Grave burials and funeral customs at the Vučedol site

The largest part of the investigated structures at the Vučedol site consists of above-ground residential and workshop buildings with associated infrastructure, as well as semi-open spaces for work and living. In addition to the profane elements of everyday life, within the settlement itself there are objects that indicate a sacred function and ritual activities. In addition to the old excavation from 1938 at the Gradac site with above-ground cult buildings ('Copper Caster's Megaron') and the well-known excavated 'Married Couple Grave', a ceramic bird-shaped vessel widely known as 'Vučedol Dove'[2] and a deer burial, to which a ritual and magical role are attributed (*Schmidt 1945.41–47; Dimitrijević 1979.332; Milićević-Bradač 2001; 2002*), pit graves with human and animal remains were found in the settlements (Vineyard Streim and Cornfield Streim) and certain conclusions can now be drawn (*Marković 1985; Težak-Gregl, Durman 1985; Durman 1988; 1999; 2000; 2004; 2006; 2009; Hoti 1993. 183–184; Forenbaher 1994. 314–319; Teschler-Nicola, Berner 1994.64; Hincak 1995; 2005; Balen 2007.64; Hincak* et al. *2007; 2013; Hutinec 2012; Durman* et al. *2015; 2017; Miloglav 2018.131–134; Hincak Daris* et al. *2022.33–34; Roksandić Vukadin 2022.31–32*). This occurrence of burials within the settlement of the Vučedol culture is unique for the Vučedol site, and Vučedol necropolises have not been recorded anywhere else so far. In total, more than 20 Vučedol burials with more than 60 deceased were excavated at the Vučedol site within the settlement (Vineyard Streim, Cornfield Streim and Gradac) (Tab. 1).[3] Burials of the Vučedol culture appear in several other sites in Eastern Slavonia, such as Vinkovci, Osijek – Ciglana and Zeleno polje, and Beli Manastir – Popova zemlja. However, these are skeletons attributed to the Vučedol culture based on indications or exclusively according to radiocarbon dates without findings or other circumstances that would support it (*Dimitrijević 1979.285; Hincak 2005; Krmpotić* et al. *2016; Janković, Novak 2018; Matheison* et al. *2018; Miloglav 2018.131–134; Los 2020*). Outside the home area of the Vučedol culture, graves under tumuli are found in Serbia (Velika Humka in Batajnica, Humka in Vojka) and Montenegro (Mala Gruda, Velika Gruda and Boljevića Gruda) (*Dimitrijević 1979.285–286, 333; Durman 1988; Primas 1996; Baković, Govedarica 2009; Baković 2012; Saveljić-Bulatović* et al. *2015*).

According to the published and processed results so far, graves of the Vučedol culture from the Vučedol site can be characterized as intramural (within the settlement), primarily divided according to the type of burial into human and animal burials with several subcategories: **(a) according to the type of grave/tomb**

2 One of the most famous pieces of pottery and symbol of Vučedol is the ritual bird-shaped ceramic vessel, the so-called 'Vučedol Dove', found in an excavation of Gradac in 1938 (*Schmidt 1945*). The latest interpretation by Durman, however, is that the vessel is in the shape of the male partridge, a symbol of fertility, whose limping defensive behaviour against attack by predators on a partridge nest has symbolic meaning and is linked to the limping shaman–copper smelter (*Milićević-Bradač 2002; Durman 2004*).

3 Partial skeletal remains and findings from graves found during excavations of trenches V 84, V 85 and V 87 disappeared or were destroyed in the Croatian War of Independence, and the majority of them are not published, but sporadically mentioned in the literature. That's why 'it is hard to distinguish how accurate the number of graves is and what is the minimal number of the deceased in them. The cultural belonging of some of them is also in question. The revision of the documentation is currently being worked on in the archive of the Vučedol culture Museum, so the accurate results will be published soon.

(layer, pit, dislocated bones), (b) according to the number of deceased (single, double, triple, group, parts of skulls and limbs, cenotaph?), (c) according to the type of ceremony (ritual, laid without traces of ritual), (d) according to social status (findings pointing to social stratification – elite individuals and others?). The majority of Vučedol graves can be associated with the practice of rituals, more or less lavish, with contributions of various objects of daily use, objects of special purpose and contributions of animal bones, *i.e.* parts of animal skeletons with traces of cutting, butchering or burning (*Jurišić 1990; Hincak 1995; Mihelić, Leiner 2022*). Independent ritual burials of animals were found at the Gradac and Vineyard Streim positions, but most of them have not been processed or published (*Schmidt 1945.28; Jurišić 1990.22; Miloglav 2012*). Complete appendages of animals have so far not been found with human skeletons. The remains of animal bones, along with human deceased, were mostly recorded in large quantities and indicate a large number of individuals, and they certainly speak of the prosperity of the Vučedol community, which could afford such 'gifts' in food (*Jurišić 1990; Mihelić, Leiner 2022*). Of course, animal offerings also had a deep, symbolic role (*Durman 1988; Jurišić 1990; Hoti 1993; Milićević-Bradač 2001; 2002; Pasarić 2018*).

According to the type of grave/tomb in Vučedol, burials are mostly found in deep and shallow pits, in the layers next to the floors of houses, between pits, and dislocated human bones are found around the settlement and on the slope of the tell (*Schmidt 1945; Dimitrijević 1979; Marković 1985; Težak-Gregl, Durman 1985; Durman 1986; 1988; 2000; 2006; Balen 2007; Hutinec 2012; Radman 2018*). A catacomb tomb related to the well-known 'Married Couple Grave' that is associated with steppe influence are mentioned in the excavations of Gradac (*Schmidt 1945.44; Tasić 1967. 59; Garašanin 1970.135; Dimitrijević 1979.284–285; Milićević-Bradač 2001.211*). No such types of tombs were found in the other investigated positions. There are mostly deep or shallow pits, cylindrical in shape, with vertical walls descending to a flat bottom (subsoil) or they spread in a bell-shaped manner towards the bottom, forming a burial niche, thus somewhat reminiscent of a catacomb burial (*Težak-Gregl, Durman 1985; Durman 1988; 1999; 2000; 2009; Hoti 1993; Milićević-Bradač 2001*). The deceased lie on a flat subsoil in the pits, and are buried in the layer/filling of the pits or in niches on a loess charge. They were buried towards the edge or in the middle of the pit, and no special pattern for laying the deceased has been discerned – in fact, each grave is specific. They are laid in various positions: partially or heavily crouched on their left or right side, stretched out on their backs and on their chest, and in the so-called sitting position. The position of the arms, legs and head varies. Apart from graves in pits, several burials of skeletons are found in the layer between the floors of houses without traces of a defined burial pit, and for now only at the position of the Vineyard Streim (*Balen 2007.64*). The filling of pit-graves, apart from a large amount of ceramic, bone, stone and metal objects, is specific due to the layers of ash, charcoal, pieces of daub, ochre or cinnabar, as well as shells and snails (*Schmidt 1945; Durman 1988; 2000; Milićević-Bradač 2001; Hincak Daris* et al*. 2022; Roksandić Vukadin 2022*). Such a custom has been known since the Neolithic, and we find identical examples in the graves of the Baden and Kostolac cultures (*Filipec* et al*. 2009; Balen 2010; 2011; Horváth 2010; 2017; Horváth, Kohler 2012*). The number of deceased can vary from one, two or three to groups with more than 20 individuals. With regard to previous anthropological analyses, slightly more burials of women and children were recorded, and fewer of male individuals. Although human sacrifices are associated with Vučedol, most of the skeletons show no signs of a violent death (*Durman 2000.40–57; Hincak* et al*. 2013*). The health status of the analysed skeletons does not deviate from the standard traces of work activities, and some diseases typical of the Eneolithic period. However, some specific traces on the bones, for example lesions or shallow depressions on the skulls of the deceased (Grave 3 from 1985 speak of some specific treatment of the deceased before death. In addition to complete, undisturbed skeletons, secondary burials of body parts of the elderly deceased were recorded inside the graves, mostly complete skulls, parts of skulls or extremities, *i.e.* long bones of arms and legs (postmortem manipulation). This custom can be traced not only within graves, but also within other objects at the Vineyard and Cornfield Streim sites on house floors, in house walls, layers, and as independently laid in pits (*Durman 1988; 2000; Hoti 1989; 1993; Teschler-Nicola, Berner 1994.64; Milićević-Bradač 2001.214; Hincak* et al. *2013; Hincak Daris* et al. *2022; Roksandić Vukadin 2022*). We have seen this custom since the Neolithic in the Carpathian Basin, especially in the Lengyel culture (*Bánffy 1990/91.225, 228*) and in the Baden and Boleráz cultural groups, and they are connected to the cult of skulls or the cult of ancestors (*Banner 1956. 206; Milićević-Bradač 2001.214; Horváth 2010.37–42; 2017.402–403; Bondár, Szécsényi-Nagy 2020*).

Site	Label	Burial type by number of individuals	Burial type by context	Cultural affiliation	Sex	Skeleton elements in grave burial
Gradac	Grave 3, 4 ‘Married couple grave’	double (2)	pit	Vučedol culture	♂	complete
					♀	complete
Gradac	Grave 5	single (1)	pit	Vučedol culture (?)	♀	partial (destroyed grave)
Vineyard Streim	Grave 1 V 85 ‘Orion grave’	single (1)	pit	Vučedol culture	♂	complete
Vineyard Streim	Grave 2 V 84	single (1)	pit	Vučedol culture (?)	?	complete, commingled?
Vineyard Streim	Grave 4 V 84	single (1)	pit	Late Eneolithic	?	complete
Vineyard Streim	Grave 6 V 84	single (1)	pit	Late Eneolithic	child	complete
Vineyard Streim	Grave 7 V 84	single (1)	pit	Late Eneolithic	child	complete
Vineyard Streim	Grave 1 V 85	group (3 or more)	pit	Late Eneolithic	?	commingled?
					?	complete, commingled?
					?	commingled?
Vineyard Streim	Grave 2 V 85	?	?	Late Eneolithic	?	?
Vineyard Streim	Grave 3 V 85 ‘Mars and Venus grave’	group (8)	pit	Vučedol culture	♀/1	cranium (postmortem manipulation)
					♀/2	complete
					♀/3	complete
					♂/4	complete
					♀/5	complete
					♀/6	complete
					♀/7, child	complete
					♀/8	complete
Vineyard Streim	Grave 4 V 85	single (1)	pit	Vučedol culture	♀	complete
Vineyard Streim	Grave 5 V 85	single (1)	layer	Late Eneolithic	♀, child	complete
Vineyard Streim	Grave 1 V 87	?	?	Late Eneolithic	?	?
Vineyard Streim	Grave 2 V 87	single (1)	pit	Late Eneolithic	♀	complete
Vineyard Streim	Grave 3 V 87	double (2)	pit	Vučedol culture	♂, child	complete
					♀	complete
Vineyard Streim	SJ 37 V 04	double (2)	layer	Vučedol culture	?	postcranium (postmortem manipulation)
					?	commingled
Vineyard Streim	SJ 37 V 04	double (2)	layer	Vučedol culture	?	commingled
					?	commingled
Cornfield Streim	Grave 2 V 12	single (1)	pit	Vučedol culture	?	cranium (postmortem manipulation)
Cornfield Streim	Grave 3 V 12	group (3 or more)	pit	Vučedol culture	?	commingled
Cornfield Streim	Grave 4 V 17	single (1)	pit	Vučedol culture	?	cranium (postmortem manipulation)
Cornfield Streim	Grave 5 V 17	single (1)	pit	Vučedol culture	♂	complete + extra ulnar bone (postmortem manipulation)

Cornfield Streim	Grave 6 V 17	group (22)	pit	Vučedol culture	?	15 crania (postmortem manipulation)
					?	complete
					♀	complete
					?	complete
					?	complete
					?	complete
					?	commingled
					?	commingled

Tab. 1. List of excavated graves with available data from all positions in Vučedol site (authors S. Bošnjak and D. Roksandić Vukadin).

In addition to pits with human and animal burials, there are pits filled with a large amount of finds, as well as objects of special purpose attached for ritual purposes without traces of any deceased. Whether this means that these are independent ritual pits of the cenotaph type or that there is a deceased person in the immediate vicinity in another building is a question that is still impossible to answer (*Roksandić Vukadin 2022*). Most of the graves in Vučedol, which are cylindrical and bell-shaped pits prepared in advance for burial, contain the deceased who were carefully treated and placed in various positions within the pits. Such pits are mostly sealed with lids or seals with several layers of loess, filled with daub and are often well burned (*Hoti 1993; Milićević-Bradač 2001*). The pits themselves, *i.e.* their shape and function, can perhaps be symbolically interpreted as symbols of fertility and well-being, especially those with a bell-shaped cross-section, which are interpreted in the literature as storage pits for storing grain (*Reynolds 1974; Jiménez-Jáimez* et al*. 2020*). Older graves in pits are often used as waste pits, so most of the skeletons inside are destroyed and dislocated by secondary use. Despite the common claims that older waste pits or storage pits could serve as graves, and that the deceased were buried inside, the authors of this paper did not observe such cases while reviewing the documentation. What can be concluded is that the pits were carefully prepared for burials, with regular floor plans and flat, aligned floors, and vertical, polished and reinforced walls, and some have prepared niches and loess charges for laying the deceased. Such pits were certainly marked and visible in the area, and probably corresponded with other objects in the area and formed a cluster of two, three or four tombs. It is thus considered that the larger graves/tombs of group burials may have been family, *i.e.* clan-organized, within the settlement (*Hoti 1993; Forenbaher 1994.320; Milićević-Bradač 2001. 215*). The most famous group burial iscertainly Grave 3 from 1985 from the location of Vineyard Streim, in which eight deceased were ritually buried, and the largest group grave investigated so far was found in the recent excavation of the Cornfield Streim from 2021 (Grave 6) with at least 22 individuals. In both cases it was a ritual burial and the deceased were laid in several stages, over a period of time of perhaps several weeks. Both pits were prepared in advance for the ritual, the deceased were carefully placed in different positions, they were covered with a large amount of charcoal and ash with a large amount of grave goods mostly ceramic pots and animal bones. In both graves, skulls from some older graves were secondarily added, which may point to a cult of ancestors, and on some skulls depressions, *i.e.* lesions on the top of the head or forehead, were noticed. The cause of death of the deceased is unknown in both graves. This points to a large and long-lasting ceremony in which many people participated and placed prestigious gifts in the graves, and the large amount of animal bones with traces of cutting and burning point to a kind of ritual feasting (*Durman 1988; 2000; Milićević-Bradač 2001; Hincak Daris* et al*. 2022; Roksandić Vukadin 2022*).

The burial of human remains in pits within the settlement is taken over by the Vučedol culture as a traditional element of older Late Neolithic cultures, especially the Sopot-Lengyel cultural circle. During the time of the Lengyel culture in the Carpathian Basin, the social hierarchy changes, social differences increase and the population begins to be buried in separate necropolises, however, the tradition of burying a certain type of people within the settlement still remains (*Novotný 1962.162–163; Bánffy 1990 (1991).192–193; Toth 2019.39–43*). Such customs, which can be more directly connected with the Vučedol culture, can be seen in the sites of the Baden culture in Hungary (Budakalász, Szentes, Balatonlelle-Rádpuszta, Szentes-Nagyhegy, Balatonősződ-Temetői dűlő, *etc.*) (*Banner 1956; Horváth 2010.37–42; 2017.402–403; Horváth, Kohler 2012; Bondár, Szécsényi-Nagy 2020*). It should be noted that at the Vučedol site, below the oldest layer of the Vučedol settlement, we can trace the Kostolac and Baden settlement layers with buried graves in pits, whose burial pattern apparently continued during the Vučedol culture. The Baden and Kostolac burials from Vučedol have not been extensively researched or published, but there are certain similarities in the burial ritual between these two cultures (*Schmidt 1945.41–47; Dimitrijević 1979. 202–203; Težak-Gregl 1985*). In the area of eastern Slavonia and Syrmia, among the few explored graves of the Baden and Kostolac culture within the settlement, burial customs show certain similarities with the Vučedol site (*Mihelić 2008; Nodilo 2012.14; Balen 2010; 2011; Horváth, Balen 2012*).

Burials from recent research from the position of the Cornfield Streim

Recent archaeological excavations took place at the position of the Cornfield Streim (trenches V 12 and V 17) in the time frame from 2012 to 2022 on an area of 1200m^2 where, in addition to the already mentioned workshop part of the settlement, five graves were also excavated (Grave 2–5) *i.e.* burial units from the Vučedol culture period (*Durman* et al*. 2013; 2014; 2015; 2016; Hutinec* et al. *2017; Hutinec, Šuljug 2018; Durman, Hutinec 2019*).[4] Graves were found within all construction phases of the settlement (phases 1 to 5), and they are mostly individual or group skeleton graves inside pits, and individual skull bones or long bones of limbs (postmortem manipulations) placed within layers in shallow pits between above-ground objects.

Burials of human bones defined under numbers 2 and 4 (Graves 2 and 4) are considered postmortem manipulations, *i.e.* there are parts of skulls, one complete and one crushed, which were placed in a layer that had no traces of other bones. The context of Grave 2 (SJ 204) from 2015 is quite clear with the well-preserved bones of a complete skull that was buried in a shallow pit (J 39, SJ 184/185) next to the so-called House 13 in the third construction phase of the Vučedol culture (Fig. 2). Grave 4 (SJ 498) from 2017 refers to the destroyed skull bones that were placed in a shallow pit (J 97, SJ 496/497) between the above-ground objects in the second construction layer. Both burials of skulls belong to the layers of the Late Classic B2 Vučedol culture and were most likely placed in the mentioned layers with a specific intention, *i.e.* as part of the ancestor cult tradition mentioned in the previous chapter. Traces of trauma or violent death on these skull bones have not been preliminarily established (*Durman* et al. *2016; Hutinec, Šuljug 2018*).

Such burials are known to us from old research from the 1980s, for example the skull of a woman without a mandible in Grave 3, and the human femur bone from Pit 20 from 1985 at the Vineyard Streim location (*Milićević-Bradač 2001.214*). Interesting information is given by M. Milićević-Bradač about a complete skull from 1981 found at the location of Cornfield Streim during probing excavations, that was found on the floor of the house next to the hearth, near the altar that was in the form of the so-called consecrative horns

Fig. 2. Skull placed in the pit J 39, SJ 184/185 as part of the ritual (postmortem manipulation) (author D. Roksandić Vukadin).

4 In 2012, at the position of trench V 12, a skeletal burial without a proper grave was found, attributed to the Vinkovci-Somogyvar culture period, which was located at the very edge of the settlement next to the so-called rampart of Vinkovci culture (Grave 1, SJ 021/022). The graves from this period are known from the first excavations of Vučedol done by Brunšmid in 1897, when the cemetery in rows was excavated (see ft. 1).

(*Hoti 1989.34; Milićević-Bradač 2001.214*).[5] This phenomenon of burying parts of human skeletons as separate burials or as grave contributions is known from all excavated positions in Vučedol and is indeed one of the most important traditional elements known since the Neolithic that the Vučedol culture inherited and maintained throughout its entire period at the Vučedol site. Graves 3 and 6 are defined as group graves dug in deep pits previously prepared for the burial of a large number of the deceased with a large amount of contributions and finds with a special purpose that indicate a ritual character (*Durman* et al. *2016; Hincak Daris* et al*. 2022; Roksandić Vukadin 2022*). Grave 3 (SJ 226) was found in 2015 inside a pit (J 46, SJ 227/228) that was previously prepared for the burial of the deceased. The pit has a relative depth of about 2m, cylindrical shape and contains at least three deceased people whose bones were destroyed and dislocated due to the digging of the pit from the younger layer of the Vučedol culture (J 45, SJ 220/221). Preliminary anthropological analysis established that there were at least three individuals of a younger age who were buried along the southern edge of the pit wall on a loess charge just above the very bottom. The burial pit was almost completely destroyed by a younger burial, the bones and contributions were dislocated, and it is difficult to draw concrete conclusions. Grave 3 belongs to the third construction phase of the Vučedol culture at this position. Grave 6 from 2021 is defined as the largest group grave in Vučedol, as well as in the entire Vučedol culture, with a minimum of 22 deceased. The burial pit consists of two parts, a smaller pit (J 155, SJ 866, 867, 882, 883, 884, 890) and a larger pit (J 158, SJ 775, 776, 779, 780, 781, 856–858, 865, 868, 871–876, 882–884, 887–889) that form a whole-tomb. The pit was carefully planned, dug and prepared for the burial of the deceased. An earthen type grave, made of loess with walls covered with fine clay and then fired for hardness. It consists of two spaces, one main larger one (funeral chamber), with a diameter of 3m where the deceased were buried, and a smaller pit that served as an antechamber where numerous grave contributions were found. Layout wise, it is a pit burial in the shape of the number eight, which is sealed at the top with 1.5m layers of clay and fired earth, on top of which was a fireplace with the remains of charcoal and ashes. The deceased were buried in various positions and orientations, and were sprinkled with layers of ash, charcoal, river shells, animal bones and fragments of ceramic pottery. Traces of red colour were found with the deceased in the layers, which also indicate evidence in favour of a ritual burial that is known throughout prehistory. Fifteen skulls without other skeletal remains were placed on these layers. What is important is that those 15 skulls were secondarily placed on top of the grave without other skeletal remains, and they can be treated as grave contributions, *i.e.* they may have been ritually brought from another location or from older graves, which could indicate a cult of skulls and a cult of ancestors and a special relationship to the dead and the afterlife (*Milićević-Bradač 2001; Bondar, Szécsényi-Nagy 2020; Stavreva 2022.20–22*). Many complete pots and parts of richly decorated pottery and animal bones were placed along with the deceased. The remains of clay altars in the form of consecrative horns were also found in the tomb, which speaks of the cult of worshiping horned animals, primarily cattle (*Hoti 1989*). Animal bones in this context should be understood as a grave goods, and some of them show traces of butchering. Numerous processed finds made of animal bones were also found, primarily hollow cattle horns and deer antlers that show traces of sawing or cutting, probably with metal tools, as well as various bone awls, spatulas made of animal ribs and many other tools used in everyday life or rituals. With a complete zooarchaeological analysis, it will be possible to say how many animals were killed in this ritual and how many kilos of meat were sacrificed, but it is certainly case of several tens of kilograms. The ritual of the Vučedolians itself is not completely known, but analogies from older cultures show that a special ritual took place here for some separate class that held a higher position in society, with a real ritual feast that could last for several days, where the deceased were exposed and specially treated (*Horvath, Kohler 2012; Horváth 2017; 2019; Hincak Daris* et al*. 2022; Roksandić Vukadin 2022; Stavreva 2022*). A spatial analysis of this part of the settlement will surely establish some regularities in the planning, construction and relationships between profane architecture and graves,

5 Excavations on the position of the Cornfield Streim in 1981 was led by Durman when he opened three small trenches, the largest of which measuring 10x5m was located inside the recent trench V 17, which is a continuation of the research of trench V 12 from 2012. The mentioned skull find was thus located in the vicinity of other recent graves investigated from 2012 to 2021. The documentation and findings from the research were destroyed by the destruction of Vukovar in 1991 during the war, and unfortunately we cannot obtain more specific information about this burial. Revision surveys of the probe from 1981 were carried out during the expansion of the V 12 probe from 2017, but nothing else was preserved apart from the destroyed stratigraphy.

which obviously function in some symbiosis. Considering the relatively small number of burials from this position, but also from the entire Vučedol site, and their partial and insufficient analysis and publication, one gets the impression that the Vučedol culture shows certain inconsistencies regarding the burial of the dead and funeral customs. Indeed, each mentioned grave burial shows certain peculiarities, but also some common elements and the following of certain established patterns, thus creating a general picture of the treatment of the dead at the Vučedol site. Grave 5 (SJ 689/690) was excavated in 2019, and refers to an individual skeleton burial in a burial pit (J 101, SJ 515/516). That is also the only excavated individual grave inside the pit from the position of the Cornfield Streim. In the next chapter, we present the knowledge and conclusions that resulted from the first systematic and comprehensive analysis of this grave burial, and it represents an important contribution to the knowledge of funeral customs at the Vučedol site.

Grave 5 – stratigraphic relations, analysis and interpretation of the burial

Grave 5 (SJ 689/690) is located next to the western profile of trench V 17, buried just below the pit object with a relative depth of 280cm (J 101, SJ 515/516). It was excavated during the 2019 campaign as a continuation of the excavations of the objects of the third and fourth construction phases of the Vučedol settlement. The location of the grave within the excavated part of the settlement is rather isolated, so it cannot be seen whether it is part of an unit, an object or if it is in a relation to others. However, the proximity of a pit (J 103, SJ 533/534) defined as a ritual or cenotaph type pit with a large amount of intact richly decorated pottery, as well as various finds and objects of special purpose that speak in favour of a ritual character, is interesting. Other pit objects in the vicinity belong to the type of waste pits or storage pits, and the above-ground objects, houses, show a distinct workshop character with traces of certain processing activities (*Hutinec* et al. *2021*). The stratigraphic relations of the grave and the younger layers are clearly visible in the cross-section of the western profile of the trench, they speak of the use of similar objects in the younger phases of the settlement applied in the same spot and of the pragmatic use of space and existing resources (Fig. 3). Pit J 101 was dug during the second and third construction phases of the settlement (SJ 039, 565/567, SJ 516/1-5), and was probably also visible in the youngest phase, the first construction phase (SJ 024, 036), where the floors of the houses were sinking due to the poor foundation on the loose filling of the pit (Fig. 3). Primarily, Grave 5 (SJ 689/690) belongs to the fourth construction phase of the settlement, it was buried in the oldest Vučedol layer SJ 270 and SJ 691, and goes deeper into the subsoil to a relative depth of 350cm (108.80–108.00m AMSL). The grave was filled with several layers of soil mixed with daub, charcoal, biological remains and small finds marked as SJ 689/1–6. The upper edge of the grave is at an absolute height of 108.82m and is defined as a layer of loose grey soil with admixtures of daub and charcoal (SJ 689/1–2), and this is also the lower edge of the pit J 101, which did not destroy the grave with its dig as is usually the case. An example of the destruction of an older pit and of the secondary dig is the already mentioned Grave 3, which was destroyed by the digging of a pit from the younger phase of the settlement, and numerous examples of secondary uses of pit burials can be seen throughout the site (*Durman 1988; Forenbaher 1994; Težak-Gregl 1998; Balen 2010; Miloglav 2016*). In the example of Grave 5, there was no secondary use of pits and graves. However, there is an interesting stratigraphic situation where, in one small area in the section of the layers that are 350cm thick, we can follow the constant burial of similar objects, in this case of pits that are clearly separated from each other, ranging from the youngest to the oldest phase of the settlement. Obviously, due to the looseness of the soil this part of the terrain was constantly used for dumping and burying waste. The investigated pits in the vicinity, especially in the southern part of the trench, where the edge of this settlement plateau is located, were defined as waste pits with a large amount of animal bones, ashes and daub. This is certainly evidence in favour of the authors who place larger waste disposal sites at the very edge of the settlement (*Hayden, Cannon 1983*). In the recent layers of humus SJ 001 and SJ 001a, subsidence of the terrain is visible in that place but also in several others towards the very edge of the plateau, which immediately indicates the long-term digging of what are probably older pits with loose fillings. In these places, during the excavation certain geological anomalies and cracks in the soil caused by tectonic movement and water washing were recorded in the subsoil, causing deep natural depressions into which the cultural layers sank (*Bognar 1976*).

Typologically, the grave belongs to the type of individual skeletal burials in a pit (one male person), and according to stratigraphic relationships, it was buried in the fourth construction phase of the Vučedol settlement (Fig. 4).

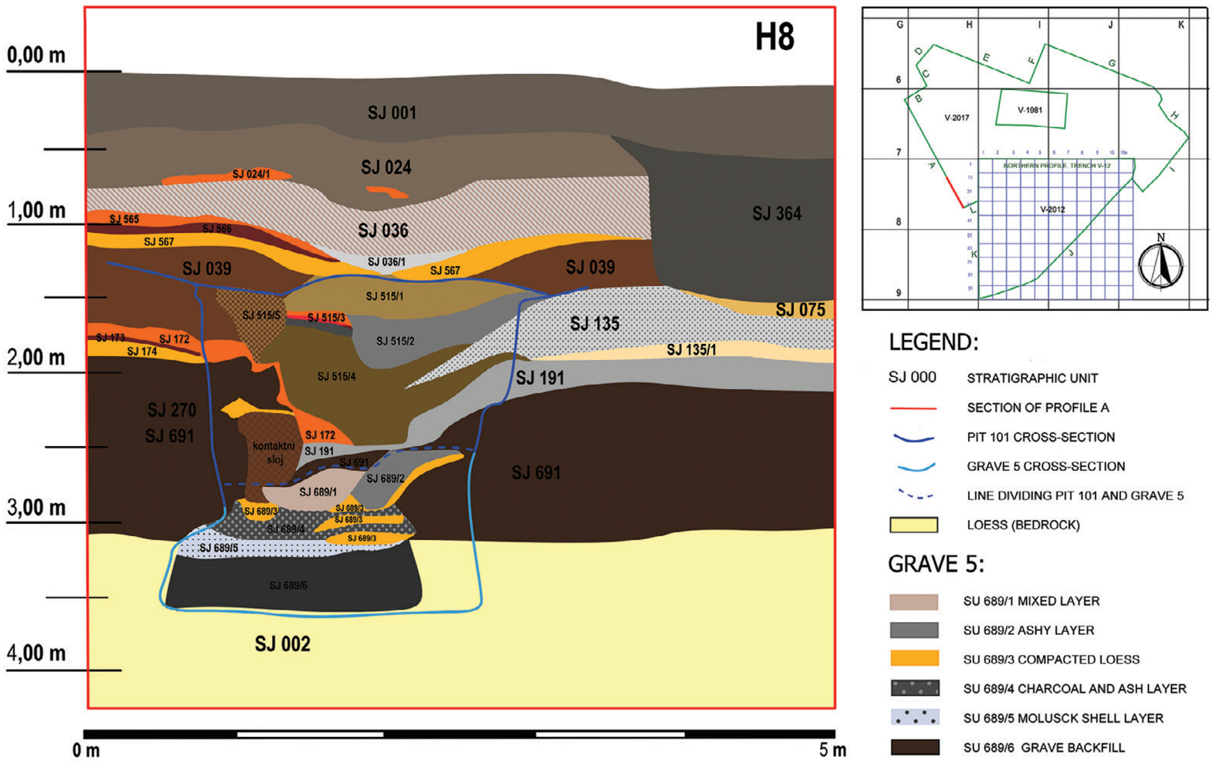


Fig. 3. Part of the western profile of trench V 17 (profile A) with a section of pit J 101 and Grave 5 (authors S. Bošnjak and D. Roksandić Vukadin).

The calibrated absolute dates obtained from the bone sample of the deceased also speak in favour of older phases of settling at this location (2910–2670 cal BC, 4222±33 BP).[6,7] These dates fit the existing radiocarbon dates of the Vučedol culture from the Vineyard Streim site, which are mostly in the range of 3000 and 2500 BC and confirm the existence of the Early and Classic phases of the Vučedol culture (Fig. 5). According to the dates from the research done after 2000 in the V 04 trench from the Vineyard Streim position, the theory of the existence of the Late Classic B2 phase of the Vučedol culture is put forward, contrary to what was the common opinion until then, that Vučedol was inhabited only in the A and B1 phases (*Balen 2010.T. 8*). Recent investigations of the position of the Cornfield Streim definitely established the existence of B2 phase in several construction phases, but also the existence of B1 phase precisely with the date from Grave 5 (*Hutinec* et al. *2021*).

Burial Grave 5 (SJ 690), with a relative depth of 80cm, has vertical walls that widen towards the bottom and form a bell-shaped burial pit with an extension in the form of a niche (Fig. 6). The deceased was laid on the flat bottom of the pit, on a prepared subsoil in a niche along its southern edge.

The filling of the grave (SJ 689/1–6) consists of six layers in which the skeleton was buried, indicating certain symbolic and ritual behaviour. Layer SJ 689/1 (109.02–108.64m AMSL) is the contact layer between Pit 101 and Grave 5 and consists of dark grey-brown soil. The older layer is SJ 689/2 (108.82–108.62m amsl), which consists of grey loose earth with admixtures of ash, and may indicate a certain part of the funeral ritual that includes lighting a fire and sprinkling ashes on a fireplace above the pit after the burial of the deceased, burial and sealing of the grave. Fill SJ 689/3 (108.65–108.42m AMSL) is a harder layer of yellow charge made of pure loess and brown earth, 5–10cm in thickness. It is placed in order to seal the grave by compacting a layer of loess and harder, fatter earth. We see these layers of sealing in most of the excavated graves on Vučedol. Layer SJ 689/4 is a loose fill of grey soil

6 AMS results: AMS 14C Lab Code: DeA-25458; Sample prep. Nr.: I/24101; Sample ID: PN 3457; Sample material: bone; Conv. ^{14}C age (yrs BP, ±1σ): 4222±33; Cal. Age (cal AD/BC, 2σ): BC 2910-2670.

7 MS radiocarbon measurements were performed in the laboratory of Isotoptech Zrt. (Debrecen, Hungary) on one bone sample from Grave 5. We thank Mirela Hutinec, the director of the Vučedol Culture Museum for providing us the report done by Isotoptech Zrt. Laboratory from 30.04.2020.

Fig. 4. Position of the skeleton in the Grave 5 (author S. Bošnjak).

with a large amount of charcoal and ash, 20cm thick (108.65–108.40m amsl) (Fig. 7a.1, a.2). Such layers are already known in almost all graves in the site and are apparently a standard part of rituals throughout the entire period of the Vučedol culture (*Durman 1988; 2000*). Covering the deceased with charcoal can have multiple meanings. Traces of charcoal and ash may indicate that fires were lit over the deceased to reduce the unpleasant smell of decomposing bodies. The ritual could have lasted several days or weeks, so the grave could have been open for a long time. In this ritual, beech, ash or elm wood rich in tannins and plant proteins with a bacteriostatic effect or maybe some grasses and aromatic herbs could have been used. These things, in combination with the thermal effect, could denature the proteins in the bodies, preventing decomposition for some time (*Milićević-Bradač 2001.215–216*). Temperature and smoke together with tannins can also have a slight mummifying effect, as we know from the tombs of, for example, the Yamnaya culture (*Majchrzak, Włodarczak 2021.169–172*). The perception of fire as an act of purification and protection has a universal character and occurs in different geographical areas, in different historical periods and in different contexts (*Horváth 2010.68–69; 2017.396; Stavreva 2022.17–18*). It is used in rituals for purification and protection during some important life events or transitions: birth, marriage, and death (*Grebenarova 2009.194*). According to folk beliefs, fire is used in the grave to protect the dead from reincarnation, but also to break their connection with the living, to protect them from their possible harmful effects and from a new death (*Stavreva 2022.18*). As can be observed in Grave 6, a group grave, charcoal and ashes can, together with other finds such as ceramic pots and animal bones, point to a ritual feast (*Milićević-Bradač 2001; Horváth 2019*). Below this layer, layer SJ 689/5 of river snails and shells appears, 15cm thick (108.45–108.30m amsl) (Fig. 7a.1). Such backfills are known from other excavated graves from Vučedol, however, they have never been recorded in this quantity, *i.e.* the thickness of the layer. The custom of placing freshwater shells and molluscs in graves has been known since the Neolithic (*e.g.,* the Linear Pottery culture in Slovakia and Transdanubia), it is not excluded that as food they could have had a symbolic meaning (a symbol of rebirth) and that they were consumed as a ritual meal during religious ceremonies or that they indicated warmer periods, spring or summer (*Pavúk 1980.208; 1994.98; Hromada, Varsik 1992.47; Jelínek 2010.32–34; Toth 2019.39–40*).

The layer just above the skeleton is SJ 689/6, which consists of loose brown soil mixed with charcoal and animal bones (108.35–108.00m amsl). Traces of charcoal and animal bones with traces of scraping, cut-

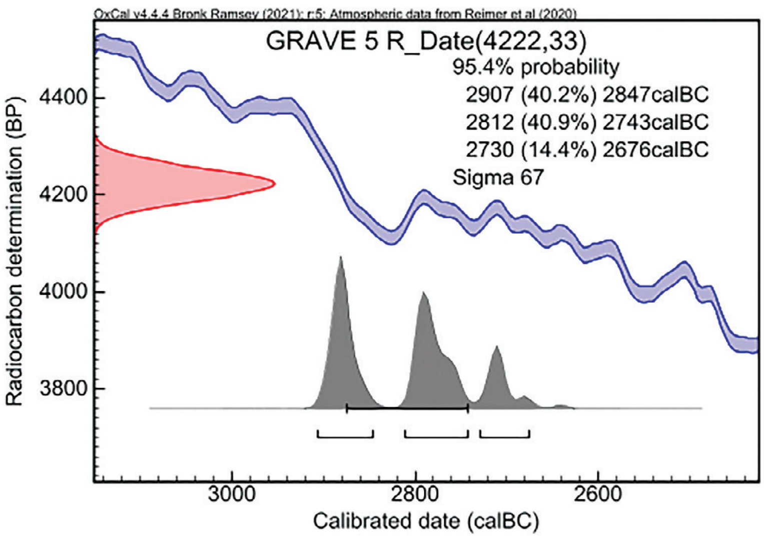


Fig. 5. Radiocarbon date (AMS) for Grave 5 (OxCal v. 4.4.4, Bronk Ramsey 2021; Atmospheric data, Reimer* et al. *2020) (prepared by S. Bošnjak).

ting and burning point to a ritual feast. We find a similar situation in the graves of the Baden culture in Hungary, but also in other positions at the Vučedol site (*Durman 1988; Jurišić 1990; Hincak 1995; Horváth 2006; 2010; 2019*). A preliminary analysis of the animal bones established several species of domestic and wild animals (cattle, deer, pig, small ruminants, sheep or goats and fish), while a detailed zooarchaeological analysis brings the results presented in the following chapters. The burial of animals with humans is explained by social, religious and emotional motives (*Behrens 1964.161–162*). Most of the pits in Vučedol record a large amount of animal bones, so one gets the impression that bone material occupies a larger part of the total researched finds. It is almost impossible to explain such a quantity of animal bones, and then define and separate the burials as ritual or profane with certainty. Funeral rites must have some common characteristics, recurring aspects (in the way of dying, character of burial, location, finds, *etc.*) and coincidences that suggest that a particular burial is not a common, profane death (*Horváth 2010; Pasarić 2018*). At Vučedol, two types of ritual burials of animals can be distinguished for now: parts of animal skeletons laid next to the human deceased as part of a ritual feast, and independent burials of complete animal skeletons as sacrifices of some communal ritual probably related to the cult of fertility or social status (*e.g.,* a pit with a deer burial in front of the sacral-workshop building the 'Copper Caster's Megaron') (*Schmidt 1945.28*). Nevertheless, the majority of complete animal burials from the excavation done so far at the Vineyard Streim site belong to the Baden and Kostolac cultures, while in the pits of the Vučedol culture settlements we record more partial parts of skeletons or fragmented, cut or split bones (*Jurišić 2010*). In Grave 5, in addition to the animal bones, there are also two hollow cattle horns (Fig. 7.b, PN 3458, PN 3468) which show a distinct ritual character, can be connected to the cult of fertility, and are placed next to the thigh and chest of the deceased. Cattle certainly have a special meaning in the Eneolithic period, starting with the arrival of the Baden culture. With the advent of the Eneolithic, the general European symbolism of cattle gradually changes in some details, although it most likely still retains its primordial, ancient general meaning of worshiping female deities. Cattle burials were discovered in the area settled by the Baden culture, the vast majority of which were interpreted as ritual burials (*Banner 1956.81; Jurišić 1990.27; Horváth 2010; 2019*). Cattle burials were also found in Vučedol, and they are associated with the cultures of Baden and Kostolac (*Jurišić 1990. 22–23*). From the earliest sanctuaries that contain bucrania or only horns, through many Neolithic cultures up to the Eneolithic, it is possible to trace the appearance of cattle in different forms and contexts. Real cattle horns were already replaced in the Neolithic by their schematized representations, as a hint of what we call consecrative horns in the Kostolac and Vučedol cultures (*Hoti 1989; Šimić 2020.165–173*). Consecrative horns at the Vučedol site are found in most houses located on the floor near the hearth (*Hoti 1990*). Real horns in the form of bucrania are found in front of Vučedol houses or on the floors, while horns or parts of horns are found in layers, pits and graves. The two horns in Grave 5 certainly have a strong symbolic role, and while on the one hand they are a symbol of fertility, abundance, birth and life, on the other they are related to dying, death and the underworld.

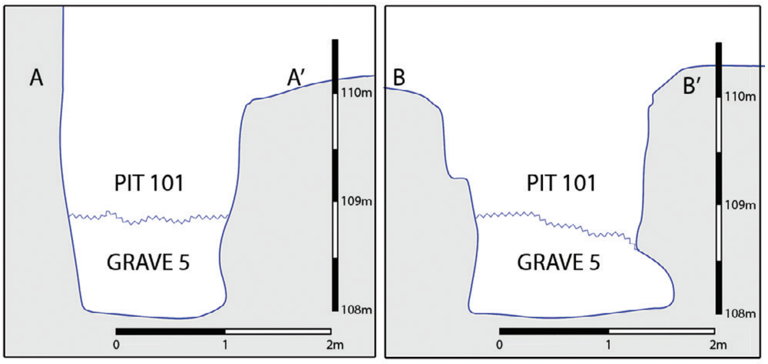


Fig. 6. Layout and cross-section of Grave 5 and Pit J 101 (authors S. Bošnjak and D. Roksandić Vukadin).

Layer SJ 689/6 is 30cm thick and in addition to animal bones the outlines of a human skeleton lying on the flat bottom of the pit in a layer of yellow compacted loess (subsoil), could be seen there. In this layer a larger piece of stone (grindstone) was also recorded, which was deliberately placed on the torso of the deceased, which for now is another phenomenon and a new element recorded in burials at Vučedol. This piece of grinding stone was certainly not accidentally thrown at the deceased, but it probably indicates a ritual function. Placing a stone on the body of the deceased can be interpreted as a precaution to immobilize the deceased at the bottom of the grave so that he cannot get out. This custom is recorded in graves until the Middle Ages. We find similar cases in the Eneolithic graves in Bulgaria at the site of Durankulak and Demir Baba Teke, where stones were placed on various parts of the body of the deceased (shoulder, legs, pelvis, skull) (*Bartelheim, Heyd 2001.268–269; Stavreva 2022.16*). In the case of the deceased from Grave 5, the weight of the stone destroyed parts of the bones of the chest, causing movement and rotation of the skull, arms, vertebrae and pelvis (Fig. 7.a.1).

The deceased (young male person, age 11–15 years) was laid in a very crouched, *hocker* position on his left side, which indicates that he was placed in the grave immediately after death while the body was flexible, before stiffness, *rigor mortis*, occurred, but there is also the possibility that he was tied. The most common

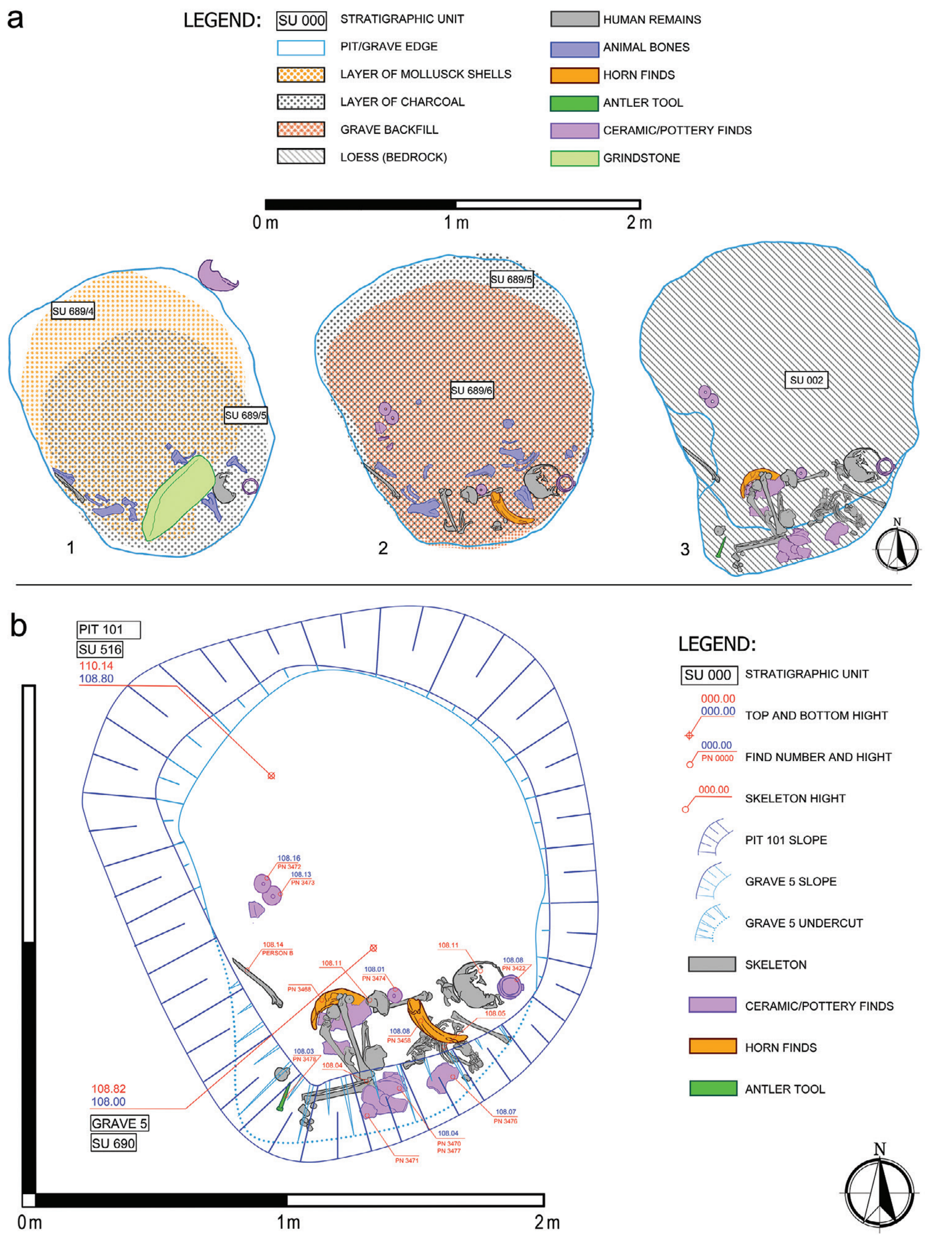


Fig. 7. Layout of Grave 5 by research phase (a.1–3, b) (authors S. Bošnjak and D. Roksandić Vukadin).

positions of the deceased at Vučedol are: strong or relaxed *hocker* left or right (on the chest or back with deviations in the position of the head, arms and legs), stretched out on the back and on the stomach (with deviations in the position of the head, arms and legs), and in a so-called sitting position. Throughout the Eneolithic there are examples of gender differentiation according to the position of the deceased, especially in the *hocker* position with respect to the left or right side. In the Tiszapolgar culture, men are buried in a crouched position on their right side and women on their left side. The position of the head is a similar case (*Borić 2015*). The direction in which the body was facing could possibly be in accordance with the direction in which the dead would have directed their gaze (*Stavreva 2022.12*). For a long time it was thought that the burial pattern at Vučedol was similar (differentiation according to gender), *i.e.* that women were buried on the left side and men on the right, however, it seems that this is not the case, as confirmed by the anthropological analysis of the deceased in Grave 5 in the following chapter. The position of the hands of this deceased individual is questionable. Due to the movement of the entire chest the bones of the arms are dislocated, *i.e.* the right hand can be seen on the left side, while the left hand is dislocated towards the head. In Vučedol graves, we notice various positions of the hands (folded towards the face, folded on the face, separated on the chest or towards the side, separated in various positions, above the head), and no specific pattern can be observed. It should also be kept in mind that the original position of the deceased can change as the body decomposes and the bones move, and an important factor is the consistency of the soil and the influence of weathering. The skeleton's skull is rotated with its face towards the ground, so the facial bones are quite fragmented. On the frontal part of the skull, depressions-lesions were observed that resemble those from the skulls of the deceased male person from Grave 3 from the Vineyard Streim (V 85) from 1985 (group grave of seven women and one man, the so-called 'Mars and Venus Grave') (*Durman 2000.41–57*). Unusual depressions were visible on their skulls, which Durman explains as the dripping of incandescent metal. The depressions were made during the life of the deceased, probably at an early age, and it was a sign that these eight people had been specially marked and sacrificed for some reason (*Durman 1988; 2000; Teschler-Nicola, Berner 1994*). We can see such a custom on the skull in the double grave, Grave 3 from the Vineyard Streim (V 87) from 1990, and in the group grave, Grave 6 from the Cornfield Streim (V 17) from 2021 (*Hoti 1993; Hincak 2005; Hincak Daris* et al. *2022; Roksandić Vukadin 2022*). Traces of a dull red colour were also found on the mentioned skulls inside the hollows, which indicate the use of cinnabar, which is a custom, as well as sprinkling with ochre, known in remote Prehistoric times (Çatalhöyük, Varna I) (*Schotsmans* et al. *2022; Hincak* et al*. 2022; Stavreva 2022*). In prehistoric times, the presence of red ochre in graves is associated with the concept of preserving life by the passage of the soul to the afterlife, and the red colour provides magical power to cross the border between the two worlds. The other bones of the deceased were relatively well preserved, and according to preliminary analysis it was a younger male person (adolescent). Next to the legs of the deceased was another human bone (left ulna of an adult male person, age 40–50 years) that does not belong to the mentioned person, and no other bones were recorded (Fig. 7.b). This finding is in support of the ritual of secondary laying of individual bones from an older grave, in this case upper limbs, namely arm bones. This phenomenon can be related to the cult of ancestors, and it constantly appears in Vučedol, especially related to ritual burials, which we wrote about in previous chapters. Offering parts of the human body is a traditional ritual in many societies, and is explained as protection for the living or for their redemption (*Stavreva 2022*).

Finds with the skeleton of the deceased are contributions in a ritual burial, and we can divide them into ceramic (pots and loom whorls), bone (antler awl), stone (whetstone), and horns (hollow horns of cattle) (Pls. 1–3 (see below), cat. no. 1–12, Fig. 7.b).

Ceramic pots are a typical repertoire in Vučedol graves, as grave contributions in the form of whole pots or more or less fragmented ones. They are mostly fine tableware items, but there are also fragments of coarse kitchen pottery. There are large quantities of them in the graves: the 'Married Couple Grave' records 21 complete pots, 30 broken ones and over 800 fragments, Grave 3 (V 85) contains 4670 ceramic fragments, Grave 2 (V 84) contains more than 40 pots (*Schmidt 1945. 41–44; Durman 1988.48; Milićević-Bradač 2001.213*). Large quantities of pots in graves indicate some kind of wealth and prosperity, but they are not primarily a symbol of prestige in the Eneolithic cultures and Vučedol society. In addition to complete pots, fragmented pots with traces of older breaks were also placed in the graves. These contributions were placed in the graves as prestigious gifts, whether from family, tribe or allies. In Grave 5, we find a generally small amount of items. There are mostly ceramic pots (four complete and three fragmented) placed by the head and central part of the body of the deceased (Fig. 7.b; Pl. 1–2, cat. no. 1–7). The most recognizable form of Vučedol pot with a fine structure is the so-called terina, a bowl with a convex top and biconical belly with a single handle. We find these in the context of residential, workshop, and burial objects. As a rule, they are decorated with geometric motifs made by a combination of grooved incising, notching and incrustation. The decoration is made on, above or below the biconity in the form of a line or strip. There are also examples of undecorated terinas, as well as terinas that are richly decorated above the biconity. The appearance of decorations under the biconity is extremely rare. Terina handles are almost always decorated (*Dimitrijević 1956.17; 1979. 287; Durman 2000.60; Balen 2005.44; Rajković, Balen 2016.78*). Richly decorated terinas are known from Vučedol graves, for example, the 'Married Couple Grave' from Vučedol's Gradac or the terina from 'Mars and Venus Grave' (Grave 3, V 85) from Vineyard Streim from 1985, and the decorations on them contain some symbolic message (*Schmidt 1945.41–45; Durman 1988.48*). In Grave 5, terina-type pots are dominant, one of which is smaller, miniature and placed next to the head of the deceased and has a strong symbolic role (Fig. 7.b; PN 3422, Pl. 2. 4, cat. no. 4). Miniature ceramic pots in the form of glasses or cups and terinas that are found next to the deceased or in their hands speak of the symbolism of drinking containers in graves, which is an extremely wide phenomenon in European prehistory, as well as in cultures that precede Vučedol, and they indicate the stratification of society and the leading class, typically men in the Vučedol culture, who were buried with drinking pots (*Trigger 1995; Milićević-Bradač 2001*). Drinking sets made it possible to consume a specific substance – alcohol. Alcohol is an important ritual and social phenomenon, the production and joint consumption of which is a significant element in establishing social relations in the community. It also becomes a symbol of a certain social status, and is used during religious rites or rituals, and in the Eneolithic it was possible to consume beer, fruit wine, mead or spirits (*Krištuf 2005.72–73; Toth 2019*). We find a direct analogy for this smaller terina (cup?) in Grave 1 (V 84), the so-called 'Orion Grave'from 1984, where the deceased was found in a very unusual position with his hands above his head touching a terina-type pot, of smaller dimensions and without decorations. Grave 1 from 1984 is dated to the earliest phase of the Vučedol settlement at the Vineyard Streim, *i.e.* phase A of the Vučedol culture (*Durman 1988.cat. no. 53; 1999.3, Fig. 1; 2000.62, Fig. 25; 2009.254–255*). The appearance of smaller, undecorated terinas is very unusual and we have such examples from the Sarvaš site near Osijek where they are defined as cups (*Rajković, Balen 2016.T. 34,204,206, 207*). The small terina (cup) from Grave 5, according to stratigraphic relations and absolute dates, undoubtedly belongs to the classic B1 phase. We are of the opinion that older theories about the existence of phase A at the investigated positions on Vučedol should be reconsidered. Another terina, of larger dimensions, with a straight line on the biconity and a specific triangular decoration, was located next to the feet of the deceased (Fig. 7.b, PN 3470, 3477, Pl. 1.1, cat. no. 1). It should be noted that the triangular motif is quite well represented as a decorative motif on items of the Vučedol culture. It appears in many different combinations: independently, in a row as a wreath, as a pattern that fills the frieze (*Dimitrijević 1956.25*). Similar triangle motifs on other parts of the pots, in various orientations, independently or in a row are relatively represented on ceramic material from the Vineyard Streim, which is unpublished. However, for now we are not aware of the presence of such decoration on terinas in a grave context, except on the handles where the triangle motif is very often executed in the form of an hourglass (clepsydra) (*Dimitrijević 1956.25*). Durman notes that terinas with a decoration of a simple straight line on the biconity are similar to the earliest examples of such pots (phase A according to Dimitrijević), and he attributes to the same phase the pots that have geometric motifs above such a line. Durman also provides examples of two terinas from the Vineyard Streim (from the floors of houses) that can be connected with the example from Grave 5 in terms of shape and decoration on the biconity, although their decoration is somewhat simpler *(Durman 1999.3–5, Figs. 2,3; 2000.62, Figs. 26,27; 2009.254–255*). The best parallel to this type of pot is the terina from Sarvaš, which has almost the same motifs of grouped concentric triangles in a row (*Balen 2005.119, T. 33*). Unfortunately, we do not know the exact context of the discovery of this pot. However, Dimitrijević uses the mentioned terina from Sarvaš in his chronology and dates it to the B1 phase of the Vučedol culture (*Dimitrijević 1979.T. XXIX, 9*). A terina with a horizontal strip above the biconity is located next to the chest of the deceased (Fig. 7.b, PN 3476, Pl. 1.3; cat. no. 3). Decorations with a 'decorative strip' consisting of alternately placed two or more flowing ornaments separated by empty rectangular fields are most often found on bowls and terinas (*Dimitrijević 1956.26*). Various zigzag motifs and then chain, wavy, double toothed, and mesh patterns and other motifs can be found within these strips (*Dimitrijević 1956.26*). Border decorations are most often placed under the edge of the opening of the pot, where the needle motif dominates, followed by drip-shaped and harpoon (herringbone), zigzag lines and wavy lines are also common. Sometimes, only the motif of slashes or a series of stabbing motifs was used for this purpose (*Dimitrijević 1956.27*). Examples of biconical terinas with a decorative strip and a decorated handle are extremely numerous in all sites of the Vučedol culture. We can thus find parallels in Vučedol itself (Gradac, Vineyard and Cornfield Streim) (*Schmidt 1945; Durman 1988; 1999; 2000; Roksandić Vukadin 2021*), Sarvaš (*Balen 2005.2; Rajković, Balen 2016. 77–78*) and Vinkovci (*Durman 2000*). A terina of this type, richly decorated, was included in group Grave 3 (V 85) from Vineyard Streim from 1985 (*Durman 2000.50*). In Graves 3 and 4 ('Married Couple Grave') from Gradac from 1938, a richly decorated terina was found turned upside down and placed over a woman's head (*Schmidt 1945.T.36*), which Dimitrijević dates to the B1 phase (*Dimitrijević 1979.T. XXIX.1*). Closer analogies to the terina from Grave 5 can be found in the same grave, *i.e.* two terinas with the same decoration (*Schmidt 1945.T. 38.1, 2*). A shallow, decorated biconical bowl with handles was found at the feet of the deceased in Grave 5 (Fig. 7, PN 3471, Pl. 1.2, cat. no. 2). This type of pot and those like it are one of the most represented types in the Vučedol culture. Parallels to it can be found at Vučedol (*Schmidt 1945; Roksandić Vukadin 2021*), Sarvaš (*Balen 2005.42; Rajković, Balen 2016.77–78*) and Vinkovci (*Durman 1988; Miloglav 2012*). According to the typology proposed by Ina Miloglav, it belongs to the A4 c type (*Miloglav 2012*). Other examples of pottery in the grave belong to coarse kitchenware of the pot type with tunnel-shaped handles, and are found next to the deceased (Pl. 2.5–7; cat. no. 5–7). Pots with tunnel-shaped handles under the neck (smaller amphorae) are a typical inventory among coarse kitchenware for everyday use. Such pots are often decorated in two rows, along the rim of the pot and at the transition of the neck to the body of the pot, often made with applied strips with fingerprints and less often, as in this case, by stabbing. The neck is very often more or less polished, and the belly is covered with barbotine. All these elements speak of an extended Neolithic tradition (*Dimitrijević 1979.290–293*). A significant number of coarse kitchenware is undecorated and a relatively rough surface is left, without secondary interventions (*Dimitrijević 1979.290*). Miloglav singles out S-profiled pots as the most represented form of the group of pots, and especially pots with a cylindrical neck (*Miloglav 2012*). We have analogies for these findings from Vučedol, Vinkovci and Sarvaš (*Schmidt 1945; Dimitrijević 1979. 290–293; Durman 1988; Balen 2005.40; Miloglav 2012; Rajković, Balen 2016.76–77*). Coarse pottery is also found in Graves 3 and 4 from Gradac from 1938 (*Schmidt 1945.T. 32.1, 3, 4*).

Of the other ceramic items in Grave 5, we find three types of spindle whorls, conical, round and discoid type (Pl. 3.8–10, cat. no. 8–10), as textile tools in the process of a textile spinning technology. Ceramic loom weights and spindle whorls often appear in a Neolithic context throughout Europe, while in the Late Eneolithic period loom weights are very rare and differ in form from earlier and later examples (*Grabundžija 2016; 2018*). At the Vučedol site spindle whorls outnumber loom weights and the lack of weights is noticeable in other Eneolithic sites. Loom weights could be lacking in archaeological contexts due to the perishable materials used for their production. Additionally, according to some authors more unconventional forms such as spools might have also been applied to provide the necessary tension for warp threads (*Grabundžija 2018.272*). In the prehistory of Europe, starting from the Neolithic period (*Barber 1991.91–100*), vertical looms on which the threads are stretched using weights, usually ceramic, are considered a characteristic type of loom. The question of the technological solution for weaving in the late Eneolithic period, at the time of the Vučedol culture, is still open due to the absence of direct and unequivocal material evidence of the weaving technique. The particular issue of recognizing textile tools, which often have a multifunctional character, is addressed in experimental research (*Grabundžija* et al. *2016*). Similar types of whorls as in Vučedol site are present in Eneolithic sites throughout continental Croatia (*Grabundžija 2018. 264–265, Fig. 1*). We also find them in graves of the Baden culture together with other finds such as pottery, stone and bone tools and the like (*Němejcová-Pavúková 1979; Horváth 2017; Toth 2019*). At Vučedol, they appear in the context of residential objects and speak of a highly developed weaving craft, while we have no records of them in the published graves (*Karavidović 2021*). The symbolism associated with the burial of whorls in graves is complex and appears to be associated with individuals and their relatives. It was once thought that the whorls were only buried in women's graves, but this theory has been rejected. The fact that they were placed next to the deceased in a similar way to other items suggests that they are probably a part of the social identity of the deceased. It is possible that they were owned by the deceased or were passed down through generations within a family group (*Douglas, Muti 2019*). Along with the deceased in Grave 5, there were two other tools that could possibly be tied to weaving, a tool made of antler (Pl. 3.12, cat. no. 12) and a piece of (whetstone) stone (Pl. 3.11, cat. no. 11). The tool made of deer antler would fall under the group of pointed tools, and can be categorized as an awl made of antler or more likely as a piercing tool because it has a stronger, more resistant working tip (*Vitezović 2010.284*). It shows careful craftsmanship with its square-shaped base that serves as a handle attachment, and the entire surface of the tool is polished. The top is damaged, which indicates that the object was used before being placed in the grave. It is known that an exceptional amount of tools made of deer antlers appeared during the time of the Vučedol culture. There are numerous massive tools, while small tools like this one from Grave 5 are less common (*Mitrović, Vitezović 2017.187–88; Vitezović 2018.178–81; 2022; Bošnjak* et al. *2020*). The stone tool (Pl. 3.11, cat. no. 11) is a square-shaped whetstone with traces of use and damage before the burial. Both of these tools with the three loom whorls may be a toolkit that was used or passed down within the family of the deceased, and they speak of a certain social status and particular identity in the community, in this case of textile manufacturers or weavers.

Anthropological analysis of human bone remains

Material and methods

The osteological human remains originate from trench V 17, Cornfield Streim, Grave 5 that was analysed during the autumn of 2019 (V 17, SJ 689, Grave 5, PN 3457). The material was stabilized, cleaned, reconstructed and analysed on the premises of the Forensic Science Office of the University of Zagreb.

Although fragmented, the bones of the skull and lower jaw, as well as most of the postcranial osteological elements, have been well preserved, allowing the determination of the sex and age at the time of death. Methods of analysing human bone remains include macromorphological and morphometric approaches. Basic dental analysis is limited to the dental status, possible pathology, and determination of macromorphological features. According to Rudolf Martin and Karl Saller (*1957*), osteological measurement was performed with a standard set of anthropological instruments GPM – Sieber Hegner.

Sex determination is performed according to the appearance of the greater sciatic notch of the ilium and according to the sexual sign expression of the mandible: *corpus mandibulae*, *trigonum mentale*, and *angulus mandibulae* (*Buikstra, Ubelaker 1994*). Age determination is carried out according to maximum diaphysis lengths of humeral, radial, femoral and tibial bones, by measurements of the scapula and hip bone, and by the closure of epiphyseal lines (*Black*, *Scheuer 1966; Stloukal, Hanakova 1978; Saunders 1993; Cunningham* et al. *2016*) together with the dental status analysis of both mandibular and maxillary teeth (*Buikstra, Ubelaker 1994; Schaefer* et al. *2009*). Pathological changes were registered morphologically and morphometrically (*Ortner 2003; Aufderheide, Rodrigez-Martin 2011*). The development of ulnar muscle attachments of person B, an adult male, was analysed.

Results

The osteological remains of two persons, an adolescent (person A) and an adult male (person B), were found in the grave. The skeleton of person A is almost completely preserved (Fig. 8), while only the left ulna of person B is preserved.

Person A

Sex: male; age at death: 14–15 years ± 30 months; pathological changes: *cribra orbitalia* second and third degree.

The bones of the skull are almost completely preserved. The described damage was caused postmortem, after the discovery of the grave. The frontal bone is completely preserved with open coronal suture. The upper surface of both orbits are thickened, with dense porosity. The surface of the left orbit is cribrotic (second degree), while changes on the right orbit are trabecular (third degree) (Fig. 9).

The skull's bones are almost completely preserved. The damage described occurred postmortem after the grave was discovered. The frontal bone is completely preserved with an open coronal suture. The upper surface of both orbits is thickened with dense porosity. The surface of the left orbit is cribrotic (second degree), while changes on the right orbit are trabecular (third degree). On the median plane of the frontal bone, 45mm from *sutura coronalis*, a slightly oval

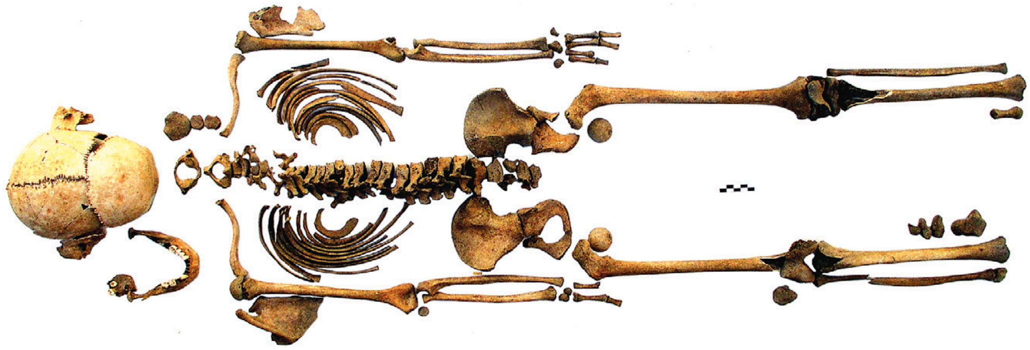


Fig. 8. Skeleton of person A in anatomical position (author Z. Hincak Daris).

bony depression measuring 6x6.7x1.3mm is observed. Another depression is located laterally and to the right of the first, measuring 11x10x0.6mm. Both are almost level (Fig. 10).

Both parietal bones have been preserved, the left almost entirely and the right mostly. The sagittal suture is completely open. A shallow, oval, bony depression with thickened edges is observed on the right parietal bone, measuring 7.5x5.33x1mm. It is located 57.63mm from the coronal suture, and 33.35mm from the sagittal suture (Fig. 10). Another shallow, irregularly elongated depression with a rough surface measures 14x 8mm and is located 24mm from the previous one and 52.3mm from the sagittal suture. This last one differs in appearance and depth from the three depressions described earlier. The occipital bone is partially preserved, mostly along the lambdoid suture located by the left parietal bone and less so along the right parietal bone. More distally, the internal occipital protuberance with the cruciform eminence, *i.e.* the muscle attachments of the nuchal region on the outside of the skull, is preserved. Stronger porosity is recorded on the posterior parts of the parietal bone, towards the sagittal and lambdoid sutures, and close to the proximal parts of the occipital bone. Both temporal bones are partially preserved in a part of the squama temporalis, but the other parts are fully preserved: the mastoid process, tympanic, and petrous parts of the bone. Of the cervical vertebrae, a series from the atlas to the fifth vertebra, which is preserved in half of the body and arch, and the seventh vertebra, whose arch is partially preserved, have been preserved. On the dens axis of the second cervical vertebra, which has broken off from the body, a slight epiphyseal line is visible at the point where the tip, the apex dentis, meets the rest of the tooth. All the damage to the vertebrae occurred postmortem, and the fresh edges of the fractures are visible. The thoracic vertebrae are preserved in rows from the first to the fifth and from the seventh to the twelfth, but from the twelfth on only the vertebral arch is preserved. The lumbar vertebrae are preserved in the entire row, from the first to the fifth, and the third is damaged on the lateral right edge of the body and arch of the vertebra. The first sacral vertebra is partially preserved, and the distal part of the body shows an unfused joint of the first and second sacral vertebrae. In the row from the second to the fifth sacral vertebrae only the bodies are preserved, which are not fused, and the last two bear half of the medial sacral crest. The left ribs are preserved in a row from the first to the twelfth ribs, the fourth and tenth ribs are preserved in the proximal half, the fifth rib in the proximal two-thirds, the proximal and distal third of the eighth rib is preserved, the proximal fragment of the eleven-

Fig. 9. Cribra orbitalia third degree, right orbitae, detail (person A) (author Z. Hincak Daris).

Fig. 10. Norma verticalis: shallow depressions on the frontal and right parietal bone are indicated by black arrows (author Z. Hincak Daris).

th and another shorter fragment are preserved, while the proximal three-quarters of the twelfth rib are preserved. Three shorter fragments of the rib body were isolated, for which the side they belonged to could be determined. The right ribs are preserved in full sequence, from the first to the twelfth ribs. The second rib is preserved in the proximal third, while the twelfth is preserved in the distal three quarters of the rib body. The sternum is partially preserved. The manubrium, as a proximal part of the sternal bone, is preserved in full, while only two divided segments of the body or middle mesosternum were preserved, first and second as individual, nonfused juvenile sternebrae. Both clavicles are completely preserved, sternal and acromial or middle end have an open diaphysal surface. The age at the time of death of person A, according to the clavicle measures, is in the age range of 12–13 years according to the table of measurements of the longest lengths of the clavicle in the infans II and juvenile phases, according to Black and Scheuer. Measurements: clavicle; left clavicle, maximum length = 114.7mm, right clavicle, maximum length = (111.2 mm). The right scapula is completely preserved, while the left one is preserved partially in the glenoid cavity and partly in the body, mostly in the lateral border. According to measurements of scapular width and scapular length, age at the time of death of person A was in the range of 9–10 years, according to the values of measurements 6 and 5, according to Saunders' table. Measurements: right scapula: length of glenoidal surface = 20.7mm, middle diameter of the glenoidal surface = 15.6mm, length of glenoidal mass = 26.7mm, spine length = 91.8mm, scapular width = 75mm, scapular length = (101.4mm), infra-scapular height = 83.3 mm. The long bones of the left arm are completely preserved, the diaphysis and parts of the proximal and distal epiphysis are not fused. The humeral diaphysis is completely preserved with measurements maximum diaphysal length = (229mm).The left radial bone is completely preserved, and measures: maximum diaphysal length = 181mm. Age at the time of death of person A, based on the maximum diaphysal length, is 14 years according to Stloukal and Hanakova's measurement table. The left ulnar bone is completely preserved, and the maximum diaphysal length = 204mm. From the group of carpal bones, the scaphoid bone, capitate bone and trapezoid bone are preserved. Metacarpal bones are preserved in a row: II–V, on all specimens, the distal epiphysis is fused, and the proximal one is not completely fused. Phalanges of the hand – proximal row: II, III, medial row: II. In terms of the right arm, the diaphyses are completely preserved and in terms of the epiphyses, the proximal epiphysis – head of radius – is preserved.

- Humerus, maximum diaphysal length = 235mm
- Age at the time of death of person A, based on the maximum diaphysal length, is 12–13 years according to Stloukal and Hanakova's measurement table.
- Radius, maximum diaphysal length = 182mm
- Age at the time of death of person A, based on the maximum diaphysal length, is 12 – 13 years according to Stloukal and Hanakova's measurement table.
- Ulna, maximum diaphysal length = 303mm
- Among the right carpal bones, the scaphoid and lunate bones are preserved, and among the metacarpal bones II and IV and from hand phalanges – proximal row I.
- Hip bones
- Male sex is determined by a narrow, 'U-'shaped greater sciatic notch, the scoring of which is +1, arcus compose is not developed.
- Left hip bone
- The iliac bone is completely preserved, and the maximum iliac length = (101.3mm), maximum iliac width = 98.2mm.
- Ischial bone is completely preserved, and the maximum ischium length = 70mm, maximum ischium width = 48.2mm.
- The pubic bone is partially preserved in the acetabulum and the superior pubic ramus.
- The right hip bone
- The iliac bone is completely preserved, and the maximum iliac length = 101.2mm, maximum iliac width = 98mm.
- The ischial bone is completely preserved, and the maximum ischium length = 67.4mm, maximum ischium width = 48mm.

- The pubic bone is completely preserved, and the maximum pubic length = 87.2mm.

Out of the right leg bones, the diaphysis of the femur, the unfused head of the femur and the free, unfused distal epiphysis are almost completely preserved. The trace of a fresh fracture is visible on the anterior surface with a length of 7.6mm in the most distal part of the diaphysis (postmortem). On the proximal part, diaphysis of the tibia is almost completely preserved. On the distal third of the bone, on the *facies lateralis,* the trace of a more regular fresh fracture (postmortem) is visible, measuring 97mm in length and 7mm in width. A triangular fracture measuring 32.4mm in length and 26.7mm in width is visible on the medial surface. The distal half of the diaphysis and the proximal quarter of the leaf bone are preserved. The fractures visible on the diaphyses are fresh, postmortem fractures. The patellar bone is completely preserved. The right tibial bone is completely preserved, and the maximum diaphysal length = 279.8mm. The age at the time of death of person A, based on the maximum diaphysal length of right tibia, is about 14 years, according to Stloukal and Hanakova's measurement table. The right fibular bone is preserved in the proximal and distal third of the diaphysis. From the right talar bones, the navicular bone, intermediate cuneiform bone and medial cuneiform bone are preserved. From the left leg bones, the diaphysis of the femur, the completely unfused head of the femur, the distal epiphysis, almost the entire diaphysis of the tibia, the proximal epiphysis, and the entire diaphysis of the metatarsal bone are preserved. The femoral bone is completely preserved, and the maximum diaphysal length = 343 mm. The age at the time of death of person A, based on the maximum diaphysal length, is about 14 years, according to Stloukal and Hanakova's measurement table. The tibial bone is completely preserved, and the maximum diaphysal length = 280mm. The age at the time of death of person A, based on the maximum diaphysal length, is about 14 years, according to Stloukal and Hanakova's measurement table. The fibular bone is completely preserved, and the maximum diaphysal length = 268mm. The first metatarsal bone is preserved.

Dental analysis

Sex: male; age at the time of death: 15 years ± 30 months.

The mandible is completely preserved. Left side of the mandible: I1–I2 (postmortem empty alveolus), C, PM1, PM2, M1, M2 and M3, which is visible in the semi-closed alveolus (Tab. 2). Right side of the mandible: I1–I2 postmortem empty alveolus, C, PM1 fully closed alveolus, PM2 postmortem empty alveolus, M1, M2, while M3 is observed in half-open alveolus (Tab. 2). The maxilla is preserved only in a very small part of the body of the right maxilla and the dental row: M^1–M^3. The other teeth of the maxilla are outside the alveoli: left – I^1, C, P^1, P^2, M^2 and M^3 and right – P^1, M^1, M^2 and M^3 (Tab. 2). A thin ring of calcified tartar, dental calculus, is visible on the teeth.

The age at death of a person A is determined according to the dental status as presented by Ubelaker. Surface wear of all M1 upper and lower jaws indicates abrasion, unusual for such a young age, with a lower level of bone at the cemento-enamel junction. Approximal caries of the first degree are located at the contact of M1 and M2 of the right side of the mandible and M1 and M2 of the right maxilla. Horizontal caries of the second degree are visible on the buccal side of the right half of the mandible, on the M1 and M2 crowns, along the edge of the tooth neck. Outside the alveoli are P^1 and P^2 of the left maxilla, and at their contact, on the crowns of both teeth, approximate caries of the first degree are visible. Diagnosis: caries of the first and second degree.

Two transverse lines and tiny pits are visible on the anterior surfaces of the preserved canines and the first incisor of the left upper jaw (Fig. 11). Measurements were taken on the upper left canine, according to Reid: crown height = 10.6mm, height of the first transverse line = 5.4mm, height of the second transverse line = 8mm. Diagnosis: linear enamel hypoplasia. According to measurements, the timing of linear enamel hypoplasia on the crowns of the teeth during growth was 4–4.5 years (the first transversal line) and 5–5.5 years (the second transversal line), according to Reid's method.

upper right	upper left
M^3, M^2, M^1, P^2, P^1, C, I^2, I^1	I^1, I^2, C, P^1, P^2, M^1, M^2, M^3
M_3, M_2, M_1 ,P_2 ,P_1, C ,I_2 ,I_1	I_1, I_2, C, P_1, P_2, M_1, M_2, M_3
lower right	lower left

Legend: **black** – tooth in dental alveolus, **red** – tooth out of dental alveolus, **blue** – empty dental alveolus (postmortem), **green** – resorption of dental alveolus, **orange** – tooth and dental alveolus are missing.

Tab. 2. Dental status of person A, mandibula (Grave 5) (author Z. Hincak Daris).

Person B
In the grave, but far from the adolescent's skeleton, there was an almost completely preserved left ulna of an adult. Sex: male; age at the time of death: 40–50 years.

The male sex of a person is determined according to the robustness of the bones and the expression of the muscle attachments. A strongly developed attachment of the brachialis muscle (*m. brachialis*) can be observed. The *flexor digitorum profundus* muscle is pronounced. The development of the attachment of the supinator muscle (*m. supinator*) is pronounced and accompanied by the development of the supinator crest, as well as the pronator quadratus muscle (*m. pronator quadratus*). A short, oval olecranon spur (*calcar olecrani*) was developed on the superior and posterior surfaces of the olecranon. An age in the wide range of 40–50 years was determined according to the degree of osteoarthritic changes on the edges of the articular surfaces of the proximal epiphysis of the left ulna. An oblique section is visible on the distal sixth of the diaphysis as a result of sharp force trauma or more precisely due to the action of a sharp object on the surface of the bone, on the edge between the anterior and posterior surfaces measuring 12x3mm. It represents a trace of a bone cut that does not exceed half a millimetre in thickness. Distal damage caused by the action of a sharp object expands into a sharp-edged trauma in the shape of an inverted letter 'U', which measures 24.6x9.2mm. According to the appearance and features of the incisions, the trauma is perimortal, and thus occurred around the time of the person's death.

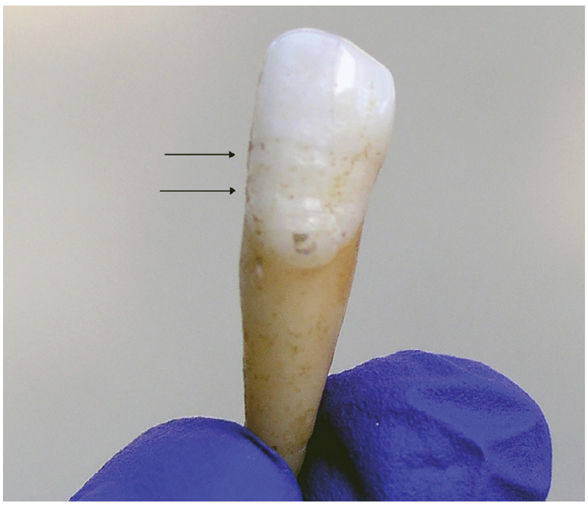


Fig. 11. Linear enamel hypoplasia (arrows), canine tooth, left half of mandibula (author Z. Hincak Daris).

Discussion
Grave 5 at the Vučedol site is located in the Vukovar loess plateau of eastern Croatia, in a loess of a very porous and slightly alkaline thick sedimentary deposit (*Bognar 1976*). The Danube wears away and erodes the west side of loess-palaeosol horizons, leaving cliffs up to 20m high, with a clear stratification (*Galović* et al. *2008*). The altitude of the site and the elevated position of the plateau does not presuppose seasonal flooding of the terrain, but heavy rains and changes in seasons, along with the action of permeable and easily mobile loess sediment, can have a significant impact on the situation in the grave. Even after the early stage of decomposition, bones became detached from the skeleton, and the disintegration of the soft tissues of the body led to the movement of certain osteological elements of the skeleton of person A, when the loose sediment filled the gaps created by the disintegration and 'pushed' the osteological elements in the spacious burial pit. The position of the skull of person A is particularly interesting, as it had been turned upside down, while the lower jaw had sunk below the left cheekbone. The head movement occurred while the lower jaw was still attached to the skull. The bottom of the grave is slightly sloping, and the person's head was placed on the side and in an elevated place, and after the skull connection was broken – *i.e.* the atlas (first cervical vertebra) – it ended up in the described position.

Pathological changes were found on the bones of the skull and on the teeth. Trabecular *cribra orbitalia*, or third degree *cribra orbitalia*, is observed on the upper orbital surfaces, in this case as a thick and spongy bone. Hermann Welcker (*1888*) describes this pathological change on the superio-lateral surface of the orbitae for the first time. The cause of this development is still being debated, with reasons for it being attributed to malnutrition, scurvy, gastrointestinal bleeding and iron deficiency anaemia (*Ortner 2003; Walker* et al*. 2009; Aufderheide, Rodrigez-Martin 2011; Mann, Hunt 2012; Viva* et al. *2021*). In the bioarchaeological context, the hypothesis of the origin of *cribra orbitalia* as a consequence of iron deficiency anaemia is accepted and still used as an explanation even today, and is also described as a feature that is exclusive to childhood. However, the literature describes cases of *cribra orbitalia* not only in children and very young people, but also in the elderly (*Hens* et al*. 2019*). Newer research reveals the connection between the occurrence of *cribra orbitalia* and frequent respiratory infections, which are today a leading cause of mortality

(*O'Donell* et al. *2021*), or the determination of *cribra orbitalia* as vascular in nature, and bony evidence of vascular anatomical variation (*Rothschild* et al. *2021*). Although scientists have been investigating this pathological change for about a hundred years, it seems that the aetiology of *cribra orbitalia* still remains unclear. Linear enamel hypoplasia is a disorder that occurs in the early, embryonic phase of tooth development, as a result of stopping the apposition of hard dental tissues (*Šutalo* et al. *1994*). A number of pathological conditions are usually cited as the cause – severe infections, a lack of vitamins A and C and the deficiency of prenatal vitamin D, calcium deficiency, scarlet fever and gastrointestinal diseases in children (*Mantegazza 2016; Reed* et al. *2016; O' Donell* et al. *2020; Wang* et al. *2024*). However, since *cribra orbitalia* and linear enamel hypoplasia are only secondary indicators of the disease, it is impossible to determine more precisely the cause of their development.

The appearance of enamel hypoplasia certainly increases the risk of dental caries. Perhaps this, but also the general health status of person A, is the cause of the large number of established caries lesions in the teeth of a very young person and the generally poor dental condition of the jaw. Earlier investigations of the dental status of skeletons of the Vučedol culture from the Vučedol site did not indicate a poor dental status of individuals, and it was even established that, despite the advanced age of maturus II, no pathological changes in the teeth were found (*Hincak* et al. *2013*).

It is not uncommon for skeletons of children and adolescents to be found in graves from different archaeological periods, which, according to the results of dental analyses, show a higher age range than the results of analyses of the bone remains of the same person. According to dental analyses, the age at the time of death of person A was in the range of 15 years ± 30 months, while according to the results of osteometric analyses of the bones of the skeleton, that range is lower, mostly around 11–14 years. It should be mentioned that the results of osteometric analyses for the scapula bone were compared with the results for modern populations as per Saunders, and that is a possible reason for the low result for the age (9–10 years). Another possible explanation of such discrepancies for other osteological elements (range of 11–14 years) lies in the fact that skeletal maturation and growth are not free from environmental influences, nor from the influence of the individual's health status. Pathological markers such as third grade *cribra orbitalia* (Fig. 9) and enamel linear hypoplasia (Fig. 11) point to nonspecific indicators of metabolic stress during early childhood. Skeletal maturation is also not free from environmental influences related to food source availability or food quality, nor from health status and disease, such as the possible presence of parasites in the diet. Moreover, cultural practice influencing the length of breastfeeding and weaning could have played a major role in the creation of pathological markers such as *cribra orbitalia* and linear enamel hypoplasia. Studies of dental development and skeletal growth indicate that dental development is less sensitive to socioeconomic factors than skeletal development (*Coneição, Cardoso 2011*), but hereditary, ecological, nutritional and hormonal factors also play a major role (*Goodman, Armelagos 1989; De Souza Araujo 2011*).

The three regular bone depressions on the bones of the head are very shallow and their traces are not visible on the endocranium (Fig. 10). We could call them lesions, although based on the characteristics it is not possible to accurately conclude how they formed. Similar lesions were described on the skull bones from the burial pit of the Vučedol culture at the Vinograd Streim site from 1985 (Grave 3) (*Hincak* et al. *2013*). In both cases it is only possible to establish that they are of unknown aetiology. The fourth depression, which, due to its irregular shape and very small depth and irregular surface, differs from the ones described earlier, probably represents a trace of a healed, shallow lesion as a result of an injury.

The development of the muscle attachment of the left ulna of person B reveals the 'individual's frequently repeated movements. Strongly developed muscle attachment of the brachialis muscle indicates flexion movements of the forearm at the elbow. The deep flexor muscle of a hand is prominent and indicates a firm holding of an object in the hand. The strong development of the muscle attachment of the supinator muscle and the pronounced supinator crest is responsible for the lateral rotation of the hand, and the strong grip of its antagonist, the pronator quadratus muscle, enables the medial rotation of the hand. The development of these muscles is common in people who work with metal (*Angel* et al. *1987*) or pick fruits (*Wienken, Wood 1988*). On the basis of only one bone, it is possible to conclude only how well developed the muscles of the ulna are, with a special emphasis on the movements of turning the hand while the arms are outstretched, perhaps as a part of the specific work the person was engaged in. This includes movements that lead to enthesopathy, oval and short olecranon spur (*calcar olecrani*) on the posterior surface of the olecranon as a result of stress, repetitive forceful flexion-extension movements. Such movements in the elbow describe a large number of physically demanding activities, such as those of a woodcutter (*Galera, Garralda 1993*) or fisherman, who casts a heavy net many times a day (*Dutour 1986*). But in order to conclude anything about the physical activities of a person, it is necessary to study the muscle attachments on the skeleton, and not on an isolated bone.

Animal osteological remains of Grave 5

Material and methods

Methods of animal osteological analysis include macromorphological analyses of mammal and fish remains (*Schmidt 1972; Nickel* et al. *1995; Radu 2005; König 2009; France 2010*).

Results

Sample U 837

Cattle (Bos taurus, L.*)*

Six short fragments of cranial bones have been preserved. A short body fragment of the right half of the mandible of an adult animal with the dental row from P2 to P4 has been preserved. The thoracic and lumbar vertebra have been preserved. The body is preserved in its entirety, and the arch is partially preserved, as well as another fragment of the arch of the lumbar and cervical vertebra. The first and second left ribs and three shorter fragments of the rib body are partially preserved. The distal half of the left humerus is preserved, with an obvious cut mark of a sharp object on the distal third of the diaphysis. The edges of the trauma are sharp, the cut surface is flat. The distal third of the right humerus bone has been preserved with the same, already described cut mark of a sharp object, which starts on the caudal side of the diaphysis and descends cranially about 40mm towards the distal epiphysis (Fig. 12.a). The distal epiphysis is preserved with a short part of the diaphysis, on which an irregular cut mark of the proximal part of the bone is visible. According to the macromorphological characteristics, the trauma is of a perimortal nature. The proximal third of the right ulnar bone is preserved. A well-developed left ulnar bone with partially preserved olecranon in the distal part is preserved. The longitudinal strip of the diaphysis and lateral part of the left fourth metacarpal bone and the distal third of the fourth metacarpal bone have been preserved. The medial phalanx of the third or fourth finger of an adult animal is preserved. Three femur heads have been preserved, two left ones and one right one that belonged to adult animals, which were cut diagonally from the neck of the femur to the edge of the femur head with a sharp object. The incision is oval, starting caudally on the epiphyseal line between the head and the rest of the proximal epiphysis obliquely towards the caudal surface of the bone. The third head of the femur is preserved in the unfused part of the proximal epiphysis of a young animal up to 2.5 years old, along with a shorter fragment of the neck. Two damaged condyles of the distal epiphysis and four fragments of the diaphysis have been preserved. The proximal left third of the tibia of an adult animal is preserved. The fracture marks on the distal part of the sample are fresh and postmortem. The left half of the tibia is preserved with partially open epiphyseal lines on the proximal epiphysis, as a result of which the age at the time of death of the animal was estimated to be approximatetely three years. The longitudinal half of the left metatarsal bone is preserved. The left calcaneal bone with partially preserved tuber is preserved, as are two middle phalanges.

Red deer (Cervus elaphus, L.*)*

The distal third of the right humeral bone has been preserved, with clear traces of cutting off the proximal part of the bone with a sharp object, just as it was in an already described humerus bones of a cattle. The edges of the trauma are sharp and the surface is smooth. According to the macromorphological features, the trauma is perimortal.

Small ruminants, sheep/goat (*Ovis aries, L., Capra hircus, L.*)

The right side of the mandible of an adult small ruminant is preserved, with a preserved P2–M3 dental row.

Small ruminants sheep/goat (*Ovis aries, L., Capra hircus, L.*)

The right side of the mandible of an adult animal with a P3–M3 dental row is fully preserved. The body and partially the ramus of the left side of the mandible with a dental row of dp2, dp3, dp4, and M1 is preserved. The age at the time of death of an individual was around three months (Fig. 12.c). Two left ribs have been preserved, the body of one and almost the whole of the other, both from a younger animal. Theright scapular bone of an adult individual is preserved. On the caudal border, three shorter incisions measuring around 4 mm are visible. Tiny traces of teeth are also visible on the lateral surface of the bone, in seven positions (Fig. 12.d). The dorsal edge is partially destroyed. The right scapula of a young animal, no older than six months, is preserved, and the dorsal part of the body is partially preserved. The head and a part of the neck of the right humerus are completely preserved and the epiphyseal line between the head and the neck of the bone is clearly visible. Age at the time of death of the individual was less than three years. The left metacarpal bone is preserved in the proximal quarter together with three fragments of the diaphysis of the same bone. The distal third of the right femoral bone is preserved, and the age at the time of death of the animal was in the range of up to three years, according to the unfused distal epiphysis. The right talar bone is completely preserved.

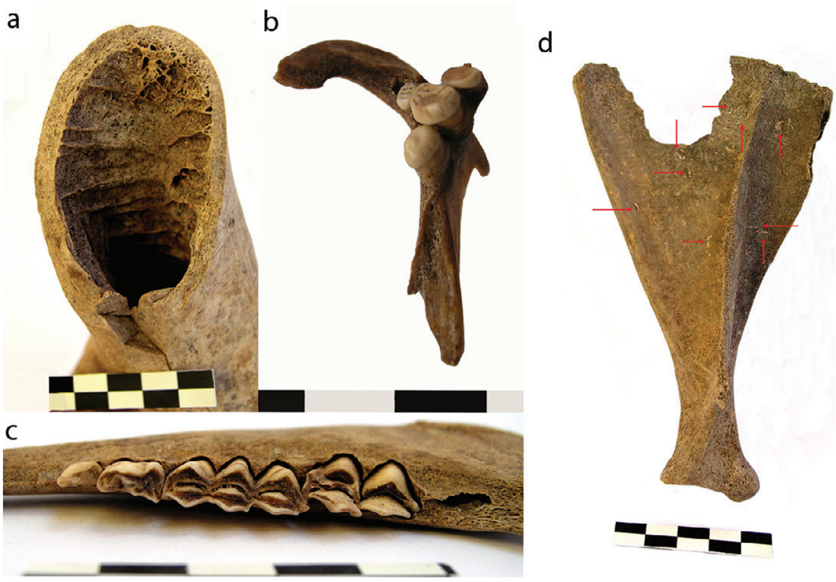


Fig. 12. a ***Detail – oblique section on one third of right humeral bone of cattle due to perimortal sharp force trauma;*** b ***molariform shape of pharyngeal teeth, left pharyngeal bone,*** **Cyprinidae*;*** c ***left half of a young sheep or a goat mandibula with a dental row: dp2, dp3, dp4, M1, (the age at the time of death is around three months);*** d ***teeth marks (red arrows), right scapular bone of a sheep or a goat, lateral surface (author Z. Hincak Daris).***

Boar (Sus scrofa sp.)
The proximal half of the left third metacarpal bone is preserved.

Fish (Pisces)
Three vertebral bodies of an adult and two fish spines have been preserved.

Ordo: Cypriniformes, family: *Cyprinidae*
Pharyngeal teeth in two right pharyngeal arches of the throat of an adult fish are preserved (Fig. 12.b). Both are molariform shapes of pharyngeal teeth, very similar to Eurasian carp (*Cyprinus carpio*).

Sample PN 3446
Cattle (Bos taurus, L.*)*
The proximal half of the adult animal's horn and 11 smaller fragments of the distal half of the rib are preserved. All fractures on the horn fragments are fresh and occurred postmortem.

Sample PN 3448
Twelve small animal bone fragments have been preserved, without a more precise taxonomic determination.

Ruminants (Ruminantia)
A bone fragment of the base of the skull, two rib fragments, three diaphysis bone fragments and a fragment of the vertebral body of large ruminants have been preserved.

Small ruminants: sheep/goat (Ovis aries, L.*, Capra hircus,* L.*)*
Three fragments of the rib body and four fragments of the diaphysis of long bones have been preserved.

Sample PN 3449
Ruminants (Ruminantia)
A fragment of the arch of the cervical vertebra and two fragments of the rib body of a large ruminant have been preserved.

Small ruminants: sheep/goat (Ovis aries, L.*, Capra hircus,* L.*)*
The acetabulum and ischial bone have been preserved partially and the ilium of the left hip bone has been completely preserved. The body of the mandible and a fragment of the body of the rib are preserved in a short strip.

Sample PN 3450
Cattle (Bos taurus, L.*)*
A molar of the upper jaw of an adult bovine, a part of the arch of the thoracic vertebra, a fragment of the

body of the scapula, a fragment of the diaphysis of the femur, two short fragments of the body of the rib and the *medial phalanx* of the third or fourth digit have been preserved.

Small ruminants: sheep/goat (Ovis aries, L., *Capra hircus,* L.*)*
The left rib is preserved in the dorsal two thirds, two fragments of the diaphysis of the humerus bone, the distal half of the diaphysis of the right humerus bone of a young animal, no older than ten months, a fragment of fibular bone, proximal two thirds of the right metatarsal bone.

Sample PN 3454
Cattle (Bos taurus, L.*)*
The medial phalanx, a fragment of scapular body, and two fragments of vertebral arch are preserved.

Sample PN 3458
Cattle (Bos taurus, L.*)*
Twenty fragments of the horn have been preserved.

Sample PN-3469
Cattle (Bos taurus, L.*)*
The caudal half of the cervical vertebra is preserved.

Sample PN 3478
Bone awl (Pl. 3.12, cat. no. 12)
A conical tool has been preserved, a processed and smoothed fragment of a parochial deer horn, which measures 109.2mm, while the width in the proximal, widest part is 23mm, and distally it extends into a spike.

Sample PN 3447, PN 3455, PN 3459
Numerous remains of freshwater and terrestrial malacofauna, snail shells and shells have been preserved.

Discussion
The osteological analysis included 165 samples, of which there were 137 bone (83%) and 28 dental (7%) animal remains from the Grave 5. The degree of preservation of the material is low. Fragmented samples comprise 97% (160 samples), while only 3% (five samples) are completely preserved. The number of specific animal samples according to species and genus is 51.3%. The rest of 48.7 includes a group of small (sheep/goat/roe deer – *Ovis aries*, *L.*, *Capra hircus*, *L.*) and large ruminants (deer/aurochs/cattle – *Ruminantia*). The minimum number of individuals (MNI) at the site is eight. Among them there are two cattle (*Bos sp.*), according to two preserved samples of the distal third of the right humeral bone, two small ruminants (sheep/goat – *Ovis aries, L., Capra hircus, L.*) according to two preserved right scapular bones, two fish from the family *Cyprinidae* according to two right pharyngeal bones with teeth, one deer (*Cervus elaphus, L.*) according to the distal third of the upper arm bone and one pig (*Sus scrofa sp.*) according to the left metacarpal bone.

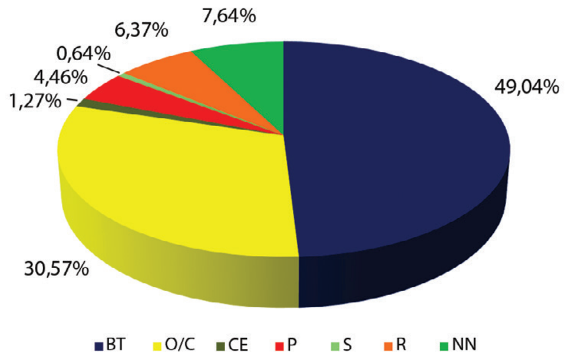
The results of the percentage representation of individual animal species at the site are shown in Graph 1. The most numerous group are cattle with 49.04%. The next largest group with 30/57% are small ruminants, sheep and goats (*Capra hircus, L., Ovis aries, L.*). The remains of ruminants (*Ruminantia*) follow with 6.37%, and there are samples that are too fragmented for a more accurate taxonomic determination. The *Cyprinidae* family is represented by 4.46% of the remains, while the remains of deer (*Cervus elaphus, L.*) accounted for 1.27% of the total and pig (*Sus scrofa sp.*) just 0.64%. Extremely fragmented remains, for which it was only possible to determine that they are animal remains (NN), are 7.65% of the total.

In the Graph 2, the percentage representation of an individual anatomical element in Grave 5 shows a significant percentage of head bone samples, at 24.49% of the total. In that group, the largest number belongs to fragments of cattle horns, at 61.11%, skull bones with 19.45%, lower jaws with 13.88% and pharyngeal arches with 5.56%. To this we can add a high percentage of bones of the thoracic cage, at 27.21%, such as ribs which make up 67.5% of these and vertebrae with 32.5%. The teeth of small ruminants, cattle and fish from the family *Cyprinidae* are account for 19.05% of the total, of which 3.57% are outside the jaw. There is a slightly smaller number of bones of a thoracic limb, at 8.85%, and a high percentage of samples of the upper arm bone at 61.54%, followed by fragments of the scapula with 23.08% and ulna bone with 15.38%. The bones of the pelvic limb are also less represented, with 7.48%, of which the most numerous remains are the femur with 63.64% of these, the tibia with 18.18%, and hip bone and fibula, each with 9.09%. More fragmented samples of diaphyses of long bones are represented by a high 4.76%, and unidentified samples account for 8.16%.

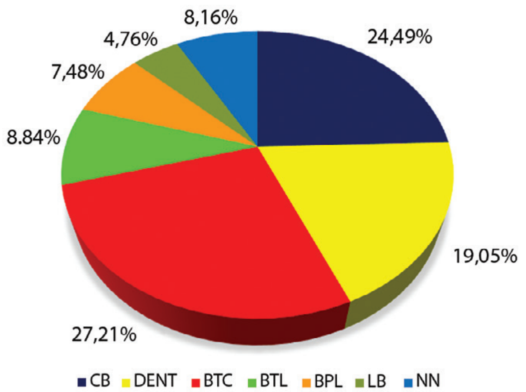
There are nine samples of bones on which traces of human activity were found. The largest share of these, seven, is bones on which traces of cutting with a sharp object are visible. According to the features of the edge, it is assumed that the traumas are of the perimortal type, and thus occurred around the time of death. The bones on which a cutting mark was recorded are the distal third of the humerus, in three cases of cattle and one of small ruminants (Fig. 12.a,c,d). If we add to that three samples of obliquely cut femur heads of cattle, it is possible to assume that what is being observed is a butcher's technique of cutting meat. Three short cuts on the neck of the scapula on a small ruminant bone sample were observed, and these are the only traces of shallow cuts. Only for one sample, a processed deer antler, is it possible to conclude with certainty that it represents an object, *i.e.* a tool – a simple awl. On the lateral side of the right scapular bone of a small ruminant, a sheep or a goat, traces of teeth are visible and they are marked by red arrows in (Fig. 12.d). Their imprints are not deep enough and wider possibilities of comparative studies are very limited. However, according to what has been determined, all the prints could belong to a man because there are traces of two incisors and canines, incisors with rectangular and canines with triangular marks. The scapula of small ruminants is still a culinary specialty today, and on the lateral side, due to two depressions (*fossa supraspinata* and *fossa infraspinata*) divided by a ridge (*spina scapulae*), the lack of muscle tissue and the teeth marks on the described part can be explained by this.

Conclusion

Grave 5 is one of the last findings from the recent excavations of two trenches (V 12 and V 17) at the Cornfield Streim, which is defined as the easternmost part of the tell-type settlement at the Vučedol site. The excavated trenches are located along the southern edge of the plateau covering an area of 1200m^2. The layer of the Vučedol culture is located very shallowly at a depth of 0.50–0.70m just below the layer of the Vinkovci culture and can be traced in five construction phases that date back to the Classical phase (the B1 and B2 phases of the Vučedol culture). This part of the settlement is architecturally very different from the ones previously investigated (Vineyard Streim and Gradac), and the well-preserved layers of aboveground objects and pits, as well as movable finds, speak in favour of workshop activities. Between these objects, five graves of the Vučedol culture (Grave 2–6) and one grave of the Vinkovci culture (Grave 1) were excavated. All graves were buried in deep or shallow pits, and according to the types we can distinguish here individual and group graves (of three or more people), and burials of parts of skeletons (skulls). Pits with graves were carefully placed, excavated and prepared for the deceased, and according to the spatial layout some links between certain objects can be observed. All examples show a certain pattern of ritual behaviour from the very preparation of the pit, the laying of the deceased, the grave goods burial and sealing. In addition to pits with human remains, pits without human bones were recorded with a large amount of ceramics and other objects that speak of some form of communal sacrifice or cenotaph-type graves. So far, more than 20 burial units with more than 60 deceased have been excavated at the entire Vučedol site. These are mainly double and group graves, some of which have more than 20 individuals, and



Graph 1. Representation of analysed animal species (bone and tooth fragments), Grave 5. Legend:* BT *cattle (*Bos taurus, *L.) cattle;* O/C *small ruminants (sheep, goat –* Ovis aries L., Capra hircus L.*);* CE *red deer (*Cervus elaphus L.*);* P *fish (*Pisces*);* S *pig (*Sus scrofa sp.*);* R *ruminants (*Ruminantia*),* NN *unidentified (author Z. Hincak Daris).



Graph 2. Percentage representation of individual osteological elements of animals in Grave 5. Legend:* CB *cranial bones;* DENT *teeth (dentes);* BTC *bones of the thoracic cage;* BTL *bones of the thoracic limb;* BPL *bones of the pelvic limb;* SMSP *bones of manus and pes;* LB *long bones;* NN *unidentified (author Z. Hincak Daris).

according to the treatment of the deceased and the elite finds we believe that they are all of a special class in the society. Traces of violent death were not observed on the analysed skeletons, but we can certainly speak of human sacrifice at Vučedol.

Grave 5 belongs to the type of individual burials in a deep bell-shaped pit, laid in an extension (niche) on a levelled loess bottom. The deceased (person A) was laid on his left side, in a very crouched position. The upper part of the skeleton was significantly disturbed as a result of placing a heavy stone (grindstone) on the deceased. In the immediate vicinity of the legs of the deceased another human bone was found, a part of the hand (*ulna*) that belonged to another person (person B) (postmortem manipulation), and we are treating it as a secondary burial, *i.e.* as a grave contribution. The skeleton is covered with several layers of soil with various admixtures, and the backfill immediately above the deceased with a large amount of shells and snails, as well as a layer of charcoal and ash, stand out. Immediately above the burial pit was a younger pit (waste pit) of the Vučedol culture (phase B2), and above it a layer of the Vinkovci culture. Grave 5 was buried in the fourth construction phase of the Vučedol settlement and we date it to the B1 phase of the Vučedol culture, which is supported by the absolute dates taken from the human bone sample (2910–2670 cal BC, 4222±33 BP)

In Grave 5, the osteological remains of two people were found. The skeleton of person A, a young male whose age at the time of death is in the range of 13–15 years ± 30 months, is almost completely preserved. Such a wide range for the age was found to be due to the 'delay' in skeletal development as opposed to the dental development. With regard the reason for this, it is possible to assume the person's poor state of health, as evidenced by established pathological changes, *cribra orbitalia* on the superior-lateral surface of orbitae and linear enamel hypoplasia on the teeth, but without the possibility of revealing a primary diagnosis. Three regular, shallow bone depressions are described, two on the frontal and one on the right parietal bone. It is possible to call them lesions, but it is not possible to make an exact conclusion about the manner of their formation. The fourth depression, which differs in shape, depth and surface features from the other three, probably represents a trace of a healed lesion as a consequence of trauma. Two special marks – depressions or lesions on the skull of the deceased that are not trauma scars – indicate the special status he had in the community. Person B was buried in the same burial pit, but further away from person A. During field research, only the left ulna of person B, a male that was 40–50 years old at the time of death, was discovered. According to the development of the muscle attachments, it was determined that the person was extremely physically active. Severing of the distal third of the left ulna with the distal epiphysis, according to the features of the trauma edge, must have occurred perimortally, around the time of the person's death.

In addition to human remains, the fragmented skeletal remains of animals were also found in the grave: cattle, deer, pig, small ruminants, sheep or goats and fish from the Cyprinidae family. Shallow traces of teeth and incisions were found on eight samples, but it is possible to claim that mostly dismembered parts of animal bodies were placed in the grave, since no traces of anthropogenic action can be seen on the other bones. The cutting marks visible on the bones are traces of butchering techniques. A bone awl made of deer antler was discovered as a grave find.

Other items are ceramic finds, pots and loom whorls, as well as stone, bone tools and cattle horns. The pots are partially fragmented due to the stone being placed on the deceased, and according to the types we distinguish biconical bowls with one tunnel-shaped handle that are of a terina type, biconical bowl with two handles, and pots of smaller dimensions. The terinas are located next to the upper part of the skeleton, and according to their shape and decoration technique they belong to the Classic phase of the Vučedol culture. Ceramic whorls, a stone tool and a bone tool (antler awl) probably belong to the group of tools for weaving or fabric processing, and speak about the social status or identity of the deceased and the group (genus) to which they belonged.

Grave 5, although one of the 'most modestly' equipped graves, actually contains almost all the ritual elements that we also notice in the other 'richer' graves from the Vučedol site that have been excavated so far. From the shape and preparation of the burial pit, to the laying of the deceased, symbolic offerings and the filling of the burial with the remains of charcoal, shells and animal bones with traces of butchery and traces of human teeth, everything speaks in favour of a standardized protocol and repetitive forms of ritual behaviour and ritual feasting. Although the Vučedol culture is a representative of the Late Copper Age and already signifies a kind of transition to the Bronze Age, funeral customs do not differ much from the oldest traditional ones related to previous periods existing on the tells in this area south of the Danube. Nevertheless, we find direct links in the graves of the Baden and Kostolac cultures, and some new elements such as the unusual positions of the deceased in the graves, rich ritual feasts and the marking of the deceased before death, *i.e.* markings on the body, also indicate strong influences of Steppe cultures in which we could look for the origin of the Vučedol population.

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Appendix. Catalogue

Abbreviations:* Pl. no. *plate number;* C *clay;* S *surface;* G *grave nbr.;* SU *stratigraphic unit;* PN/N *artifact number;* h. *preserved height;* w. *preserved width;* w.t. *wall thickness;* r.d. *rim diameter;* b.d. *bottom diameter;* h.w. *handle width;* w.d. *whorl diameter;* p.d. *perforation diameter;* m. *mass.

1. A biconical bowl (terina) with a slightly everted rim with one tunnel-shaped horizontally placed handle (Pl. 1.1); C: purified with a little admixture, dark grey colour (GLEY 1 4/N Dark grey); S: hard, traces of burning, polishing, the outer surface is light brownish-grey in colour (10 YR 6/2 Light brownish grey), the inner surface is dark grey (GLEY 1 4/N Dark grey); D: incising, notching and stabbing, decoration in the form of geometric motifs (line, triangle, wave). The motif of the wave is made with grooved incising located under the rim. A complex motif of triangles made by incising, notching and stabbing located above the biconity. The decoration made by stabbing small oblong motifs in a row continuously flows along the triangle motifs above the biconity. The decoration on the handle is made by incising, notching and stabbing in the motif of complex triangles bordered by two lines and smaller oblong motifs (clepsydra motif); h. 11cm; w. 17cm, 18.8cm (with the handle); w.t. 0.7–0.9cm; r.d. 15cm; b.d. 5.5cm; h.w. 5.4cm; type terina bowl; dating B1 phase; location of the find: G 5, SU 689, PN: 3470, 3477; unpublished.

2. A shallow biconical bowl with a everted rim with two opposite handles (Pl. 1.2); C: purified with a little admixture, dark grey colour (GLEY 1 4/N Dark grey); S: hard, burn marks, polished, outer surface varies from very dark grey (GLEY 1 3/N Very dark grey) to a light reddish-brown colour (5 YR 6/4 Light reddish brown), the inner surface is light brownish-grey (10 YR 6/2 Light brownish grey); D: incising and stabbing. Decoration in the form of horizontally and vertically placed strips made with horizontal lines and oblong motifs. The horizontal strip is located above the biconity, and two vertical strips to the rim of the bowl above the handle; h. 5.6cm; w. 16cm; w.t. 0.4-0.6cm; r.d. 16cm; b.d. 5cm; h.w. 2.6cm; type: biconical bowl; dating: B1 phase; location of the find: G 5, SU 689, PN: 3471; unpublished.

3. A biconical bowl (terina) with a slightly everted rim with a single tunnel-shaped horizontally placed handle (Pl. 1.3); C: purified with larger admixtures, dark grey colour (GLEY 1 4/N Dark grey); S: hard, traces of burning, polished, outer surface, outer and inner surface are dark grey (GLEY 1 4/N Dark grey); D: incising and stabbing in the form of geometric motifs (line, mesh decoration, wave, triangle, oblong decoration).The motif of irregular oblong decorations and triangles executed by incising is located under the rim of the bowl. Complex geometric motifs are separated into a horizontal strip that continuously flows above the biconity in rows (metopes). They are separated by two vertical lines, made by incising, notching and stabbing motifs of wavy lines, lines and mesh decoration. Decoration on the handle made by incising in the motif of a cross (X-motif) bordered by lines in the shape of a rectangle; h. 8cm; w. 13.6cm, 14.9cm (with handle); w.t. 0.5–0.6cm; r.d. 13cm; h.w. 5.1cm; type: terina bowl; dating: B1 phase; location of the find: G 5, SU 689, PN: 3476; unpublished.

4. A biconical cup (small terina) with a slightly everted rim, a flat bottom and a tunnel-shaped handle (Pl. 2.4); C: refined with larger admixtures, grey colour (GLEY 1 5/N Grey); S: soft, traces of burning, polished, the outer surface is reddish-brown in colour (5YR 4/4 Reddish brown), the inner surface is reddish-grey in colour (5 YR 5/2 Reddish grey); D: unadorned; h. 6.5cm; w. 8.00cm; 9,3 (with handle); w.t. 0.5–0.9cm; r.d. 7.4cm; b.d. 4cm; h.w. 2.2cm; type: terina cup; dating: B1 phase; location of the find: G 5, SU 689, PN: 3422; unpublished.

5. Fragment of a pot with a tunnel-shaped handle (Pl. 2.5); C: purified with a few small admixtures, grey colour (GLEY 5/N grey); S: soft, polished, outer and inner surfaces are greyish brown in colour (10 YR 5/2 Greyish brown); D: decoration made by deep incising in the form of horizontal and oblique lines; h. 5.9cm; w. 6.2cm; h.w. 3.8cm; w.t. 0.9cm; type: pot ?; dating: B1 phase; location of the find: G 5, SU 689, N: 662/2; unpublished.

6. A pot with a slightly everted rim and a cylindrical body with a tunnel-shaped handle (Pl. 2.6); C: purified with admixtures, dark grey colour (GLEY 1 4/N Dark grey); S: soft, burn marks, poorly polished, very dark grey outer surface (10 YR 3/1 Very dark grey) to a light yellowish brown colour (10 YR 6/4 Light yellowish brown), the

inner surface is grey (10 YR 5/1 grey); D: imprinting and polishing. Decoration on the outer edge of the bowl in the form of oblong motifs made using the imprinting technique. Incomplete polishing is present on the outer and inner surface of the bowl; h. 11.8cm; w. 8.8cm; w.t. 0.9cm; r.d. 8cm; h.w. 3.5cm; type: pot; dating: B1 phase; location of the find: G 5, SU 689, N: 662/4; unpublished.

7. A pot with a rounded body and narrow neck (Pl. 2.7); C: a lot of admixtures, very dark grey colour (GLEY 1 3/N Very dark grey); S: soft, traces of burning, polished and barbotine, the outer surface is very dark grey in colour (GLEY 1 3/N Very dark grey), the inner surface is dark reddish-grey in colour (5 YR 4/2 Dark reddish grey): D: stabbing and barbotine. Decoration on the outer edge of the bowl in the form of oblong motifs. On the shoulder of the pot in line with the tunnel-shaped handle, there is a decoration in the form of oblong motifs using the stabbing technique. The decoration is partially polished. Polishing is present on the rim of the upper part of the pot and on the neck and shoulder, while the lower part of the body of the vessel is decorated with the barbotine technique; h. 7.4cm; w. 9.5cm; w.t. 0.7cm; r.d. 8cm; h.w. 3.3cm; type: pot; dating: B1 phase; location of the find: G 5, SU 689, N: 662/3; unpublished.

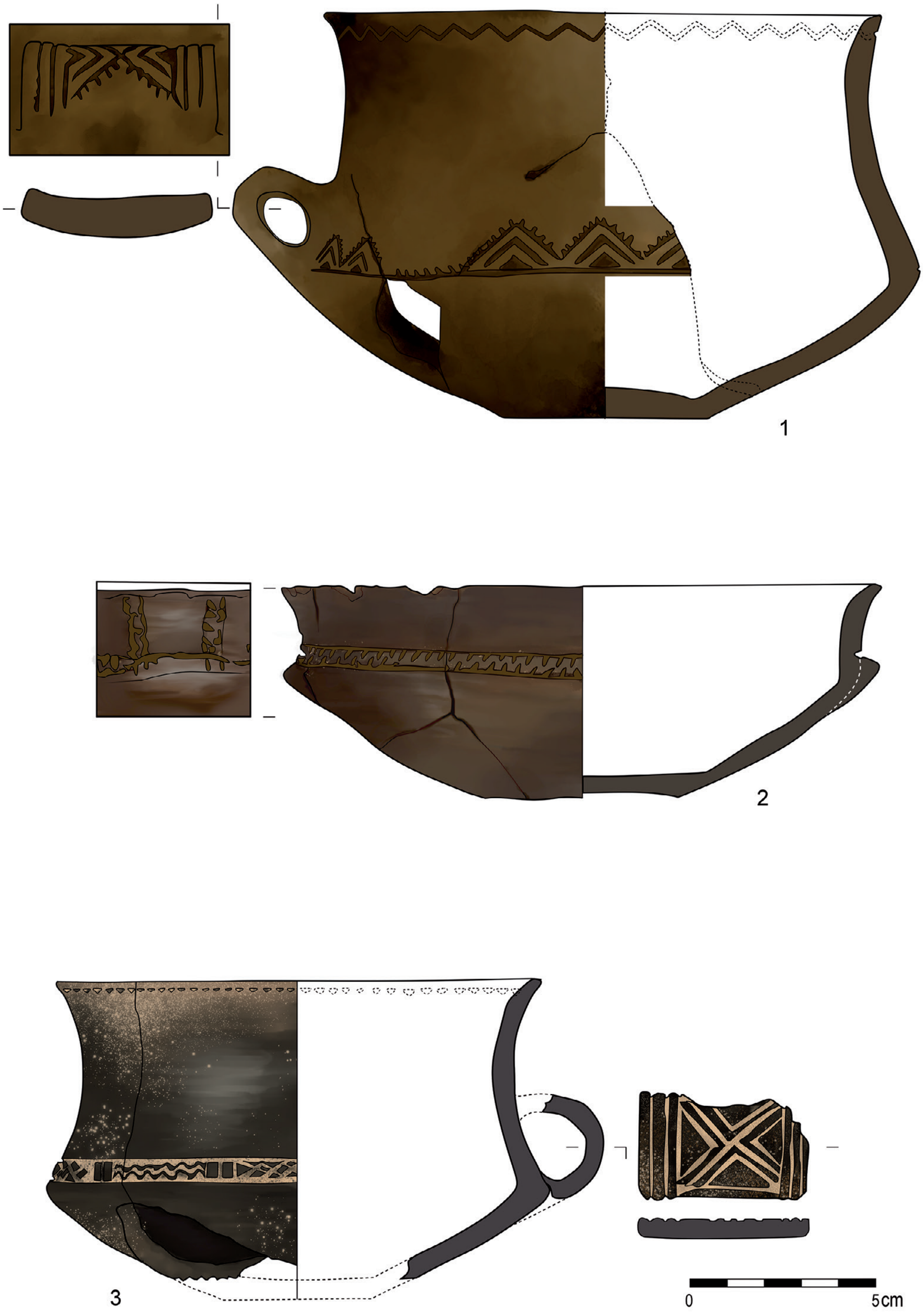
8. Round, flat (discoid) whorl (Pl. 3.8); S: polished, grey in colour (10 YR 5/1 Grey); w.d. 7.2cm; p.d. 1.6cm; h. 2,8cm; m. 126.1g; dating: B1 phase; location of the find: G 5, SU 689, PN: 3472; unpublished

9. Conical whorl (Pl. 3.9); S: polished, light brown colour (7.5 YR 6/4 Light brown); w.d.1. 2.4cm; w.d.2. 6.8cm; p.d. 1.2cm; h: 5.2cm; m. 157,7g; dating: B1 phase; location of the find: G 5, SU 689, PN: 3473; unpublished.

10. Round (spherical) whorl (Pl. 3.10); S: polished, dark grey (7.5 YR 4/1 Dark grey), burn marks; w.d. 5.8cm; p.d. 1.2cm; h. 5cm; m. 140.8g; dating: B1 phase; location of the find: G 5, SU 689, PN: 3474; unpublished.

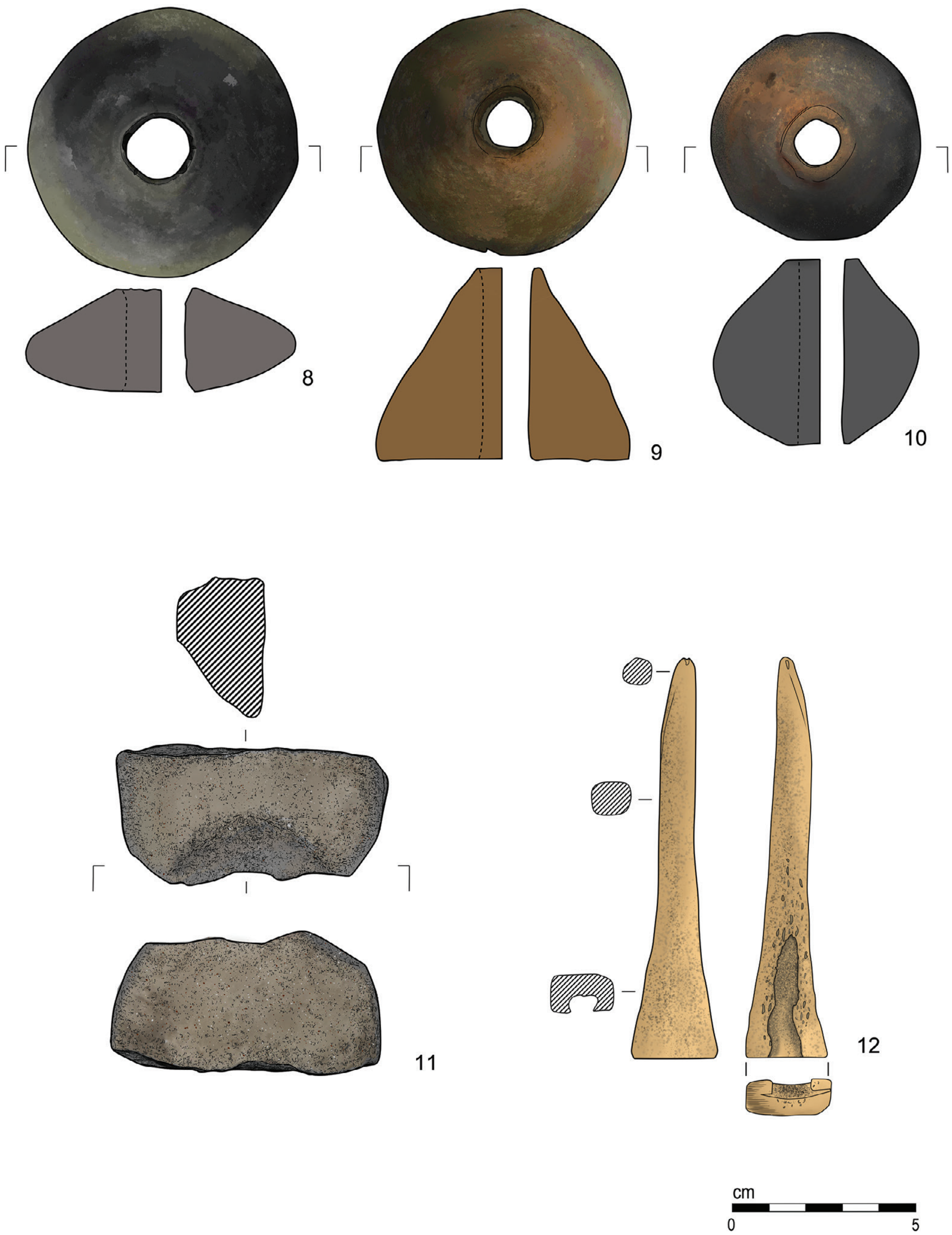
11. A fragment of whetstone of a rectangular shape with traces of use (Pl. 3.11); h. 7.3cm; w. 3.8cm; w.t. 2cm; dating: B1 phase; location of the find: G 5, SU 689, N: 662/1; unpublished.

12. A complete bone (deer antler) awl with a square-shaped base and a pointed working tip (Pl. 3.12); S: traces of processing, use and a damaged tip; h. 10.8cm; w. 1.2cm; type: group of pointed objects, awl; dating: B1 phase; location of the find: G 5, SU 689, PN:3478; unpublished.



Pl. 1. Pottery finds from Grave 5, Vučedol-Cornfield Streim: **1** ***terina type bowl (PN 2470, 3477);*** **2** ***biconical bowl (PN 3471);*** **3** ***terina type bowl (PN 3476) (author of the drawing S. Bošnjak).***

Pl. 2. Pottery finds from Grave 5, Vučedol-Cornfield Streim:* 4 *terina type bowl (PN 3422);* 5 *pot fragment with handle (N 662/2);* 6 *pot fragment (N 662/4);* 7 *pot fragment (N 664/3) (author of the drawing S. Bošnjak).



Pl. 3. Finds from Grave 5, Vučedol-Cornfield Streim: 8 ***whorl (PN 3472);*** 9 ***whorl (PN 3473);*** 10 ***whorl (PN 3473);*** 11 ***grinding stone (N 662/1);*** 12 ***Antler awl (PN 3478) (author of the drawing S. Bošnjak).***

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Rhyta and *kernoi* from the Domasław cemetery. The idea of offerings in the Hallstatt period

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ABSTRACT - *Unique ceremonial vessels such as rhyta, kernoi and pseudokernoi were discovered in a cemetery from the Early Iron Age in Domasław (Poland). The appearance of such vessels proves that the societies of the Hallstatt culture adopted cultural ideas, feasting and drinking practises and offerings from the Mediterranean world. GC-MS analyses were carried out on five vessels and compared with pottery from the Domasław cemetery (74 samples) and the nearby settlement of Milejowice (46 samples). The investigations show that the examined vessels probably contained ceremonial drinks and liquids used for offerings and libations during funeral ceremonies.*

KEY WORDS – *Domasław; kernoi; rhyta; ceremonial vessels; Early Iron Age; chromatographic analyses*

Rhyta *in* kernoi *z grobišča Domasław. Daritve v halštatskem obdobju*

IZVLEČEK – *Na starejše železnodobnem grobišču v Domasławu (Poljska) so odkrili izjemne ceremonialne posode, ritone,* kernoi *in psevdo-*kernoi*. Njihovo pojavljanje dokazuje, da so družbe halštatskega kulturnega kroga prevzele kulturne ideje gostij, pitja in libacij iz sredozemskega sveta. GC-MS analize so bile opravljene na petih posodah, te pa primerjane s posodami z grobišča Domasław (74 vzorcev) in bližnjega naselja Milejowice (46 vzorcev). Raziskave kažejo, da so proučevane posode verjetno vsebovale obredne pijače in tekočine, povezane z libacijo med pogrebnimi obredi.*

KLJUČNE BESEDE – *Domasław;* kernoi*; ritoni; obredne posode; starejša železna doba; kromatografske analize*

"I made a drink-offering to all the dead, first with honey and milk, then with wine, and thirdly with water, and I sprinkled white barley meal over the whole, praying earnestly to the poor feckless ghosts, and promising them that when I got back to Ithaca I would sacrifice a barren heifer for them, the best I had, and would load the pyre with good things…." (Homer, *Odyssey*, From Book XI. Translation by Samuel Butler.)

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Introduction

In 2006–2008, the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Wrocław conducted excavations at the multicultural site in Domasław, sites 10/11/12, Wrocław district (Fig. 1). In addition to traces of the Neolithic, Early Bronze Age, La Tène and Roman Iron Age settlements, the investigations revealed an extensive Lusatian and Hallstatt culture cemetery used from BD-HA1 to HD3 (*Gediga, Józefowska 2019.18*). The Early Iron Age necropolis yielded over 800 cremation burials, including about 300 with internal wooden structures, often richly furnished, with numerous imports.

The selection pattern and types of funerary vessels observed in the Domasław graves and the practice of providing the deceased with multiple ornaments, weapons, toiletries and other accessories indicate that local elites attempted to imitate Greek feasting practices. The burials demonstrate the existence of a uniform funerary ritual, including a recurring number, formal composition and location of the deposited ceramic vessel sets. Vessels used in the burial ritual contained provisions given to the deceased for the afterlife and/or served as drink containers during the ceremonial community libations and feasting. Central parts of the wooden grave chambers in Domasław accommodated sets of vessels (Fig. 2), consisting of vases with funnel-shaped rims and cone-shaped necks and arranged next to them sets of bowls and dippers, frequently placed on a plate-shaped bowl. In the chambers' eastern parts, a vase with a conical neck and a straight or slightly everted rim, a pot with a dipper covered with a lid and frequently a crescent-shaped firedog placed on a ceramic disc were deposited. The chambers' western parts were occupied by urns, grave offerings and vessels surrounding them, typically bowls and cups. As these brittle containers with carefully worked surfaces only exceptionally displayed macroscopically visible use-wear traces, they were likely – with a few exceptions – explicitly made for funerary purposes. Numerous heavily burned vessel fragments, less often whole vessels, were excavated from layers above the grave furnishings.

Within this ritual pattern occurred isolated specimens of morphologically distinctive vessels, such as the ceramic *rhyta*, *kernoi* and triple vessels consisting of three cups connected by hollow channels. They might be associated with pouring and transferring liquids during libation rituals (*Nebelsick 1997.71*). While such vessels were first recorded in the Mediterranean, their function might have changed upon reaching the distant places of the Hallstatt world. The shape of a *rhyton* determines its function as a vessel used for feasting and individual drinking. The *kernoi* and triple vessels were likely used for sacrifices, pouring and combining liquids.

It is assumed that feasts were of great importance in the Early Iron Age societies (*Nebelsick 1997; Dietler 2006; Ralph 2007; Mierzwiński 2012; Rebay-Salisbury 2016*). In the Hallstatt cultural zone, funerary rituals, including feasting and libations, played a significant role. Not only did feasts include liquid offerings for the gods and the deceased, but also the consumption of beverages, most likely alcoholic (*Mierzwiński 2012.27; Nebelsick 2016.22*). New feasts and rituals connected with preparing and consuming liquids are shown in the figural scenes on the Providence, Benvenuti, Kuffern, Vače and Magdalenska gora situlae (*Lucke, Frey 1962; Eibner 2018.93–96*). In central-eastern Europe, large vases were likely used as containers for fermented liquids, water and other ingredi-

Fig. 1. Cemetery in Domasław and the European Hallstatt culture sites (edited M. Markiewicz).

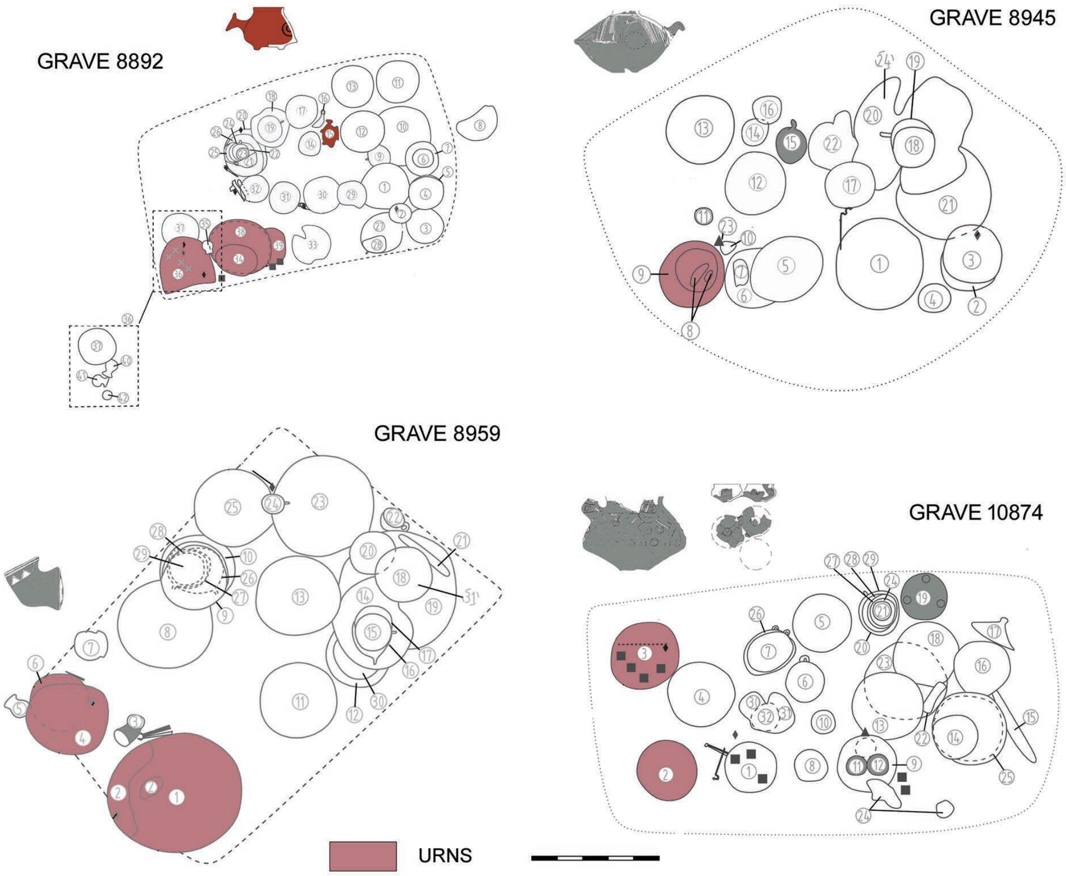

Fig. 2. Chamber graves: 8892 (with a zoomorphic vessel); 8945 (with an ornitomorphic vessel); 8959 (with a knee-shaped horn); 10874 (with a kernos and a pseudo-kernos) (drawing A. Józefowska).

ents (possibly beer or mead, *Nebelsick 2016.30,48*), served to the guests after mixing. The ritual act of drinking, involving the mixing, serving and consumption of an alcoholic beverage, was one of the main elements of the funeral feast. The ritual of pouring drinks as offerings to a deity or in memory of the deceased was common in the Mediterranean (*Malkin 2016*). Links to the Greeks and Etruscans led to the adoption of this practice north of the Alps in the Early Iron Age (*Rebay-Salisbury 2016.85; Rebay-Salisbury* et al. *2021.117*). Poured offerings – *spondí* (sponde, σπονδή), that is, measures of liquids offered during a ritual by pouring them on the ground or to another vessel, were performed during the burning of the funeral pyre, grave preparing, furnishing and filling (*Mierzwiński 2012.64; Nebelsick 2016.23,48–49*). The *spondí* – burned at the funeral pyre along with the body – included milk, water, mead or wine, *pelanos* (a mixture of olive oil, water and flour) and *kollyba* (first fruits of the harvest and fruits). Animal and animal blood sacrifices were made as well (*Wypustek 2009.42,45*). The rituals also involved *kykeon*, a ceremonial beverage made of water and barley seasoned with mint and hallucinogenic herbs, sometimes with wine, goat cheese and honey (*Mierzwiński 2012.93*). An alcoholic beverage based on honey was known back then, as well as beer. The latter was prepared using malt, with germinated and dried cereals (*O.c.91–93*). Poured offerings were made on graves, even sometime after the funeral. As the people of the Hallstatt culture readily adopted cultural ideas from the Mediterranean world, the central-eastern European societies furnished their deceased with elaborate sets of vessels for libation and feasting. Some were ritually broken to permanently remove them from use (*Nebelsick 2016.19,23–25; Metzner-Nebelsick 2017.436*).

Ceramic drinking and offering vessels from the Domasław cemetery

The cemetery in Domasław produced unique 'ritual' pottery, such as the multi-piece *kernoi* or *pseudo-kernoi* (triple vessels) and *rhyton*-shaped drinking vessels – zoomorphic and knee-shaped horns. They did not belong to a typical set of funerary pottery, but we might try to reconstruct their usage pattern and find matching examples.

Rhyta

Two chamber graves contained *rhyta* (Greek ῥυτόν, 'horn-shaped drinking vessel' deriving from the verb ῥεῖν, 'to flow'). This term encompasses a wide variety of drinking vessels, usually imitating animals or animal heads. They were used for drinking and religious rituals in the eastern Mediterranean in the Bronze Age (*Koehl 2016*).

Feature 8892 yielded a small vessel sized 8.7x6.5cm, shaped like an animal on four legs (Figs. 2, 3.1, 4). Its head featured two ears pointing up and an elongated muzzle with an opening, making it funnel-shaped. The head was attached to a bulging body shaped like a cup with a rim diameter of 4.6cm. The vessel surface was covered with flaking remains of red slip. Traces of black decoration forming two circles survived next to the tail. The 5x2mm drinking spout allowed liquids (and probably only liquids!) to pass through. The vessel was deposited in the north-central part of the chamber, which is exceptional. Around it, other vessels for scooping and drinking were deposited in a semicircle. The grave, containing remains of one or two adults and a child, also featured four miniature flask-like vessels deposited near the urns, each with a hole in the bottom (*Gediga, Józefowska 2018b.40,41,42, Pls. 812,816.35*). Such small zoomorphic vessels occurred in child and male burials from the end of the Bronze Age. A similar, painted specimen comes from a Hallstatt cemetery in Gorszewice, Szamotuły district (*Pieczyński 1954.110, Fig. 10.4*). A formally matching vessel was discovered, *e.g.*, at a barrow cemetery in Vaszar, Veszprém county (*Metzner-Nebelsick 2017. 437, Fig. 4a.4*) and in the Moravian Znojmo (*Eibner 1973.166*) and Prostějov-Domamyslice H1/2016 (*Golec, Fojtík 2020. Fig. 47.12*). In the Silesian-Platěnice culture, zoomorphic vessels on three or four legs have two openings: a cup-shaped one on the animal's back and another one in the place of its head. Such specimens were recorded in Dobřenice, Hradec Králové district, Pardubice-Hůrka, Platěnice and Předměřice nad Labem, Pardubice district (after *Venclová* et al. *2013.Fig. 49.3,5,7, 9*).

A stylistically different *rhyton* was found in grave 8945 (Figs. 2, 3.2, 5). The ornitomorphic vessel with a flat bottom was sized 13x7.5cm. A small head on a short neck was set above the curve of the biconical body, also cup-shaped, featuring wings made of knobs and a tail. The graphite-coated surface was richly decorated with an incised ornament of lines and triangles. The feature contained an urn with child's remains and at least five miniature vessels. Two of them were deposited by the cinerary vessel with a rattle, two by the bird in the central part by the chamber's northern wall, and one did not have a specific location (*Gediga, Józefowska 2018b.Pls. 881.7,10,11; 882.14,16; 883.1*).

Footless zoo- and ornitomorphic vessels were used in the central part of Silesia, Greater Poland, northern Bohemia, northern Moravia, and Saxony between HA2 and HC-D (*Gediga 1970.82–86*). The graphite coating and decorations on the discussed specimen indicate a later dating within this period. Unlike bird figurines, similar vessels rarely occur in the Lusatian culture. They were recorded, *e.g.*, in grave 33 in Kietrz, Głubczyce district (*Gedl 1973.Pl. XIV.4*) and in Manieczki,

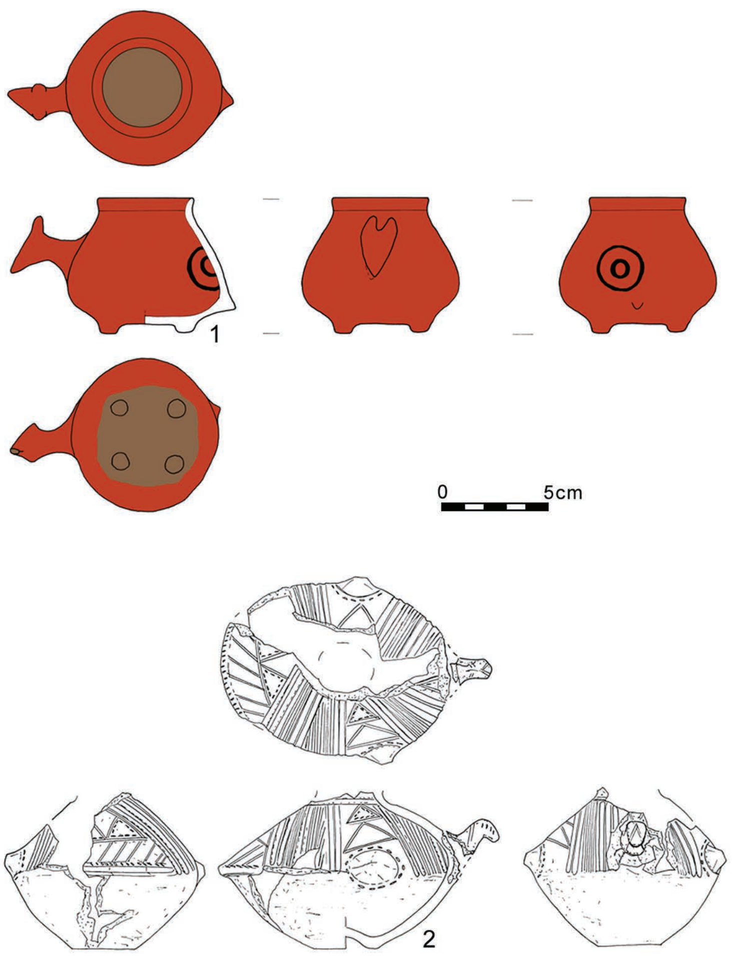

***Fig. 3.* Rhyta: 1 – 8892/15; 2 – 8945/15 (drawing M. Markiewicz and K. Świątek).**

Śrem district (*Gediga 1970.85.Fig. 23*). Notably, some zoomorphic vessels representing this type were fashioned with a *kotyliskos*-shaped inlet forming a separate cup on the top of the central vessel. It is thus possible that the liquid poured into it was an offering, as in the *kernoi*. In the Hallstatt period, they were deposited in both male and female graves, meaning their role may have shifted to other functions, such as libation (*Rebay-Salisbury 2016.85*). Vessels with a spout resembling the one from grave 8892, suitable for pouring liquids, occur in Bronze and Iron Age grave and settlement contexts. Their presence in children's graves might suggest they were also used for feeding (*Eibner 1973*; *e.g.*, from Este, Italy, *cf. Marzatico, Gleirscher 2004*; Franzhausen, Austria, *Neugebauer 1996*; Sopron, Hungary, *Preinfalk 2003*; Donnerskirchen, Austria, *Rebay 2005*; Statzendorf, Austria, *Rebay 2006. 107; Rebay* et al. *2021*), and their presence in adult graves may indicate they were used for feasting, too.

While some late Bronze and Early Iron Age vessels may have served the purpose of feeding infants, their increasingly elaborate form, increased size (*Siegfried-Weiss 1979*), and spout diameter suggest their application for pouring liquids (*Rebay* et al. *2021.117*). This formal and functional shift of spouted vessels is demonstrated by the fact that they were more prevalent in (elite) male burials than in those of women and children. The Iron Age saw the development of elaborate zoomorphic pottery shapes for ceremony and display. This tendency culminated in placing ritual pottery with a bull's head in elite graves in the eastern Hallstatt zone (*Nebelsick* et al. *1997; Preinfalk 2003; Rebay-Salisbury 2016.85; Metzner-Nebelsick 2017. 433; cf. Müller-Scheeßel 2000*).

The Domasław graves also produced knee-shaped (elbow-shaped), ceramic horns (Figs. 6–8). Four items, sized 5-8.2x7.3-8.7cm, have slightly arched, pointed bases. A specimen from chamber grave 1693 was painted red, but no remains of other decorations were preserved (Fig. 6.1). The other three have graphite-coated surfaces (grave 3784 – secondarily fired, Fig. 6.2; grave 3786. Fig. 6.3; grave 8959. Figs. 2,6.4) and incised zig-zag patterns (grave 3784) or lines around the rims (grave 3786), as well as concentric pits (graves 3784, 8959) or grooves (grave 3786) on the bases. The horns were deposited next to the urns. Chamber grave 3786 and grave 3784 containing child remains were adjacent. A similar arrangement was observed in chamber grave 1693, with the remains of a man and another adult, and grave 8959, in which

Fig. 4. **Rhyton** ***(zoomorphic vessel): 8892/15 (photo I. Dolata-Daszkiewicz).***

the horn was deposited between two urns – one with remains of an adult person, and the other – by which two miniature vessels were placed – with a person aged *juvenis-adultus*.

The unique, painted knee-shaped horns with animal-shaped handles are characteristic of the Hallstatt culture's eastern fringes. They were recorded, *i.e.*, in grave in a vineyard Kraus in Dalj Busija, in barrow IV/grave 1 in Kaptol, and in grave 1 in Tumulus 1982/XII in Goričan near Varaždin (*Metzner-Nebelsick 2017. 433,434, Figs. 2; 4b.1; 6 A,2*). Although the angled clay *rhyta* occur in various shapes, the variant with an animal handle is specific for the Drava region and Kaptol. The distribution of these vessels in Europe reflects the course of the Amber Road from the Mediterranean through Croatia, Transdanubia, and the Morava Valley to the Oder area, occupied by the Lusatian communities. On this 'communication route', the morphology

Fig. 5. **Rhyton** ***(ornitomorphic vessel): 8945/15 (photo I. Dolata-Daszkiewicz).***

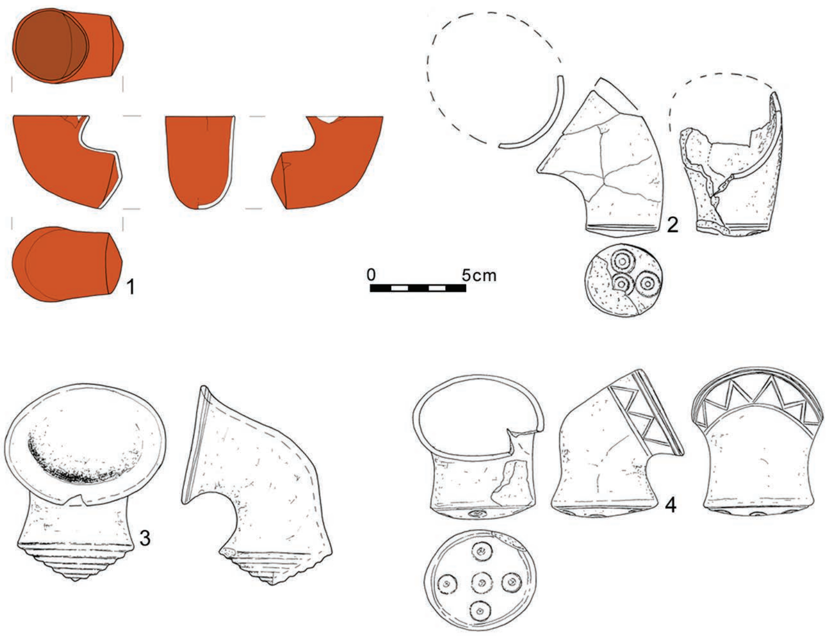

Fig. 6. **Rhyta *(knee-shaped horns):* 1 – *1693/8;* 2 – *3784/8;* 3 – *3786/8;* 4 – *8959/3 (drawing M. Markiewicz and K. Świątek).***

of an adult person. A horn from the same grave was deposited next to another urn with the remains of an adult male. Feature 4416 (Fig. 7.3) yielded two urns with child remains and three miniature vessels (*Gediga, Józefowska 2018b.Pl. 552.2,4,10*). In the richly furnished child grave 5977 (Fig. 7.4), an arched vessel deposited by the southern wall co-occurred with four miniature vessels and two rattles. The vessels are comparable to specimens interpreted as miniature replicas of dome furnaces found in a male grave from the late Urnfield period under barrow A in Gündlingen and barrow 1 in Schirndorf in Upper Palatinate (*Nebelsick 1996.350, Fig. 17. 1–2*).

of the *rhyta*, their theriomorphic design and perhaps symbolic load may have changed and passed on to new types of ritual ceramics (such as fire-dogs, oven models, discs and others – *Metzner-Nebelsick 2002.151–152, Fig. 59*).

Knee-shaped specimens occurred in Moravia and East Bohemia, such as the orange-surface specimen decorated with a tree of life motif from Brno-Holásky H2 – 'U Tuřan' (*Mirová, Golec 2018, Fig. 7.18, Pl. 27*), two specimens from grave 27 in Slatinky PH27 – 'Nivky' 43 (*Podborský 1993.377, Fig. 248.15; Přichystal 2003.Pl. VII.PH27/3–4; Golec, Fojtík 2020.152,153, Fig. 53.5*), and another from Předměřice nad Labem, Pardubice district (after *Venclová* et al. *2013.Fig. 49.8*).

Another vessel type resembling the knee-shaped horns were arched and cup-shaped vessels (Fig. 7.1-4, Fig. 8). The former have flat bases on which they can stand, and they might also be laid on a flattened or concave side, and were typically found in this position. The Domasław specimens are sized 5.5-6.7x6-7cm, featuring graphite coating. Their bodies were abundantly decorated with incised lines and bases with concentric circles (graves 4416, 5977). Alternatively, the body was ornamented with grooved zig-zag bands and pits and the base with cross-motifs (grave 1693). A base with concentric circles found in grave 3312 probably also belonged to an arched vessel (Fig. 7.2; *Gediga, Józefowska 2018a.Pl. 358/9*). A vessel from grave 1693 (Fig. 7.1) was found in a cinerary vessel containing the remains

Graphite-coated specimens with widely everted rims were frequently cup-shaped (Fig. 7.5-7). The most complete, although secondarily fired, specimen was recorded in the backfill of grave 3312 (the grave also produced an arched vessel base and a miniature vessel, Fig. 7.5). Other examples include a vessel from grave 5994 decorated with an incised ornament and concentric circles (adult grave, Fig. 7.7) and a smaller cup from grave 3795 (child grave with five miniature vessels, Fig. 7.6). Vessels fashioned as cone-shaped horns and featuring graphite-coated surfaces were recorded in cemeteries discovered in Poland (*e.g.*, in Lubiąż, Wołów district; Bryłówek, Strzelin district; Będów, Zielona Góra district) and the Czech Republic (*e.g.*, Platěnice, Pardubice district; Mělnik, Hradec Kralové district, Třebelov, Hradec Kralové district). However, their dating stretches from B2D to the Hallstatt period (*Gediga 1970.86–98*). Formally similar vessels with painted decorations were found in Wrocław-Księże Wielkie (*Glaser 1937.Pl. 15/24; Alfawicka 1970. 205, Pl. XXIX/e*) and Kamienna, Namysłów district (*Glaser 1937.Pl. 15/21*).

Kernoi

The so-called *kernoi* (κέρνος lub κέρχνος) occurred at the discussed cemetery in isolated cases. The *kernoi* are variously sized vessels with a central body and connecting funnels/cups/*kotyliskoi*. The *pseudo-kernoi* are vessels in which those containers are joined through openings/channels in their bodies but do not connect to the central vessel. The name is used because they resemble a vessel type well-known in the ancient world, already occurring in the Mediterranean world and central Europe in the Eneolithic. According to the text of Athenaeus (*Deipnosophistes XI*), libations utilizing many interconnecting, Mediterranean-type *kernoi* were practiced in the early 5th century BC during the Eleusinian mysteries. The author specifies that the *kotyliskoi* received a small amount of each of the major earth's crops: honey, oil, wine, wheat, barley, sage, vegetables and animal products (such as wool), as offerings to the deity. The products were mixed in the central vase (*Delnef 2006.218*).

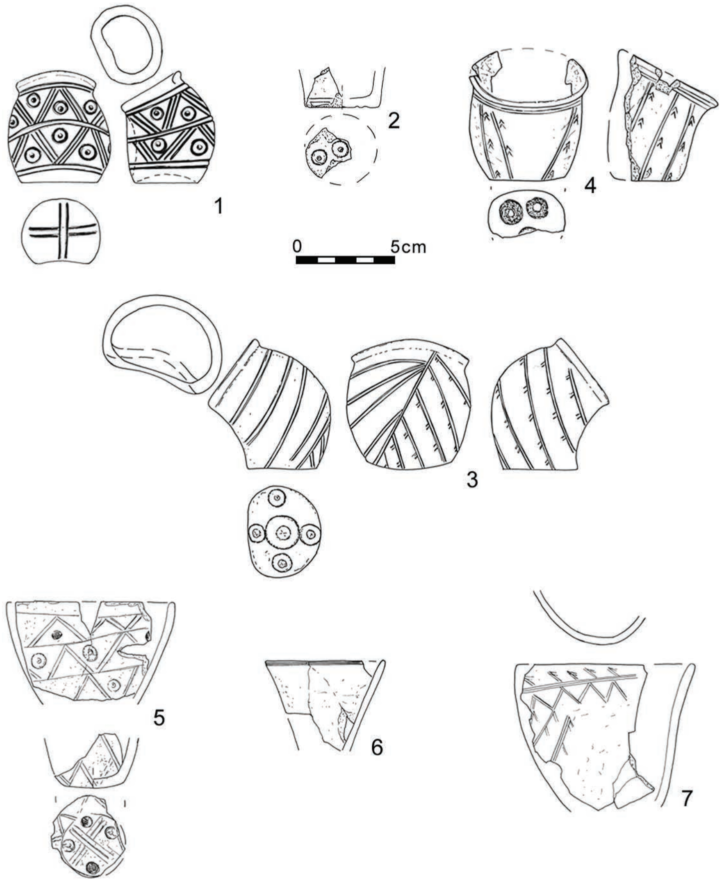

Fig. 7. **Rhyta *(arched and cup-shaped vessels):* 1 – *1693/32;* 2 – *3312/9;* 3 – *4416/5;* 4 – *5977/31;* 5 – *3312/III;* 6 – *3795/27;* 7 – *5994/10 (drawing K. Świątek).***

The Domasław cemetery yielded two graves with vessels featuring funnels. The first was a secondarily fired cup from grave 3779. Its surface was originally cream-coloured and painted (Figs. 9.1, 10). It was fashioned as a small vase-shaped vessel, only 4.5cm high, with a bulging body with a maximum diameter of 7.2cm, everted rim and short neck. Three upward-facing funnels were attached at the maximum body diameter, reaching the level of the main vessel's lip. The vessel was deposited in a child's grave located in a grave pit outside the chamber containing an urn with the remains of an adult. It was burnt through to an extent suggesting that it had been placed on a funeral pyre or was used to burn a particular substance. It might thus have served as an oil lamp, where the openings/funnels accommodated the wick. However, the *kernoi* discovered elsewhere rarely bore traces of burning (*Delnef 2006.218*). Similar vessels were found at the cemetery in Kietrz, Głubczyce district: a larger one with a black surface and an incised decoration in the centre of grave 499 (*Gedl 1973.Pl. C.10*), and fragments in graves 25 and 3/1938 (*Gedl 1973.37*).

The *kernos* from chamber grave 10874 was a 9cm tall tureen with a diameter of 13cm and graphite-coated surface (Figs. 2, 9.2). It had three funnels shaped as small, profiled vessels placed around the circumference of the main vessel's shoulder and connected to it with channels. The *kernos* was deposited in the chamber's northeastern part, but the funnels were detached. The vessel was fragile, particularly at the joint between the body and the funnels, but the even displacement of the funnels from the vessel suggests that this action might have been intentional.

Kernoi-type vessels are rarely recorded in Poland (*Łaciak 2018*). The discovered specimens come from late

Fig. 8. **Rhyta: 1 – *1693/8;* 2 – *3786/8;* 3 – *8959/3;* 4 – *1693/32 (photo I. Dolata-Daszkiewicz).***

Bronze and Early Iron Age cemeteries in Lower Silesia (Sobocisko, Oława district, *Czerska, Gediga 1975.Figs. 132,138*), Greater Poland (Biernatki, Poznań district, *Krzyżaniak 1963.107, Pl. I.2*; Gorszewice, Szamotuły district, *Narożna-Szamałek, Szamałek 2007.215, Fig. 31.1, Phot. 9, 226*; Krobia Stara, Gostyń district, *Lipińska 1964.116, Fig. 18.6*), Upper Silesia (Kietrz, Głubczyce district, *Gedl 1973.237,370, Pls. C.10; XV.10*) and settlement sites in the Lubusz land: Wicina, Żary district (*Łaciak, Orlicka-Jasnoch 2013.166, Fig. 74.5*) and central Poland: Laski, Piotrków district (*Buchner, Józefowska 2016*). Vessels with funnels also occurred in a Pomeranian culture context in Żukowo, site 2, Zamość district (*Kuśnierz 2010*).

The distribution area of the *kernoi* found at the Early Iron Age cemeteries stretches from the Caucasus to Spain (*Dular 1982.60*). Even the exceptional specimens found in rich barrow cremation burials from HB-D, *e.g.*, in Lower Austria (Rabensburg, Gemeinlebarn: *Kromer 1958.68–69, Pl. A11m; Kerchler 1977.14, Pl. 23*), Slovakia (Nové Košariská, *Pichlerová 1969.262, Pl. XXVIII/2*) and Slovenia (Novo mesto, Dolenjske Toplice, *Dular 1982.59, Pl. 20.173, 20.174*) do not indicate how they were used (*Delnef 2006.218*). Their arm- and hand-shaped protomes with upward-pointing hands have matches in the fine art of the Hallstatt period, and representations of women identified as priestesses. The women were shown praying or expressing a gesture of despair or lamentation. In the scene depicted on a vase found in Barrow 27 in Sopron, the gesture is associated with weaving, spinning and dancing (*Eibner 1986.Pl. 1*). The vessels' shape made them also suitable for hanging. In his study of grave IV/20 from Novo mesto, which contained three *kernoi*, Tone Knez argues that those (and *kernoi* from other female burials, such as Dolenjske Toplice V6, V/26 and II/35) might have belonged to an aristocrat or priestess (*Knez 1976.609*). However, most of the specimens from HC come from male burials. Using such vessels in domestic settings might also testify to domestic worship and symbolic or religious activities (*Fischer 1998.324*).

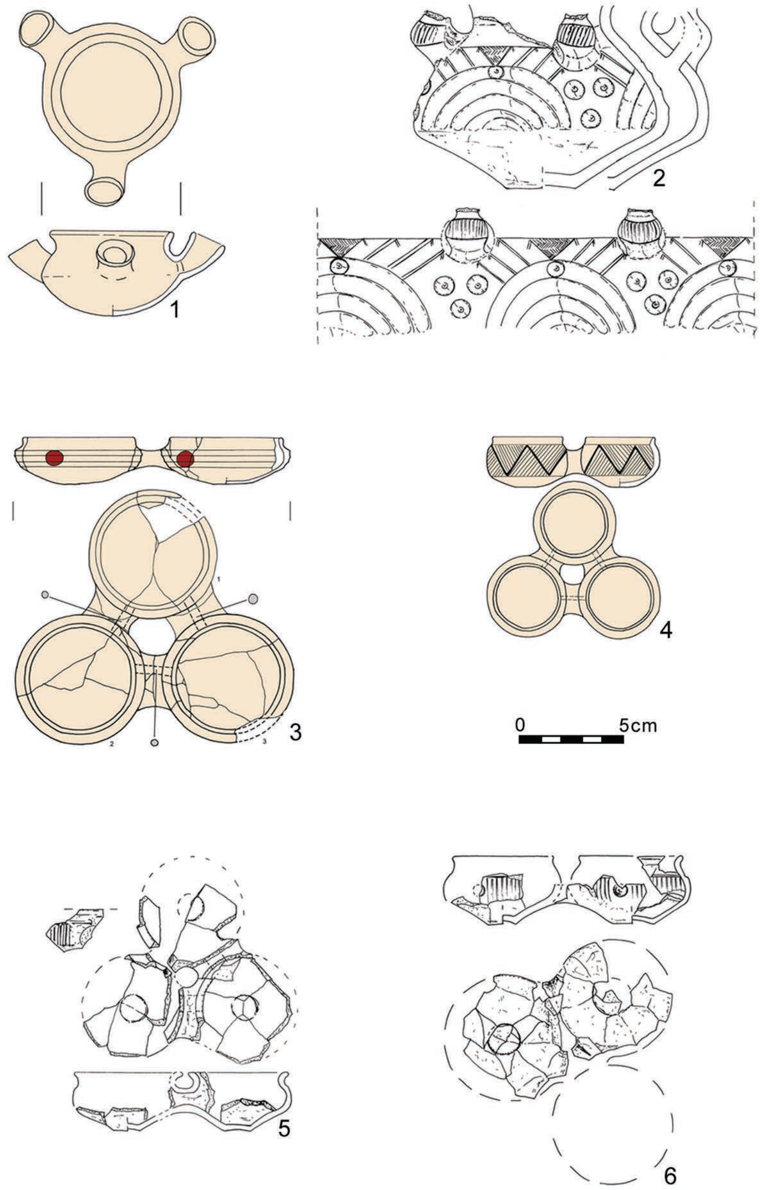

Fig. 9. **Kernoi *and pseudo*-kernoi: 1 – *3779/5;* 2 – *10874/16;* 3 – *2170/24;* 4 – *6029/2-4;* 5 – *8894/I;* 6 – *10874/19 (drawing M. Markiewicz and K. Świątek).***

Four of the Domasław's graves contained triple vessels, which might be interpreted as *pseudo-kernoi* consisting of three small cups connected with channels. The specimens are typical of the Lower Silesian Hallstatt style. Two were painted and decorated with grooves running around the vessels' circumferences, as well as red circles or bands of diagonally hatched triangular motifs highlighted in black paint. The two other vessels had graphite-coated surfaces decorated with vertical grooves and pits. One of the painted specimens was deposited in the centre of chamber grave 2170, piled with other vessels (Figs. 9.3, 11.1). The other occurred in grave 6029, in which one cup was located above the urn, and two were deposited next to another bowl along with three miniature vessels

(Figs. 9.4, 11.2). A graphite-coated triple vessel was found in child's grave 8894 (Fig. 9.5), and one more in grave 10 874, deposited in a bowl in the southeastern part of the chamber (only two of the three bowls were deposited or preserved, Fig. 9.6).

Painted triple vessels were also recorded at the cemeteries in Wrocław, Kiączyn, Szamotuły district, and Wołów (*Glaser 1937.Pl. 15.12, 15.14; Alfawicka 1970. 192,204, Pls. XVI.b, XXVIII/i*). Matching finds occurred in Moravia and Bohemia, at a necropolis in Modřice – 'Sádky a Rybníky', site 2, in grave Wombat H 1 (*Kos* et al. *2022.Fig. 10.16; Pl. 1.5*) and Vojkovice H 117, Brno district (*Golec 2005.213, Pl. 124.9*), Miroslav, Znojmo district (*Stegman-Rajtár 1992.Pl. 103.2*), Platěnice H 6/1926 and Kunětice H VI/1934, Pardubice district (*Buchvaldek 1966.49.Pl. 4.31; Vokolek 1999.222, Pl. 52.8; Venclová* et al. *2013.10, Fig. 49.6*), and Seloutky, Prostějov district (*Golec, Fojtík 2020.Fig. 47.14*). In Lower Austria, they were found in Pokampí, Maierschi cemetery (H 31, *Berg 1962.Pls. 8.6, 8*) and in the Tulln area (Gemeinlebarn grave 10.368, *Nebelsick 1997.31, Fig. 8.4*). Double vessels mainly occurred in the Kaldenberg group in northeastern Austria and northwestern Hungary (*Nebelsick 1997.39,41, Figs. 10,12; Patek 1993*). In the late Hallstatt period, however, triple vessels also emerged there (*cf. Nebelsick 1996.331, Fig. 4*). In the Billendorf culture area (*Buck 1979.125–127*) and in Greater Poland (*Żychlińska 2013.63–64*), multiple vessels consisting of joint vases with handles, jugs and dippers prevailed.

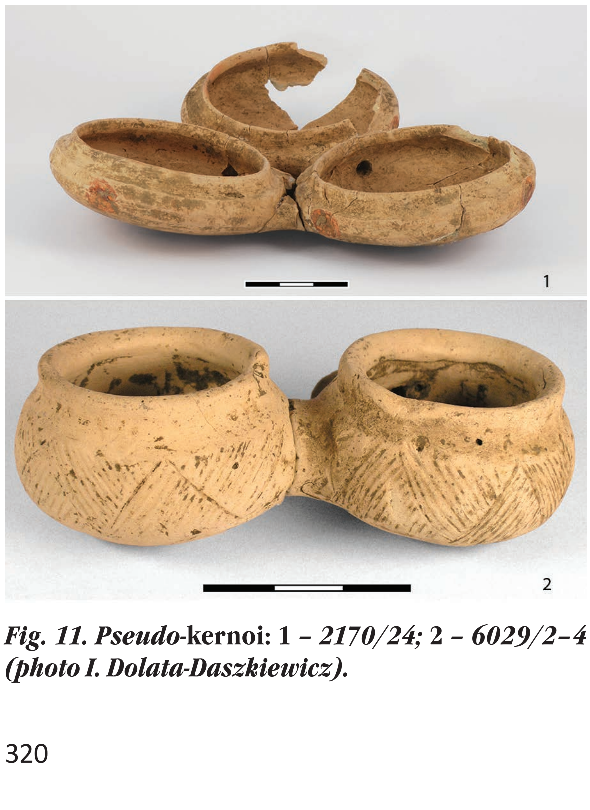

Fig. 11. Pseudo*-kernoi: 1 – *2170/24;* 2 – *6029/2–4 (photo I. Dolata-Daszkiewicz).

Fig. 10.* Kernos: *3779/5 (photo I. Dolata-Daszkiewicz).

The *kernoi* probably served a variety of ritual and practical functions throughout time and space. They might have been used as sacrifice, libation and even fermentation vessels, spice containers, lamps, candlesticks, devices for thread making and even fumigation (*Delnef 2006; Boghian 2012; Łaciak 2018*). Double and triple vessels, particularly those interconnected with channels, served most likely to combine offerings of similar or different types of liquids. Frequently, graves containing such pottery produced miniature flask- and vase-type vessels, sometimes with holes in their bottoms, which might have also been used for making sacrifices and which, in other Hallstatt culture areas, were parts of multiple vessels.

One of the horns at the Domasław cemetery was found in a cinerary vessel, and a cup-shaped specimen in the grave's backfill. Both were secondarily fired, just as the *kernos* in the child burial. The idea of depriving a vessel of its function was also reflected by detaching the funnels from the large *kernos* and bowls from two triple vessels. Creating a composition of contrasting light and dark vessels, as in the case of the red-painted, cream-coloured and graphite-coated *rhyta* and *kernoi*, was probably also intentional. Colour played a crucial symbolic role and had a recognizable meaning in the Hallstatt cultural circle (*Nebelsick 2016.52; Markiewicz 2023.159–169*).

Results and discussion

Chromatographic analyses

A gas chromatograph (6890N GC System, Agilent Technologies) coupled to a mass spectrometer (MS 5973 Network Mass Selective Detector, Agilent Technologies) was used to determine the organic compounds in vessel samples. Samples collected from ceramic vessel fragments were ground to powder in a mortar. The weighed amount of ground material (2 grams) was extracted in a Soxhlet apparatus for 4 hours. The extraction mixture contained methylene chloride and methanol (200mL, 2.1v/v) and 100μL of standard solution (tetracosane, 1mg/mL). The extracted lipid fraction was evaporated to dryness and then dissolved in 2mL of hexane. Portions of 0.5mL extract were evaporated from atmospheric pressure in a stream of nitrogen to dryness. The obtained dry residue was subjected to derivatization in the form of silylation. To convert the analytes into their volatile derivatives (trimethylsilyl esters), 100μL of a derivatizing mixture composed of two reagents was used: N,O-bis(trimethylsilyl)trifluoroacetamide and trimethylchlorosilane (100.1v/v). The sample with the mixture was heated for 30 minutes at 75°C. Following the process, 300μL of hexane was added to the sample and GC-MS analysis was performed. The analytes were separated on an HP-5MS (5%-diphenyl-95%-dimethylpolysiloxane) column at a carrier gas (helium) flow rate of 0.9mL/min. The injected sample volume was 1μL. The injector was operated in the mode without separating the carrier gas flow. The gas chromatograph oven was programmed as follows: the initial temperature was 60°C, with a temperature increase of 12°C/min until the final temperature of 300°C was reached. The parameters of the mass spectrometer were as follows: the temperature of the ion source and mass analyser were 230°C and 150°C, respectively. Mass spectra were acquired in electron ionization mode at a potential of 70eV and a mass range of 50 to 550m/z. Qualitative analysis of organic acids and biomarkers was performed using Wiley and NIST14 mass spectral libraries and commercially available standards. Quantitative analysis of fatty acids was performed using the internal normalization method. The procedure for the determination of fatty acids in ceramic samples was developed and optimized for C5-C22 acids.

The analyses included five vessels discussed in this article (Table 1; *rhyta* from graves 1693, 3795, 8892, 8945 and *kernos* from grave 10 874). However, a large group of 120 Hallstatt vessels were examined in the project – 74 from the cemetery in Domasław and 46 from the neighbouring settlement in Milejowice, where we can also confirm the existence of a privileged social class (elites). The selection of samples created a unique opportunity for comparative studies of the funeral and settlement contexts. For this study, statistical analyses were performed on all vessels, with a focus on the *rhyta* and *kernoi* groups. The results also served as a background for identifying distinctive components (acids, biomarkers) and proportions in the case of the vessels in question. This approach provides an excellent background for interpreting the *rhyta* and *kernoi.*

Chromatographic analyses provided information on the organic compounds' contents. The analysis focuses on determined fatty acids and biomarkers that can directly indicate the source of the examined organic residues. The contents of the identified fatty acids in samples from the Domasław cemetery are included in Table 2.

Seventeen acids were determined in the samples, mainly saturated acids. Unsaturated acids were represented by palmitoleic acid (C16:1) and oleic acid (C18:1). Linoleic acid (C18:2) was not detected in the drinking vessel samples. Eleven acids were present in all samples, and these were caproic acid (C6:0), caprylic acid (C8:0), pelargonic acid (C9:0), capric acid (C10:0), lauric acid (C12:0), myristic acid (C14:0), C16:1, palmitic acid (C16:0), C18:1, and stearic acid (C18:0). Arachidic acid (C20:0) was present in samples nos. 16 and 34 and the long-chain acid behenic acid (C22:0) – in all samples except No. 9. Only in two samples (nos. 9 and 14) was undecanoic acid (C11:0) determined, but in general this acid rarely occurred at the cemetery and was detected only in seven other vessels, such as the urns, the censer and the offering vessels.

Any detailed conclusions about the sources of the examined organic residues based only on the presence and content of individual acids may be unreliable. Most acids are present in both plant and animal resources. Moreover, the residue composition can change over time, and this should always be considered in archaeological samples. Consequently, researchers are looking for another way to interpret the results of chromatographic analyses. One of the methods is based on studying the proportions of selected fatty acids, as it appears that acid proportions can remain relatively un-

Sample number	Object number	Vessel number	Kind of vessel
9	3795	27	cup-shaped *rhyton*
14	8945	15	bird-shaped *rhyton*
16	10874	19	*kernos*
22	1693	8	knee-shaped *rhyton*
34	8892	15	zoomorphic *rhyton*

Tab. 1. Characteristics of the studied vessels.

changed over time. The conclusions presented in this paper were founded on the work of Jelmer W. Eerkens (*2005*). Based on his proposed proportions, the most likely sources of the studied residues were inferred. The calculated proportions of selected acids, shown in Table 3, are intriguing and suggest that all the examined residues have a mixed origin (Tab. 4). The residues probably came from seeds and nuts combined with land mammal fat, and sample 22 additionally from berries.

A higher C18:1 ratio detected in *rhyta* 9, 22 and 34, and a few other vases and pots from the cemetery, suggest that the samples contained acid-rich plant oil or derivative mixtures (*Roffet-Salque* et al. *2017*). The predominance of C16:0 over C18:0 in samples 22 and 34 is generally typical of plant oils rather than animal fats (*Colombini* et al. *2009*). Stefano F. Notari (*2012*) suggested that when the C18:0 level is slightly lower than the C16:0 amount (1.2 < C16:0/C18:0 < 2.0), it may indicate a vegetable residue (the C16:0/C18:0 ratio in samples 22 and 34 amounts to 1.67 and 1.55). However, Michael W. Gregg and Greg F. Slater (*2010*) indicated that when the C16:0/C18:0 value is between 1.0 and 2.0, the residues could contain decomposed animal fats.

The C12:0, C20:0 and C22:0 acids can be detected in significant amounts in palm and peanut oils, while C14:0 acid can be found in plant seed oils and dairy products (*Rosiak* et al. *2020*). The highest C14:0 level of all samples was in *rhyton* 34 (2.10). The C12:0 to C14:0 ratio in bird-shaped vessel 14 is 1.69, much higher than in other samples from the cemetery and settlement. C12:0>1 was observed only in one of the urns and an offering vessel, while in *rhyton* 14 it amounts to 1.88. The abundant presence of short-chain fatty acids (mainly C14:0 and C12:0) suggests dairy products. However, short-chain saturated fatty acids are only exceptionally detected in archaeological pottery due to their compositional alteration during the burial. Their changed distribution might resemble adipose fats, and thus cannot be used as a single diagnostic criterion for milk and milk processing (*Dudd* et al. *1998; Evershed* et al. *2002*).

	Sample number				
Acid symbol	**9**	**14**	**16**	**22**	**34**
C6:0	0.47	1.34	1.52	0.11	0.14
C7:0	0.34	0.66	0.58	0.15	0.18
C8:0	0.70	1.00	0.84	0.26	0.41
C9:0	1.07	1.29	1.17	0.94	1.09
C10:0	0.41	0.40	0.26	0.26	0.30
C11:0	0.06	0.08	-	-	-
C12:0	0.43	1.88	0.49	0.51	0.89
C13:0	-	-	0.16	0.17	0.24
C14:0	1.15	1.11	1.44	1.10	2.10
C15:0	-	0.47	0.46	0.42	0.71
C16:1	1.02	0.70	0.41	0.70	0.66
C16:0	3.70	5.69	11.43	12.81	13.68
C17:0	-	-	0.27	-	-
C18:1	2.43	0.93	0.52	2.89	2.02
C18:0	3.89	7.99	17.23	7.65	8.85
C20:0	-	-	0.81	-	0.45
C22:0	-	1.13	1.62	1.14	1.20

Tab. 2. Fatty acids determined in the studied samples (content in %) (-) under the limit of quantification

Gas chromatography combined with mass spectrometry made it possible to determine organic compounds from different groups. Literature studies enabled us to select compounds that might be considered archaeological biomarkers. Biomarkers are associated with one specific material or substance, regardless of its origin – plant, animal or mixed (Tab. 5).

Glycerol, a product of lipid degradation, lactic acid and cereal biomarkers were present in all samples. Lactic acid is one of the essential products of bacterial fermentation, which occurs, *e.g.*, during vegetable pickling or milk fermentation. However, malic acid (a beer and wine ingredient) can also be converted by bacteria into lactic acid, which gives the beer a sour taste (*Coote, Kirsop 1974; Li, Liu 2015*).

The simultaneous presence of oxalic acid (sample nos. 14, 22, 34), azelaic acid (sample nos. 16, 22) and suberic acid (sample nos. 16, 22, 34) may suggest that the studied residues originated from grain products including wheat or barley (oxalic acid, *Park* et al. *2017*) or rye and barley (azelaic acid, *Farag* et al. *2019*). Suberic acid, also found in cereals, is produced during castor oil oxidation and is used to produce resins.

Fatty acid proportion				
Sample number	**(C15:0+C17:0)/C18:0**	**C16:1/C18:1**	**C16:0/C18:0**	**C12:0/C14:0**
9	-	0.42	0.95	0.37
14	0.06	0.75	0.71	1.69
16	0.04	0.79	0.66	0.34
22	0.05	0.24	1.67	0.46
34	0.08	0.33	1.55	0.42

Tab. 3. Proportions of selected fatty acids in the studied samples.

Possible source of residue	Sample number
seeds and nuts, berries and fat of land mammals	22
seeds and nuts, fat of land mammals	9, 14, 16, 34

Tab. 4. Possible source of studied residues.

Castor bean plants were widely available in the eastern Mediterranean (*Polito* et al. *2019*), and were reportedly significant sources of natural substances with various applications in antiquity.

Methyl dehydroabietate, a dehydroabietic acid derivative, was identified in all samples except *kernos* 16. This acid, formed when the resin is heated in the presence of wood, is classified as a resinous acid and is considered an indicator of resin or its products (*Mayyas 2018; Rageot* et al. *2019; Breu* et al. *2023*). Resins have hydrophobic properties and can be used to seal unglazed vessels (*Serpico, White 2000*), but they were also intentionally added to alcoholic beverages to preserve, enhance, or change their flavour (*McGovern* et al. *1996; 2004; McGovern 1997; 2007*). Mentions of wines intentionally resinated with pine resins occur in historical sources, and this practice was popular and widespread throughout the ancient world (*McGovern 2009*).

Vanillin, a phenolic compound, and/or vanillic acid were determined in all vessels except arched-shaped *rhyton* 9. Vanillin has been found in many fruits and fruit products, such as elderberry juice (*Poll, Lewis 1986*), blueberries (*Hirvi, Honkanen 1983*), strawberries (*Pyysalo* et al. *1979*), wines (*Spillman* et al. *1997*), apple cider brandy (*Mangas* et al. *1997*), and mushrooms (*Lizarraga-Guerra* et al. *1997*). Vanillin may originate from tree resin or pine wood/dust, which is documented in the same samples by the presence of methyl dehydroabietate.

Tiglic or crotonic acid was rarely detected in vessels of special purpose from the cemetery (14) and absent from settlement samples. It was identified in *rhyta* 9, 14 and *kernos* 16. The compound has a spicy smell and occurs, among other things, in croton oil and the secretions of some beetles. Croton oil is obtained from the seeds of the laxative croton plant, which belongs to the *Euphorbiaceae* family. It is used as a purgative and tonic, and it possesses inflammatory properties (*Salatino* et al. *2007*; *Dey* et al. *2015*).

In bird-shaped *rhyton* 14 appeared tiglic acid and borneol, which is a compound from the terpene group with a camphor-like fragrance. It is a component of many essential oils, pine resin and herbs like, *e.g.*, tansy (*Tanacetum vulgare*), savory (*Satureja*), *Artemisia seibeni* (from the wormwood family), mint, sage, and thyme (*McGovern* et al. *2009*). Like croton oil, it has medicinal and toxic properties and may cause eye and skin irritation and vomiting. Again, it was only found in specific funerary vessels (8), such as offering vessels, an urn, and two large vases (one in the Basarabi culture style). In the Milejowice settlement, it occurred in the context of the offerings. The plant origin of the examined sample is also indicated by stigmastanol. This plant sterol occurs in vegetable fats or oils in many plants, such as beans, rapeseeds, and herbs (*Ferrer* et al. *2017*).

Fumaric acid, levulinic acid, caprolactone, and 3,4-dihydroxybutyric acid were exclusively identified in the zoomorphic *rhyton* 34. The presence of fumaric acid was confirmed during beer fermentation and wort production (*Li, Liu 2015*). Levulinic acid is a preservative with a sweet, creamy-buttery odour reminiscent of guaiacol, which is one of the sugar degradation products produced in maple syrup (*Filipic* et al. *1969*). In turn, caprolactone is a fragrance component in flowers and some fruits and vegetables and is also produced by the Khapra beetle as a pheromone. Δ-caprolactone is found in heated milk fat (*Parliment* et al. *1965*). 3,4-dihydroxybutyric acid is a human meta-

	Sample number				
Biomarkers	**9**	**14**	**16**	**22**	**34**
glycerol	+	+	+	+	+
vanillin		+	+	+	+
vanillic acid				+	+
lactic acid	+	+	+	+	+
azelaic acid			+	+	
oxalic acid		+		+	+
fumaric acid					+
adipic acid				+	
benzoic acid				+	+
stigmastanol		+			
methyl dehydroabietate	+	+		+	+
borneol				+	
dibutyl phthalate	+		+	+	
ethylene glycol	+	+	+	+	
suberic acid			+	+	+
tiglic acid	+	+	+		
caprolactone					+
levulinic acid					+
3,4-dihydroxybutyric acid					+

Tab. 5. Characteristic of biomarkers in the studied samples.

bolite detectable in the urine and the blood (*Fell* et al. *1975*), also a metabolite produced by *Escherichia* (*Wang* et al. *2017*). This acid has also been found in foods and is believed to be formed via the degradation (cooking) of di- and polysaccharides, including lactose (*Shimizu* et al. *1984; Minami* et al. *1988*). The presence of benzoic acid in this vessel may also indicate the plant origin of the examined samples, as it is a fruit and vegetable component (*Beaten* et al. *2018*). It is also recognized as, among other things, a propolis ingredient (*Çelemli 2015*). Furthermore, its occurrence could result from the degradation of anthocyanins by ketones in wine (*Fujii* et al. *2021*).

Benzoic acid was also identified in the knee-shaped *rhyton* 22. Adipic acid from sample 22 occurs rarely in nature and can be found in beets and sugar cane (*Musser 2000*).

Dibutyl phthalate, a phthalic acid, was detected in drinking horns 9 and 22, as well as *kernos* 16. However, it is important to note that its presence may result from sample contamination (similar to ethylene glycol, which was determined in vessels 9, 14, 16, and 22). However, it could also indicate the thermal processing of products within the vessels (*Poulain* et al. *2016*). Its presence in fine pottery from graves, which is unsuitable for heat treatment, could suggest that these vessels once contained products previously exposed to high temperatures.

Data analysis

Principal component analysis (PCA) was used to detect organic data structure, by reducing the number of variables, and to classify samples in new spaces defined by the uncorrelated principal components. PCA was applied to reduce the dimensionality of the feature space of selected organic compounds found in the food remains. The space of the new variables, called principal components (PCs), was then used in more detailed studies of the structure of archaeological data. Since the primary data are of similar magnitude, due to scaling, the PCA method was based on covariance as a measure of variability. A heatmap was used to visualize the hierarchical clustering of the samples and features. Ward's method was applied for the clustering, and Euclidean distance was used for the distance measures. Statistical analyses were performed using the R language, directly in the R Studio environment, and in the MetaboAnalyst (https://www.metaboanalyst.ca).

For both biomarkers and fatty acids, detected in vessels from the Domasław cemetery and the Milejowice settlement, each principal component explained a certain part of the variability of the original variables. The percentages of variance explained by the leading two components in Figures 12.a and 12.c, for biomarkers and fatty acids, are less than 30% or 50%, respectively. This indicates relatively little diversity of archaeological samples in the space of organic compounds. However, the presented PCA biplots (Fig. 12.b,d) show a quite characteristic mutual arrangement of the examined organic features and vessel samples, including the characteristic location of *kernoi* and *rhyta* samples within the components, which may lead to further conclusions.

In particular, taking into account the biomarkers, the first five principal components accounted for about 50% of cumulative variance. Lactic acid and vanillin have the highest contribution in the first principal component. The percentage share in explaining the variability of the PC1 of these substances were 15.25% and 13.69%, respectively. Methyl dehydroabietate and glycerol also have the highest share in PC1, at 12.23% and 12.08%, respectively. The second leading component in Figure 12.b is entirely dominated by stigmastanol, with its contribution over 44%. As can be seen in Figure 12.b, the points of *kernoi* and *rhyta* samples are located close to the primary variable vectors corresponding to lactic acid, glycerol, ethylene glycol, and dibutyl phthalate.

With regard to the fatty acids distribution in vessels, the first five principal components account for about 70% of cumulative variance. C9:0 and C8:0 have the highest participation in the first principal component with the contribution of variables 16.77% and 16.25%, respectively. In addition, C6:0 and enanthic acid (C7:0) fatty acids contribute to PC1 at a level higher than 10%. In turn, acids such as C20:0, C18:0, margaric acid (C17:0) and pentadecanoic acid (C15:0) have a high percentage of variability of the second main component, and this proportion ranges from 12.41% to 15.45%.

After separating the samples of *rhyta* and *kernoi* for the clustering methods, it can be seen that they constitute a characteristic group of vessels, different from the others considered both within the cemetery vessels and those originating from the settlement. The heatmaps shown in Figure 13 indicate the separation of ritual vessels, which distinguished mainly glycerol, lactic acid and ethylene glycol, C7:0, C8:0 and C9:0, as it was shown in PCA biplots. Also distinctive are tiglic, oxalic, suberic and C12:0 acids. Furthermore, cluster heatmap for selected acid proportions (Fig. 13c) also highlights the *kernoi* and *rhyta* among the other vessels from the cemetery.

Conclusions

The organic residue analysis showed that the vessels from which the samples originated may have contained food: fermented drinks, animal fat (meat or milk), oily plant products and fruits, probably of various species, and resins. The detected plant fat was not necessarily an oil but possibly an ingredient of herbs, vegetables or grains. The contents of each vessel were not exclusively of plant origin, but were in contact with animal fat, mixed with wax resin preserved in the samples. While most funerary vessels seem to have been used only for a single ceremony, they may have taken part in various rituals and activities earlier.

While it might be assumed that liquids, alcoholic beverages/offerings/libations were in or were drunk from the *rhyta*, it is rather challenging to determine the nature of those substances. The vessels contained a wide range of compounds, meaning the products were mixed. This fact is reflected in the studies on ancient

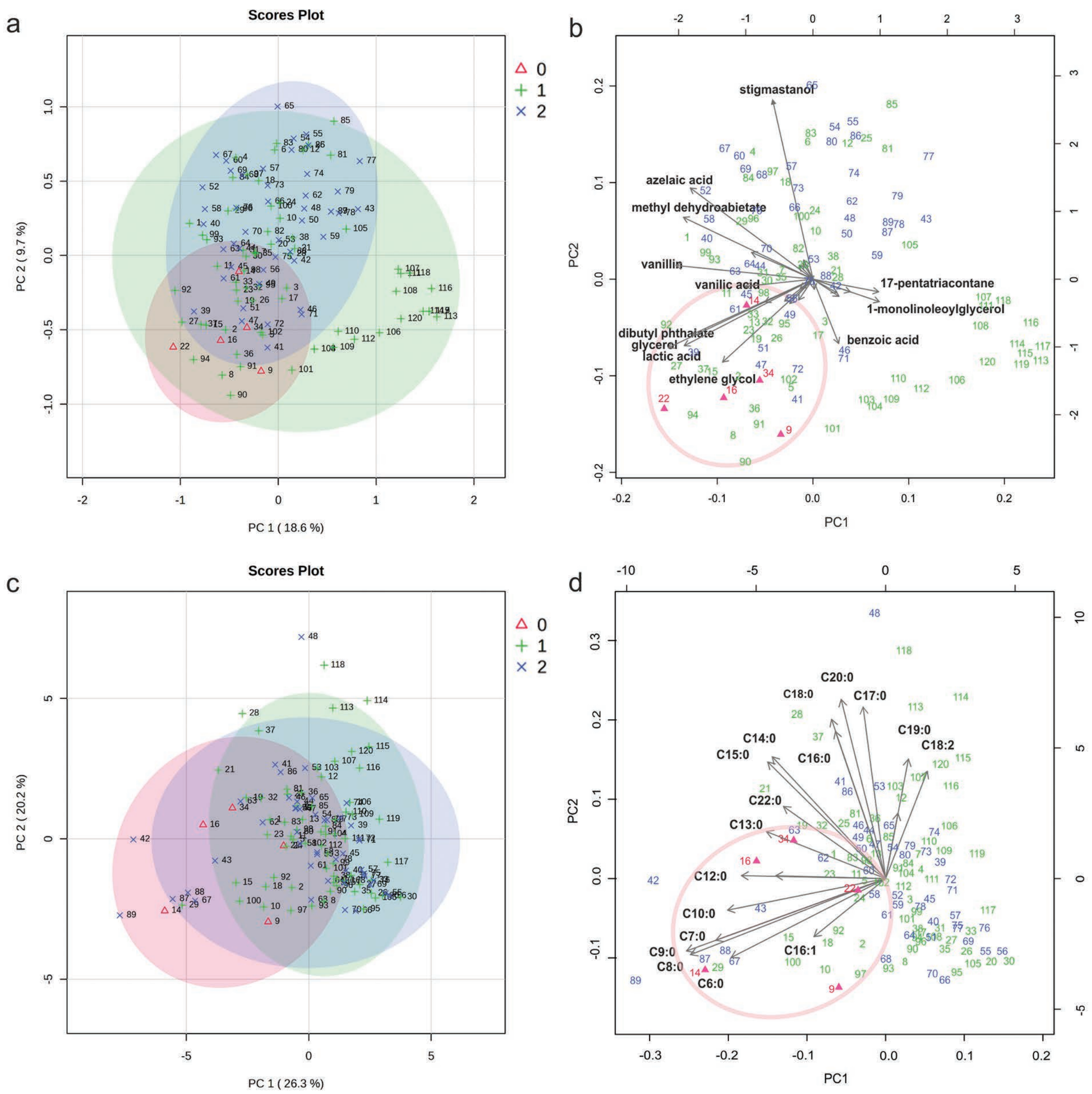

Fig. 12. PC1–PC2 plots and biplots in the plane of the first two principal components, containing vectors of primary variables and points representing individual archaeological samples. Samples of* rhyta *and* kernoi *(0) are distinguished against the remaining samples from the cemetery (1) and the settlement (2).

alcoholic beverages, and is also in concert with ancient texts, which specify that the obligatory ingredients in libations and sacrifices were wine, water, milk/cheese, flour/barley, and blood (*e.g.*, in the *kykeon* mentioned by Homer, see *Ridgway 1997; Nebelsick 2020*).

Much archaeological evidence exists of mixed types of ancient drinks, combinations of beers, wines and meads. Nordic peoples preferred a hybrid beverage, in which many ingredients were fermented together, including locally available honey, fruit (*e.g.*, bog cranberry and lingonberry), cereals (wheat, rye, and/or barley), and sometimes grape wine imported from the south of Europe (*McGovern 2009*). Birch tree resin, juniper, bog myrtle, yarrow, bog cranberry, and lingonberry were also used as additives. Plant and animal substances were attested in wine-containing vessels from Heuneburg (*Rageot* et al. *2019*). Animal fat in samples from the cemetery in Domasław may originate, among other things, from milk or cheese added to drinks or the use of dairy (milk) as a sealant agent (*Schiffer 1990; Gosselain 2002; Drieu 2017; 2020*) or, *e.g.*, from leather bottles in which the products were transported (*Nebelsick 2020*).

Beverages from Domasław, maybe a kind of *ale gruit*, were probably made of wheat, barley and/or rye due to the presence of oxalic, azelaic and suberic acids in some samples, which are suggested as markers of these cereal species (*Park* et al. *2017.349–355; Farag* et al.

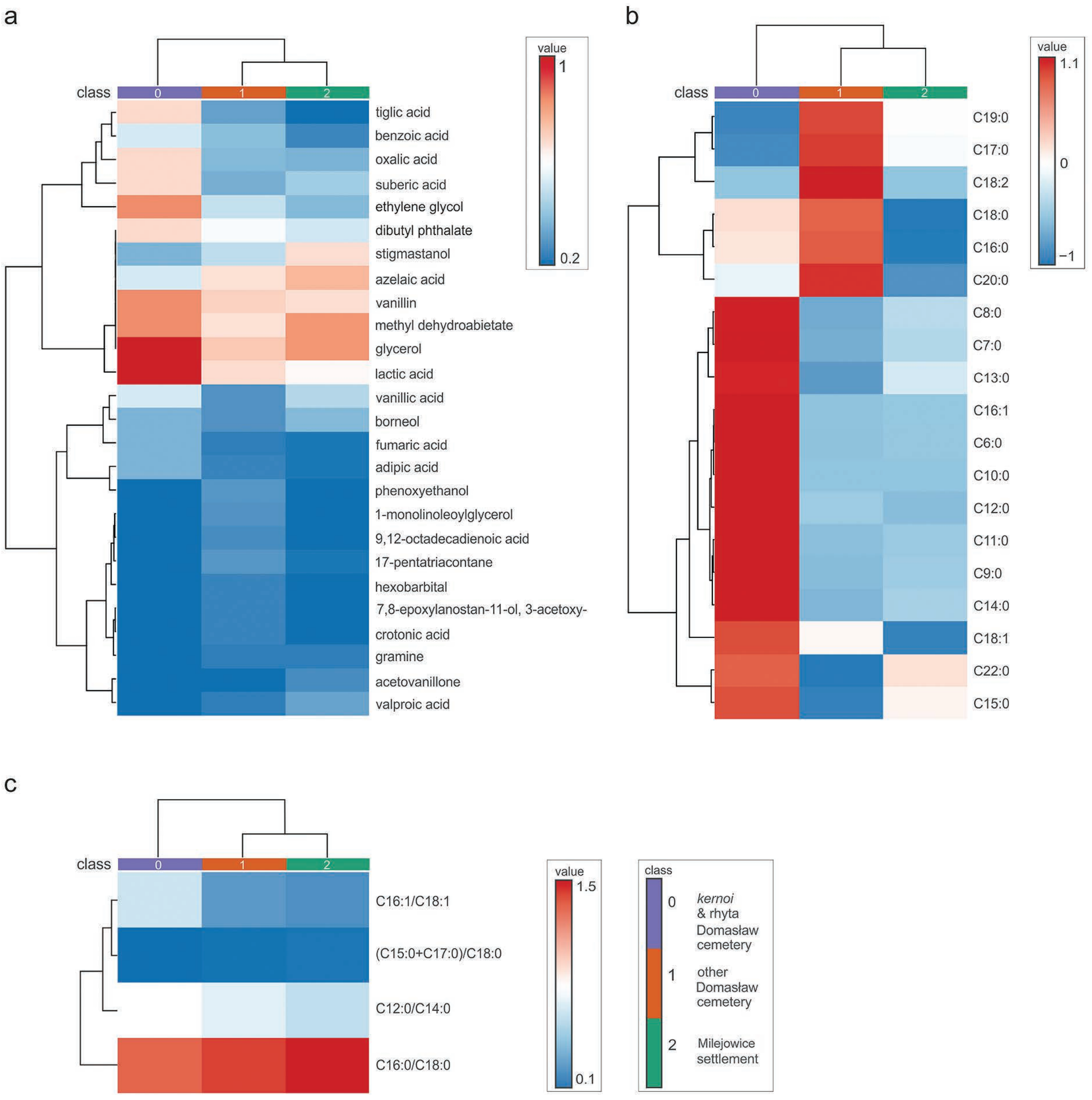

Fig. 13. Clustered heatmaps for biomarkers (a), fatty acids (b) and acids proportions (c) found in the samples.

2019). Cereal cultivation is confirmed by botanical studies, which showed the presence of burnt (or maybe fried) wheat and millet grains in samples from vessels and graves (analyses by Agata Sady-Bugajska). These isolated findings cautiously suggest that wheat was most likely used in beverages. Plantal, herbal, bactericidal and medicinal ingredients found in organic residues might have been added to improve the beverage's flavour, extend its durability, and enhance its effect.

Various herbal, grain, milk, honey and/or fruit beverages were possibly poured into the libation vessels during funerals. They were made according to recipes based on nearby plants and following specific restrictions reflecting the social or familial status, or maybe the sex or the age of the deceased. The principal bittering agents in early medieval European beer were bog myrtle, yarrow, meadowsweet, and other herbs (*Nelson 2005*). For example, native rosemary, mint, and thyme were added to a fermented emmer wheat and barley beverage at Genó, near Barcelona in Spain, around 3000 BC (*Juan-Tresserras 1998*). Mugwort was hypothesized as an additive (alongside carrot) to a dark, sour barley beer at the settlement of Hochdorf (*Stika 2010*). It was also added to some of the early Spanish brews.

The identified benzoic acid may indicate the presence of fruits and propolis components. Simple phenols, such as vanillic acid or vanillin, may also be benzoic acid derivatives (*Nelson 2005*). Tree saps, such as maple (levulinic acid), could also be consumed fresh and fermented. Adding maple sap or syrup may have a sweetening or healing effect. Alcoholic beverages made by mixing malt extract with milk were possibly also consumed, as indicated by *rhyta* 14 and 34.

Products used for funerary purposes were diverse; some might have been associated with taboos. Certain plants with symbolic significance and medicinal or poisonous effects could be used only in funerary contexts. The examined *rhyta* did not contain any intoxicating substances, as found in some cemetery vessels from the most lavish graves. C11:0 was only detected in 'special' vessels and ceramics used for offerings, which may indicate a unique oil or plant in the composition of beverages they held. Tiglic acid may indicate that the vessels contained oils (croton oil) added for medicinal purposes, flavouring or symbolic reasons. Similarly, while borneol might come from herbs customarily added during beer production, the camphoraceous, herbal or resinous flavour might have also had a symbolic meaning. A higher oleic acid ratio suggests that plant and plant oils were also added. No more reliable compounds occurring in the honey or waxes used to sweeten wine/beer/grogs or seal vessels were identified. The many uses of resins, such as sealing, polishing, sweetening, and preserving, prevent us from determining their purpose in Domasław. It cannot be ruled out that some aromas, essential and plant oils, balms and spices were imported, just like other prestigious products.

Both drinking horns and zoomorphic *rhyta* were probably used for drinking. However, the design of vessel 34, formed as a sheep or goat, allows us to associate it with liquid offerings, where the mixture could be poured out of the spout in the front. The *rhyton* has two openings, one at the top for filling and another at the muzzle to allow the liquid to flow out. Unless the mouth hole was plugged, any liquid poured into the top hole would flow out immediately. A *rhyton* could have functioned either as a drinking vessel or a funnel for filling other vessels. It might have also been used to carry the liquid from one location to another.

A group of 24 spouted vessels from Austria from the late Bronze and the Early Iron Age were also studied (*Dunne* et al. *2019; Rebey* et al. *2021*), seven of which provided results suitable for interpretation. Gas chromatography, GC-mass spectrometry and GC-combustion isotope ratio-MS analyses showed that three vessels were used predominantly for processing dairy products from ruminants, mostly milk from cattle, sheep or goats, four were used for processing mainly products from ruminant carcasses with a small admixture of non-ruminant products, pig milk, or human milk. Three vessels with clear ruminant milk signals are associated with burials of young children. In Domasław, we can also associate the small zoomorphic vessels (*rhyta* 14 and 34) with children, and they definitely cannot be compared to the impressive vessels with animal protomes known from lavish elite male burials in Europe. Most of the *rhyta* and *kernoi* were placed in children's graves or in multi-individual burials with children. It is possible that they contained different products in accordance with the corresponding ritual. The results, which might indicate a nutritious cereal-milk drink for children, would be, in this case, consistent with the nature of the other tested vessels (*Dunne* et al. *2019*). However, at the same time vessel 34 contained shorter aldaric acid (fumaric acid), considered as marker of alcoholic fermentation (*Garnier 2015; Blanco-Zubiaguirre* et al. *2019*).

The studies failed to explain how the *kernoi* and *pseudo-kernoi* were used. The funnels of *kernos* 16 were deliberately broken (like parts of a *pseudo-kernos* from this grave), which may suggest the 'killing' of its function after being placed in the grave. The vessel contained cereal markers (azelaic acid, suberic acid) and croton oil, but no resin markers were found.

The secondarily fired *kernos* from grave 3779 may have been related to fumigations or burned offerings. Organic products connected with libations or fumigations have always played a significant cultural role, especially in burial symbolism. Combining natural ingredients, such as oils and plants, carries a strong symbolic and sometimes sacred load.

Triple vessels consisting of small cups joined together might have played a role in liquid libations involving changes in the content's visible colour and density caused by mixing different substances. The arrangement of openings allows the mixing of three different liquids. These extraordinary vessels were ritual items designed to transform specific ingredients into substances with desired properties or meaning. They could contain oils, water, milk, fermented drinks, honey, blood, dyes or even urine. Unfortunately, it was not possible to collect samples from these vessels.

Special vessels, such as *rhyta* and *kernoi*, stand out from the other burial and settlement vessels. They were part of funeral rites and played a significant role in displaying the identity of the buried people. Alongside the sets of drinking vessels and other objects placed in graves at the cemetery in Domasław, they demonstrate that the Early Iron Age communities inhabiting Central and Eastern Europe adopted Greek customs of feasting and making poured offerings and libations during funeral ceremonies. The impact of the Mediterranean world made feasting and using ritual vessels for mixing, pouring and consuming liquids an element of the Hallstatt societies' identity.

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Dolsko – Spodnje Škovce and a new insight into the settlement, chronology, ceramic style(s), and subsistence strategies of the Late Neolithic Sava group in Slovenia

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ABSTRACT - *Radiocarbon dates, analysis of ceramic finds, animal bones, fruits/seeds and wood (charcoal) from settlement features of the Sava group of the Lengyel Culture at the site of Dolsko – Spodnje Škovce in central Slovenia are presented and discussed in this paper. The aim of the study was to place the excavated material culture in its regional and supra-regional context in order to improve the understanding of Late Neolithic settlement features, chronology, pottery style(s) and subsistence strategies in settlements throughout the area of distribution of the Sava group. This is the first synthesis of archaeobotanical and archaeozoological data from the 5th millennium cal BC sites in Slovenia, including the evaluation and comparison of plant macro-remains and animal bones, and the first synthesis of data on technological and typological aspects of pottery production in the settlements obtained using the same analytical approach. Uncertainties regarding the chronology of different variations of a pottery style and subsistence strategies are emphasized.*

KEY WORDS – *Slovenia; Late Neolithic settlement; Sava group of the Lengyel Culture; radiocarbon dating; pottery analysis; archaeobotany; archaeozoology*

Dolsko – Spodnje Škovce in nov vpogled v poselitev, kronologijo, keramični stil ter strategije preživljanja v času poznoneolitske savske skupine v Sloveniji

IZVLEČEK – *V prispevku so predstavljeni in obravnavani radiokarbonski datumi, analiza keramičnih najdb, živalskih kosti, plodov/semen in lesa (oglja) iz naselbinskih struktur savske skupine lengyelske kulture na najdišču Dolsko – Spodnje Škovce v osrednji Sloveniji. Namen študije je umestiti materialno kulturo v njen regionalni in nadregionalni kontekst, da bi izboljšali naše poznavanje poznoneolitskih naselbinskih struktur, kronologije, keramičnega stila in strategij preživljanja na naselbinah na območju celotne razprostranjenosti savske skupine. Gre za prvo sintezo arheobotaničnih in arheozooloških podatkov z najdišč iz 5. tisočletja pr. n. št. v Sloveniji, v katero je vključeno vrednotenje in primerjava rastlinskih makroostankov in živalskih kosti, ter prvo sintezo podatkov o tehnoloških in tipoloških vidikih poznoneolitskega lončarstva na naselbinah, ki so bili pridobljeni z uporabo enakega analitičnega pristopa. Izpostavljene so negotovosti glede kronologije različnih variacij keramičnega stila in glede strategij preživljanja.*

KLJUČNE BESEDE – *Slovenija; poznoneolitska naselbina; savska skupina lengyelske kulture; radiokarbonsko datiranje; analiza keramike; arheobotanika; arheozoologija*

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Introduction

The Late Neolithic in the south-eastern Alpine region has many similarities with the contemporaneous settlement in the Pannonian Basin, but the subsistence strategies, ceramic style(s), households and chronology are comparatively poorly known. This study brings new analyses of ceramic finds, animal bones and plant remains, as well as six radiocarbon dates from two pits of the Sava group of the Lengyel Culture at the site of Dolsko – Spodnje Škovce in central Slovenia. The samples of cattle teeth and charcoal are dated and provide a basis for discussing the uncovered material culture in the context of regional and supra-regional development. The possible use of large, irregularly shaped pits is discussed on the basis of the excavation results, the distribution and composition of the finds, and comparisons with contemporaneous and culturally related settlements. The technological and typological aspects of ceramic production were compared with those reported previous studies and the results evaluated. We also evaluated new radiocarbon measurements in the context of 5th millennium cal BC ceramic sequences in central Slovenia, while archaeozoological and archaeobotanical analyses were used to discuss subsistence strategies and environmental conditions in settlements located in different micro-regions.

Late Neolithic in the south-eastern Alpine region

The material cultures of the south-eastern Alpine Late Neolithic and the Early Copper Age have long been regarded as a single chronological phase, probably because the Late Neolithic pottery here has many similarities with the later Lasinja Culture pottery, and because finds from both periods have often been found mixed together (*e.g., Korošec 1956; 1960; 1964; 1965; 1975; Pahič 1976*). The fact that the oldest settlement dates to the first half of the 5th millennium BC was finally recognized in the 1980s with the research carried out at Moverna vas (*e.g., Budja 1992; 1994; 1995*) and at Gradec near Mirna (*Dular* et al. *1991.84–90; 2001*). At both sites, several Neolithic and Copper Age occupation layers were uncovered in a vertically stratified position. The earliest settlement was dated to the Late Neolithic, associated with the Lengyel Culture and the following to the Early Eneolithic/Copper Age and associated with the Lasinja Culture. Both sites were excavated during research projects, the results of which clearly showed that lowland river terraces and the hills were settled, with at least some of the hilltops surrounded by stone walls.

In 2002, on the occasion of the newly discovered settlements Čatež – Sredno polje and Dragomelj, the Sava group of the Lengyel Culture was introduced as "*a cultural phenomenon that was spread in the Sava River basin between Kranj (NW Slovenia) and Karlovac (NE Croatia)*" (*Guštin 2002; 2005; Guštin, Bekić 2002*). All Late Neolithic sites in the south-eastern Alpine region around the river Sava were included in the newly established group, but not the settlements in NE Slovenia and the Bela krajina region (Fig. 1). It was argued that the pottery at the Sava group sites was mostly made of medium-grained fabrics, rarely coated with coloured clay slip, and most often decorated with impressions, the rest with appliqués and incised decoration (*Guštin 2005.9–12*). In contrast, it was emphasized that the pottery from NE Slovenia is mostly decorated with appliqués, and the pottery from Bela krajina with incised decoration or in a combination of incised decoration and impressions, and most often made of fine- and very fine-grained fabrics, but more often coated with a coloured clay slip. Furthermore, it has been suggested that large pits represent traces of pit-houses or places of residence, and based on the radiocarbon measurements the settlement has been chronologically correlated with the Lengyel II phase in Transdanubia (*Guštin 2005.13; Guštin* et al. *2005.104*).

Twenty years after the recognition of the Late Neolithic Sava group, possible earlier Neolithic settlements (from the Early or Middle Neolithic) in the area of distribution of the Sava group are still unknown. Traces of above-ground, timber-framed houses are known only from two Late Neolithic sites in the wetlands of Ljubljansko barje (*Korošec 1964; Velušček 2006; Velušček* et al. *2023*) and large irregular pits at other sites are assumed to represent the remains of pit-huts (*e.g., Ravnik, Tica 2018.39; Tomaž 2022.25–27; Turk* et al. *2022.332*). Subsistence strategies in the Late Neolithic are also poorly known. Archaeobotanical and archaeozoological data are available from only a few Late Neolithic settlements, mostly with a small number of identified plant and animal remains (*e.g., Culiberg* et al. *1992; Toškan 2018; 2022; Tolar 2021.109–110; Hincak 2022; Kramberger* et al. *2023.69–71*). Moreover, the chronology of the Late Neolithic in Slovenia is less well established. According to one theory, the Sava group was contemporaneous with the Lengyel II (*Guštin 2005*) or even Lengyel I (*Tomaž 2022.105*) phase in Transdanubia, while others proposed that the sites are younger, contemporary with the Lengyel III phase (*Velušček 2006; 2011*), according to the Hungarian chronology of Nandor Kalicz (*1969; 1976*) and Pal Ra-

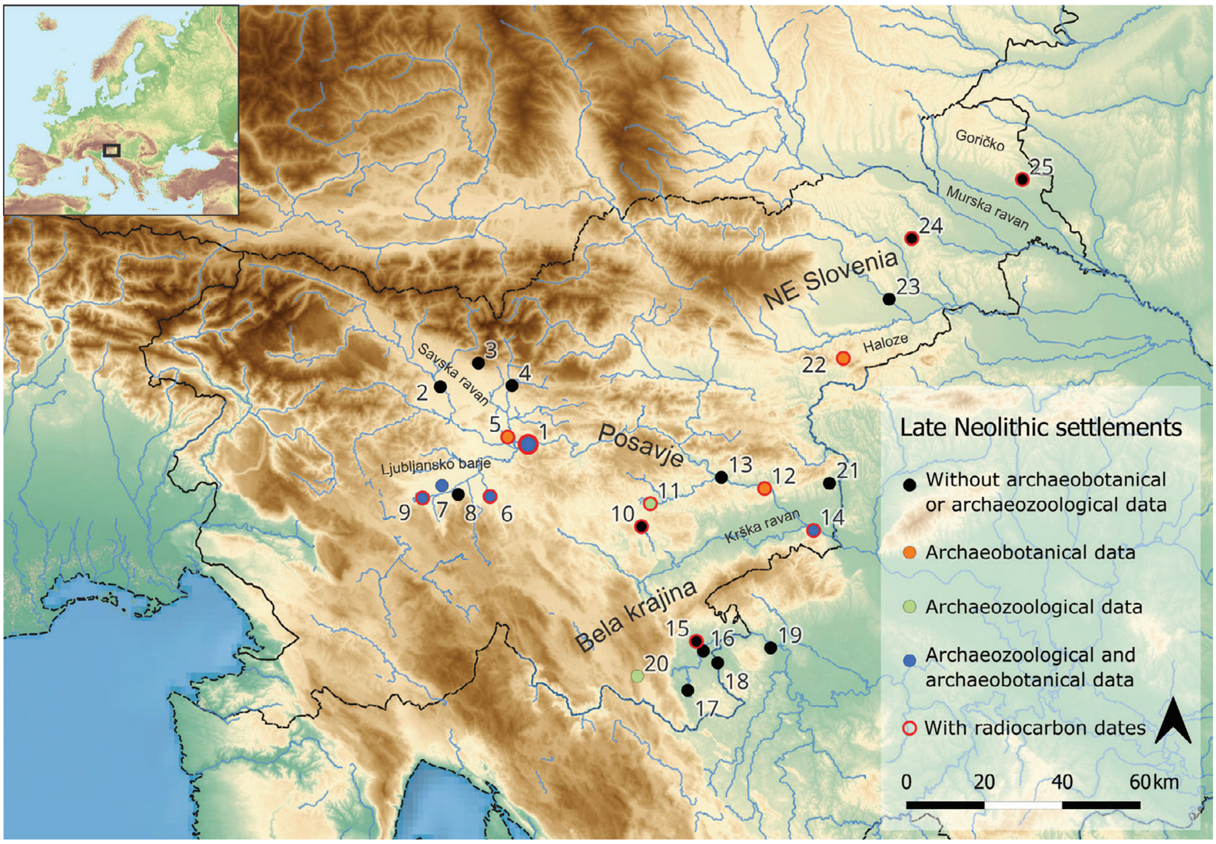

Fig. 1. Most important sites of the Sava group and Late Lengyel Culture in Slovenia and near Karlovac:* 1 *Dolsko – Spodnje Škovce,* 2 *Drulovka near Kranj,* 3 *Gradišče near Stiška vas,* 4 *Kamnik – Mali grad,* 5 *Dragomelj,* 6 *Resnikov prekop,* 7 *Zamedvedica near Plešivica,* 8 *Sv. Lovrenc,* 9 *Verd,* 10 *Ponikve near Trebnje,* 11 *Gradec near Mirna,* 12 *Dolenji Leskovec,* 13 *Sevnica,* 14 *Čatež – Sredno polje,* 15 *Moverna vas,* 16 *Gradac – Grajski park,* 17 *Pusti gradec,* 18 *Griblje,* 19 *Ozalj – Stari grad,* 20 *Spaha,* 21 *Podgorje near Pišece,* 22 *Stoperce,* 23 *Ptujski grad and Ptuj – Šolski center,* 24 *Andrenci,* 25 *Bukovnica.

czky (*1974*), which is mainly based on Pavúk's classification (*Pavúk 2007;* see also *Osztás* et al. *2016.197*). The main problem for chronological research on the Ljubljansko barje is the small number of piles from the 5th millennium cal BC and the use of timber taxa (*e.g., Alnus, Salix*), which are not suitable for dating with the help of the *Quercus/Fraxinus* reference (dendro) chronology, which has so far been established mainly for sites from the 3rd and 4th millennium cal BC (Fig. 1.6,9) (*Čufar* et al. *2010; 2022*), while in the case of other studies the research approaches used had their own risks and weaknesses. One of these studies was a typological analysis of ceramics and an attempt to correlate them with the Lengyel Culture sites (*Velušček 2006; 2011*), while other studies drew conclusions based on a comparison of radiocarbon dates with the same culture (*Guštin 2005; Sraka 2012.369–370; Tomaž 2022.105*). The first approach is not ideal, because the sites of the Sava group have a specific material culture, which does not correspond entirely to the Lengyel pottery (*e.g.,* no painting). On the other hand, the comparison of radiocarbon dates is also less than ideal, because radiocarbon dating can provide only a limited time resolution, and because dating in Slovenia is based on long-lived material (charcoal) and on dates from charred organic residues on the pottery, *i.e.* samples that have given unexpected results, probably also due to issues such as the 'old wood effect', the 'marine reservoir affect' and the 'hard water effect' (*Mlekuž* et al. *2013.132–133; Hlad 2015.13–14; Kramberger* et al. *2023, 55–68; cf. Oross* et al. *2010.392–398; Nowak* et al. *2017.189*).

Some attempts to comprehensively compare and evaluate the variability of the pottery at the Sava group sites were published in 2014 and 2020 (*Kramberger 2014; 2020*). Three groups of sites could be identified based on the similarities and differences in ceramics (Sava group Ia-b, II). However, due to the limited number of samples from short-lived materials, it was not possible to fully explain the pottery variability. The research conducted at the Dolsko site yielded new ^{14}C

AMS dates and a rich pottery assemblage, animal remains and some plant macro-remains from stratigraphically well-documented contexts. These data enabled us to conduct archaeobotanical and archaeozoological analyses, to analyse ceramics and to evaluate results in the context of the aforementioned research problems in Slovenian Late Neolithic Archaeology.

Dolsko – Spodnje Škovce: excavation, Late Neolithic settlement features

The archaeological site is located 5.56km southeast of the Late Neolithic settlement of Dragomelj (Fig. 1.5), at the edge of a second river terrace of Sava, which is between 2 and 3m high. It is located close to the Mlinščica stream (Figs. 1.1 and 2.1,2), and it is a known site of the Sava group of the Lengyel Culture, Middle Copper Age, Bronze Age and Early Medieval period, documented with several short reports (*Žorž Matjašič 2009; Žorž 2009; Žorž, Nadbath 2010*). Meanwhile, a monograph of the site is in progress, which includes the finds from all periods, including the stone tools and implements from the Late Neolithic and Copper Age (*Kramberger in preparation*). These finds are not the subject of the following study.

Nearby, 1.62km southwest of the site, there is a confluence of three major rivers. The Sava River flows from the northwest, the Ljubljanica River flows into it from the southwest, and the Kamniška Bistrica from the north (Fig. 1.1). Based on the results of archaeological excavations, both the Sava River and smaller streams shifted their beds throughout history until they were artificially regulated at the end of the 18th and in the 19th centuries, partly for economic reasons and partly for safety reasons due to frequent flooding. In both excavation areas (areas 1 and 2), several paleochannels were found, which flowed in different periods in a northwest-southeast direction and are not shown on the first or later military maps of the Habsburg Empire from the 18th and 19th centuries, each with a sequence of alluvial deposits, often containing archaeological finds from various periods (Fig. 2.3,4).

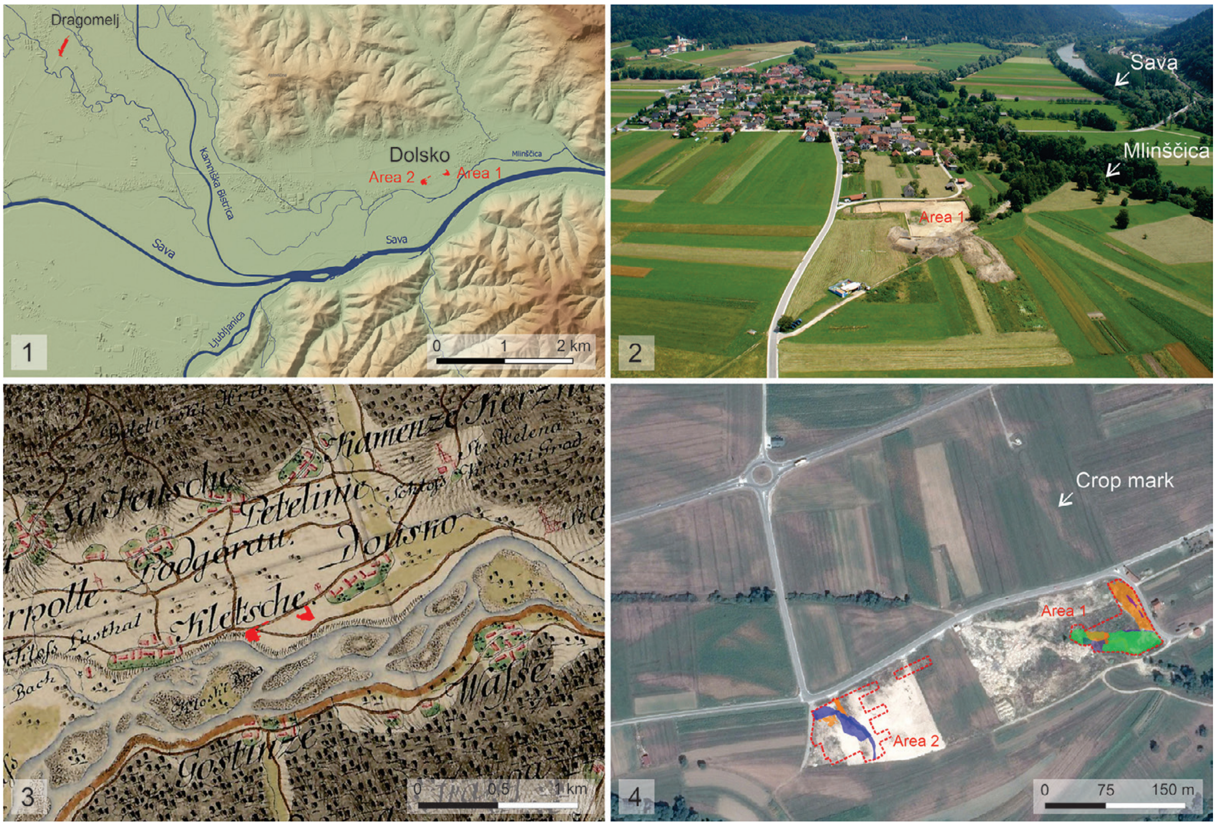

Fig. 2. Dolsko – Spodnje Škovce. **1** ***Location of the excavated areas (sources: ARSO, Lidar 2014; GURS, Hidrografija 2020; GURS, REZI 2019);*** **2** ***view on Area 1 from the west during excavation, with the Sava River in the background and Mlinščica stream in the foreground (photo: Matija Lukić);*** **3** ***the area on the map of Maria Theresa's*** **"First Military Survey"*****, 1784–1785 (source: Arcanum);*** **4** ***satellite map with paleochannels, alluvial deposits (blue, orange) and a large alluvial depression (green) discovered during the excavation (*****Google Maps*****).***

From the shape of the Sava gravel discovered at the bottom of a large depression below the uncovered former edge of the river terrace, it can be concluded that the Sava River flowed close to the settlement in the Late Neolithic (see also *Žorž, Nadbath 2010*). During this period, a layer was deposited on the edge of a terrace, probably a buried soil, as evidenced by its consistency, colour and the finds discovered (Fig. 3. 1026, 1020,1013). In later periods the Sava and smaller watercourses deposited younger sediments along the edge of the Sava terrace and the river gradually moved southwards, with this process, based on the finds, being most intensive in the Late Bronze Age. Finally, in the 19th century, the river moved to the southern edge of the valley and soon after the Mlinščica stream was artificially diverted from the nearby Kamniška Bistrica River into the former dead arm of the Sava for use by watermills and later power plants (Fig. 2.1,2; *cf.* Fig. 2.3).

Two larger Late Neolithic pits and 12 smaller Late Neolithic pits ranging in size between 0.74x0.74m and 4.02x1.10m were found during the rescue excavations in 2008, most of them in Area 1 (Fig. 3). Traces of Late Neolithic posts in ground structures were not discovered, although several post holes were found, all but one of which proved to be later based on finds and their stratigraphic positions.

The most interesting Late Neolithic features are two large pits (1 and 2), interpreted in the first publications as the sunken floors of buildings, which yielded most of the pottery from the site. They were connected by a thin layer of darker soil, with a linear layout, interpreted as a path between houses (Figs. 3.202,75 and 4) (*Žorž Matjašič 2009; Žorž, Nadbath 2010*). However, this layer could also have been formed naturally by the erosion and deposition of material from the northwest. This is suggested by the ground plan and orientation of the layer, which matches the orientation of another layer, yellowish-brown alluvial deposit (SU 21), found beneath it (Figs. 3.21 and 4). The latter may be associated with the clearly visible crop mark to the north of the site (Fig. 2.4), and one of the paleochannels documented in the section of trial trench at the north-eastern edge of Area 1. The fragments of a single pot were found scattered in both large pits (SUs 200, 148), suggesting that the pits were partially filled with the same material (Fig. 3).

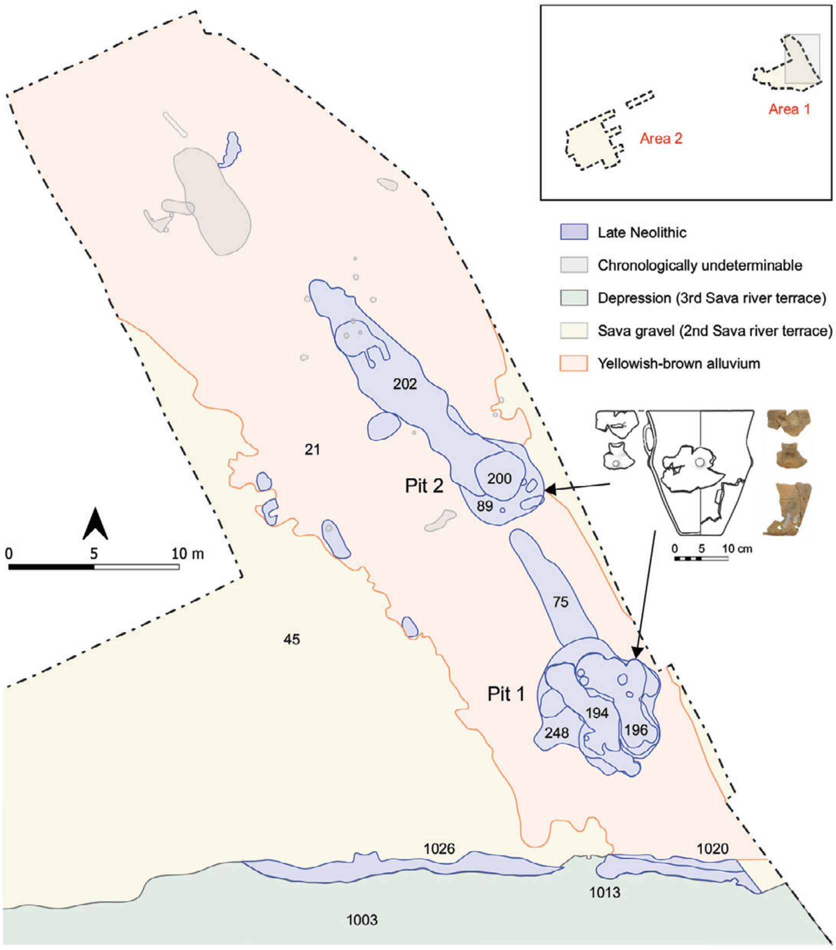

Fig. 3. Dolsko – Spodnje Škovce. General plan of the eastern part of Area 1 with the Late Neolithic pits and alluviums.

Late Neolithic pits 1 and 2 were found below the topsoil (SUs 1, 34) and were dug into the above mentioned light yellowish-brown alluvium, soft and malleable silty clay (Fig. 3.21), deposited in the Holocene over the older alluvium, the Sava gravel (Figs. 3.45 and 4), of either Late Pleistocene or Early Holocene age. The larger of the two features, pit 1 (SU 248 = a cut feature), measured 11x7m in size and yielded 6282 pottery fragments, or almost 40% of the total prehistoric pottery recovered at the site. It was irregular in shape (in plan and sections) and appeared as a complex of several smaller pits filled with three layers (SUs 113, 148, 194 = 196), each containing pottery frag-

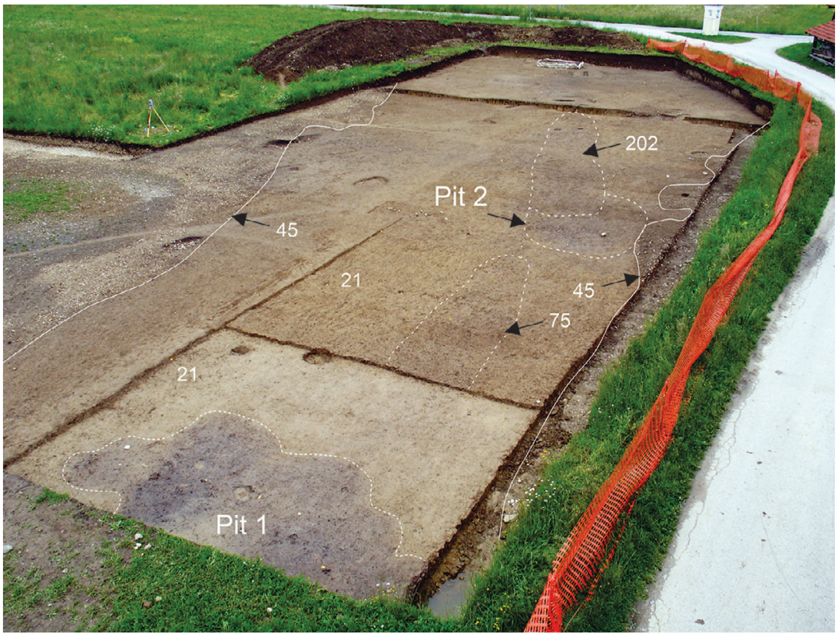

Fig. 4. Photo from the south-east on the pits 1, 2 and alluviums in the Area 1 during excavation.

ments, stone tools, flakes, animal remains, burnt clay and charcoal. Small concentrations of charcoal (SU 192, size 0.4x0.1m; SU 244, size 0.49x0.37m, 0.02m thick), possibly the remains of hearths, were also found (Figs. 5–6).

The pottery was fragmented and it can be observed that parts of individual vessels were scattered across layers in different stratigraphic positions (see Figs. 5–6). Fragments of two pots (G33, G34) were found in two different pits excavated at the bottom of the large pit and in the layer above (SUs 148, 194, 196). Fragments of two dishes (G11, G15), two pots (G37, G161) and a ladle (G58) were found in layers SU 194 and SU 148 above it. Parts of another pot (G171) and a dish (G149) were discovered in layers SUs 113 and 148. In addition to these cases, fragments of several other individual vessels were found scattered, but within the same layer (*e.g.,* G13, G29, G38, G57, G77, G81), some uncovered up to 4.5m apart (G26, G34; Fig. 6).

Pit 2 (SU 90) was discovered to the north of pit 1. It was oval in ground plan, and smaller (3.5m long). Shallow pits were found on its bottom, and a small pit of circular ground plan, probably the only Late Neolithic posthole at this site, was found close to its edge. Stone flakes, stone tools, fragments of burnt clay, animal remains and charcoal were discovered in two different fills of the pit, as well as 627 ceramic fragments: 170 in SU 200/201, which covered only the deepest part of the pit and 457 in SU 89/90 above it (Fig. 3.89,200).

Ceramic finds

A total of 6923 pottery fragments were found in pits 1 and 2, which places it among medium-sized Late Neolithic pottery assemblages from Slovenia. More pottery is only known from Čatež – Sredno polje (more than 57 000 fragments; *Tomaž 2022.34*). At the nearby Dragomelj 4256 ceramic fragments were found (*Turk, Svetličič 2022.36*), 3612 at Ponikve near Trebnje (*Ravnik, Tica 2018.59*), 1186 in SU 128 in Stoperce (*Kramberger* et al. *2023.93*) and at Dolenji Leskovec 5379 in the only studied pit so far (*Hlad 2015.15; cf. Klasinc* et al. *2010; Jovanović* et al. *2012*). At Moverna vas and Resnikov prekop many pottery fragments were also found, and 3173 from the total assemblage at Moverna vas (*Tomaž 1997.116*) and 951 from Resnikov prekop were analysed (*Tomaž, Velušček 2005.89*). At other sites, pottery finds are fewer or the data on the quantity of ceramic fragments are not available (*e.g., Korošec 1960*).

After assembling the fragments, 215 typologically characteristic pieces of Late Neolithic ceramics from Dolsko were selected for publication (*Kramberger in press*). The typological classification was based on the author's own typology (*Kramberger 2014*; *2020*), while the pottery production methods were described using macroscopic standards (after *Horvat 1999*) and the results are presented here for the first time. Only the most relevant findings are shown graphically in the continuation of this text, labels mentioned (*e.g.,* G33, G34, G36) are from the catalogue included in the monographic publication of the site (*Kramberger in press*, G1–G511) and consequently do not follow each other sequentially. Technological macroscopic analysis was conducted on all Late Neolithic typologically characteristic ceramic fragments (No. 215), while the percentages of decoration techniques are calculated based on typologically characteristic fragments with decoration (No. 104).

It can be established that the Late Neolithic pottery contained quartz, mica and iron oxides, which are common inclusions in ceramic bodies in the region and beyond. However, there are obvious differences in the size and frequency of the quartz grains, which are thought to have been added to the clay as an additive (sand tempering). In most cases, Late Neolithic pottery consisted of very fine-grained (43% – no temper) and fine-grained (36% – less temper) fabrics, followed by medium-grained (20%) and coarse-grained fabrics (1%) (Fig. 7.1).

The surfaces of the vessels are matte and smooth and they were sponged before firing to remove irregularities. In some cases, thin parallel smooth lines are noticeable, indicating the use of a harder tool for surface treatment. 27% of the vessels were additionally coated with a coloured clay slip of red, brown, pink or yellowish red colour (Fig. 7.2).

Approximately 50% of typological significant pottery fragments show decoration: most often applied decoration (62%), followed by impressions (23%), combinations of applied decoration-impressions (8%), applied decoration-impressions-incised decoration (4%),

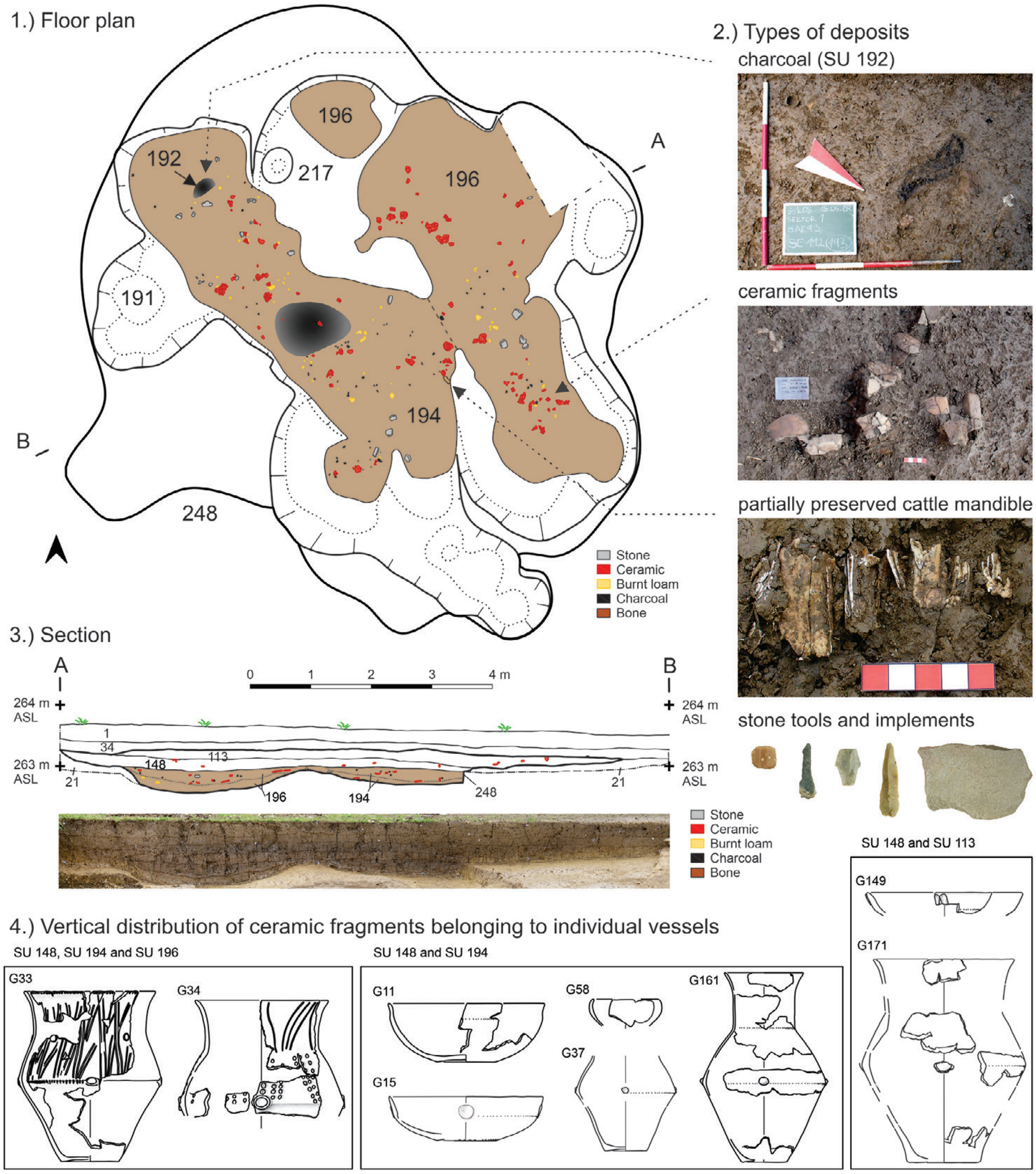

Fig. 5. Pit 1 (SU 248 = a cut feature).* 1 *Floor plan,* 2 *types of the deposits,* 3 *section, and* 4 *vertical distribution of pottery fragments belonging to individual vessels. Labels for the finds (*e.g., *G33…) are taken from the monographic publication of the site (*Kramberger in press, *G1–G511).

impressions-incised decoration (2%) and incised decoration (1%) (Fig. 7.3). Four pots, two pedestals and a small vessel with a grip attachment were decorated with incisions, other vessel types were in most cases only decorated with appliqués and/or impressions.

The firing atmosphere was fairly standardized. Pottery was generally fired under incomplete oxidizing conditions (93%), and a small amount in oxidizing (3%), reducing (3%) or oxidizing conditions with a reducing atmosphere at the end (1%).

The pottery assemblage includes pots, bottle-like vessel, pitchers, thin-walled vessels, pedestal dishes, dishes, bowls, ladles, a vessel with a grip attachment, vessels with zoomorphic/anthropomorphic grip, ceramic beads and a fired clay coil. The most common are pots (29.23%; Fig. 8.A), followed by dishes (13.51%; Fig. 8.F) and pedestal dishes (14.29%; Fig. 8.E). Just under a quarter (24.44%) are dishes or pedestal dishes (Fig. 8.G). Fragments of thin-walled vessels are also common (12.75%; Fig. 8.D), and pitchers could be reconstructed in two cases (1.20%; Fig. 8.C). Ladles are present in significant numbers (12.00%; Fig. 8.I), other types were rarer: bowls (2.44%; Fig. 8.H), a bottle-like vessels (0.59%; Fig. 8.B), ceramic beads (Fig. 8.G47–G52), a vessel with an attachment for a (wooden?) grip (Fig. 8.G57), fragments of vessels with anthropomorphic/zoomorphic grips (Fig. 8.G23, G118, G117), and a fired clay coil (Fig. 8.G123) (altogether 7.69%; Fig. 8.J). Vessels made of very fine and fine-grained fabrics (mostly dishes, pedestal dishes, pitchers, thin-walled

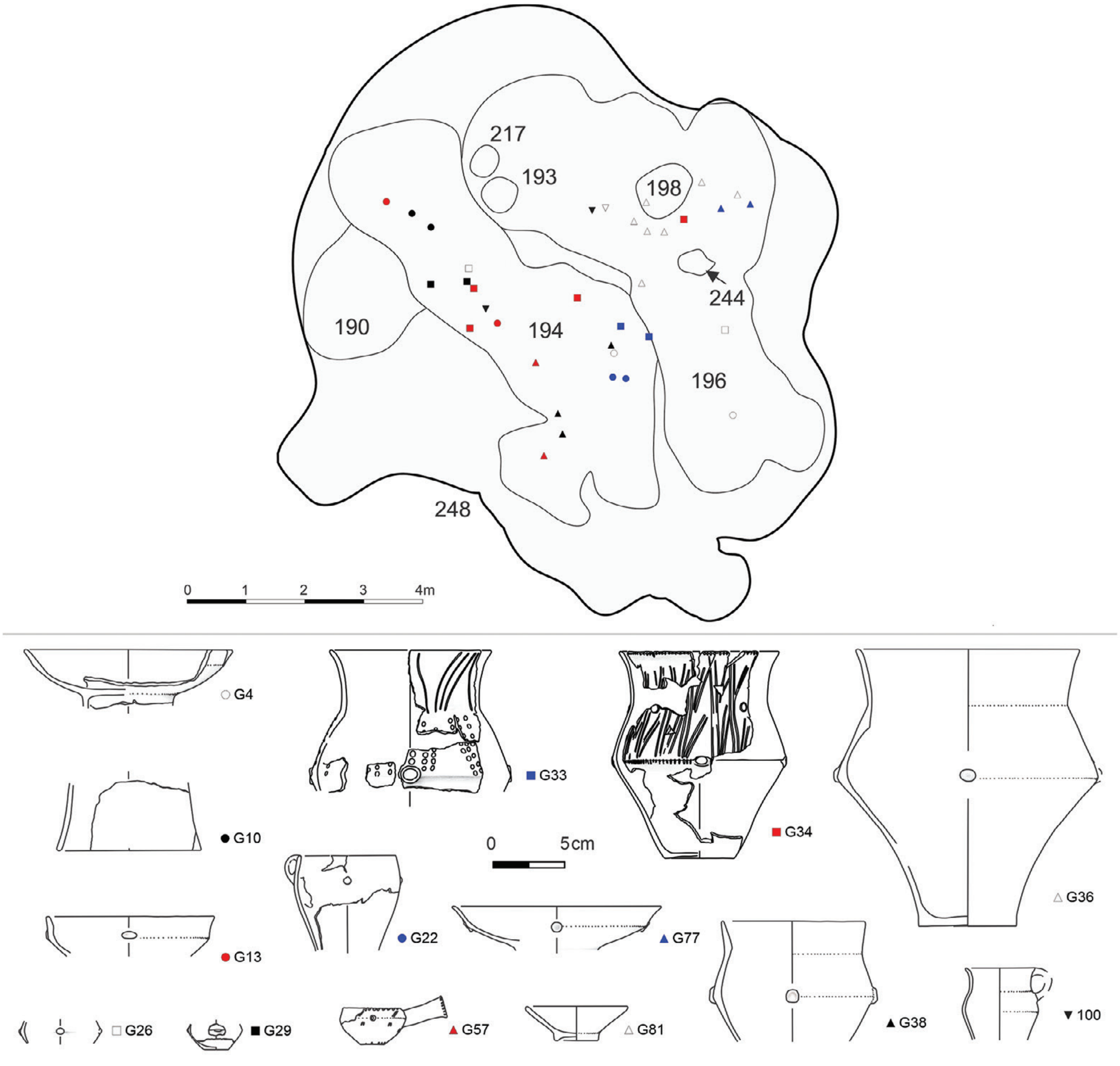

Fig. 6. Pit 1 (SU 248 = a cut feature). Horizontal distribution of ceramic fragments belonging to individual vessels. Labels for the finds (*e.g., *G4...) are taken from the monographic publication of the site (*Kramberger in press, G1–G511*).

vessels, and some bowls) usually have a surface of a uniform brownish or reddish colour, often coated with a colour clay slip. Most of the pottery with a significant amount of sand tempering (most pots and ladles) has no clay slip.

The pottery from Dolsko was typologically compared with pottery from other Late Neolithic sites and it was concluded that the pottery from Resnikov prekop, Dolenji Leskovec, Gradec near Mirna (phase 1), Moverna vas (phase 2) and Stoperce (SU 128), which are located in different parts of Slovenia, are the most similar (*Kramberger in press*; see also *Kramberger* et al. *2023*). The most chronologically relevant finds are pots with an everted neck of approximately the same length as the shoulder (Fig. 6.G33, G34, G36, G38; Fig. 8.G170, G38). They may have handles connecting the neck and the shoulder, or they may be without them As a rule, they were decorated with appliqués on the largest circumference, which is also typical for the pottery from Čatež – Sredno polje, nearby Dragomelj and Resnikov prekop (*Korošec 1964; Harej 1975; Velušček 2006; Tomaž 2022; Turk* et al. *2022*). The decoration can be complemented with impressions on the largest circumference and/or on the lip and with incisions spread over the neck and shoulder, and in the case of a pot from Dolenji Leskovec, extending into the lower part of the vessel (Fig. 9.Pot, type L7, Motif). Pots with ellipsoidal necks were found at the sites of Resnikov prekop, Dolenji Leskovec (see *Jovanović* et al. *2012.Tab. 5.5a, Tab. 22.22b*), Moverna vas (phase 2), Stoperce (SU 128) (Fig. 9.Pot, type L15/2) and others. Dishes and pedestal dishes with everted rims (Fig. 8.G1, G15, G80, G150) are decorated with appliqués (Fig. 9.Pedestal dish). In contrast, dishes with everted rim at Čatež – Sredno polje and Dragomelj are often decorated with appliqués and impressions on the transition to the rim and/or on the lip (*Tomaž 2022; Turk* et al. *2022*). Dishes with an everted rim decorated with impressions occur only occasionally at other sites: two at Dolsko (*Kramberger in press, finds 18 and 19*), one in the phase 2 at Moverna vas (*Tomaž 1999.Pl. 3.1*), one at Podgorje near Pišece (*Ciglenečki 1979.Fig. 3.1*) and one at Ptuj Castle (*Tomanič Jevremov* et al. *2006.find no. 2*).

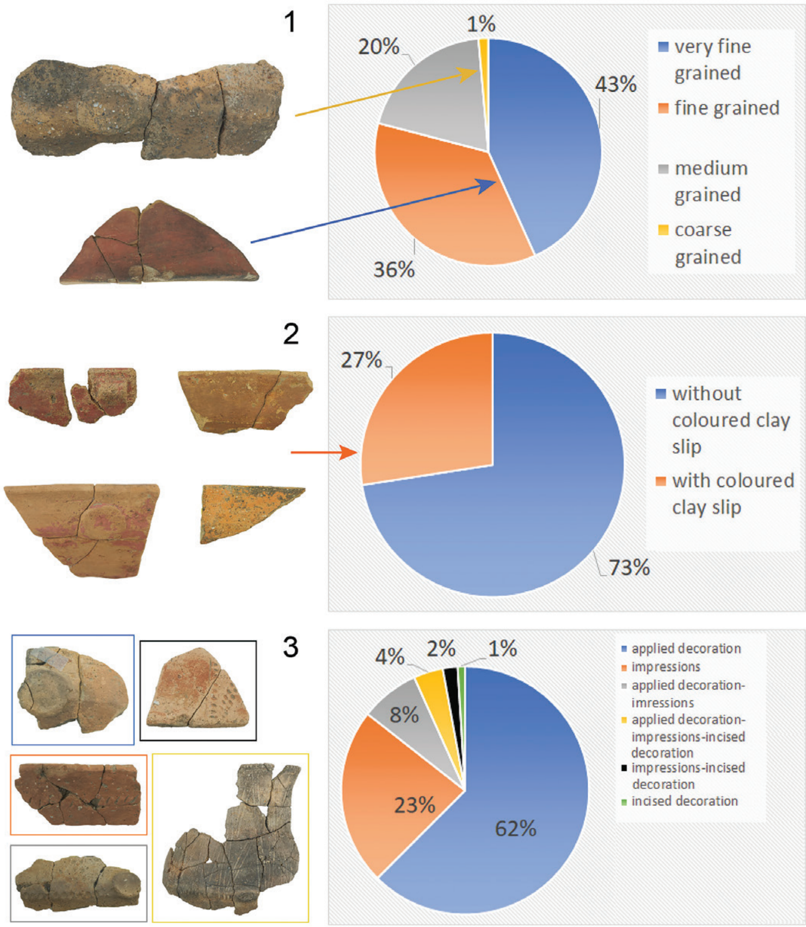

Fig. 7. Late Neolithic pottery from Dolsko – Spodnje Škovce.* 1 *Percentage of different granularity groups,* 2 *colour clay slip and* 3 *decoration techniques. Percentages of granularity groups and of colour clay slip are calculated on all Late Neolithic typologically characteristic ceramic fragments (No. 215), the percentages of decoration techniques on all typologically characteristic fragments with decoration (No. 104).

In addition, dishes and bowls with an inverted rim are found at Dolsko – Spodnje Škovce (Fig. 8.G92, G87) and Resnikov prekop, Dolenji Leskovec, Gradec near Mirna (phase 1), Moverna vas (phase 2) and Stoperce – SU 128, although in much smaller numbers (Fig. 9.Dish). These vessels are mostly decorated with small round appliqués on the maximum circumference. The ceramic assemblages at these sites are completed by pitchers, smaller vessels with a handle, which are also decorated with a round appliqué on the largest circumference and often coated with coloured clay slip (Fig. 9.Pitcher).

The pottery from Drulovka near Kranj (Fig. 1.2; *Korošec 1960*), Ponikve near Trebnje (Fig. 1.10; *Rav-*

nik, Tica 2018) and phases 4 and 5 at Moverna vas (Fig. 1.15; *Budja 1995; Tomaž 1999*) was found to be pronouncedly different (see *Kramberger 2014; 2020; Kramberger* et al. *2023*). Pots with short necks, usually cylindrical, rarely everted, predominate. Dishes and pedestal dishes with everted rim are present, but never decorated with appliqués, which is also characteristic of similar dishes at Col 1 near Podgračeno (*Horvat 2005; 2020*), Ajdovska jama (*Korošec 1975*) and Kranj – pit at Trubarjev trg (*Dolinar 2016*), where typical pottery of Lasinja Culture appears together with this Lengyel type (*e.g., Velušček 2006; 2011; Kramberger*

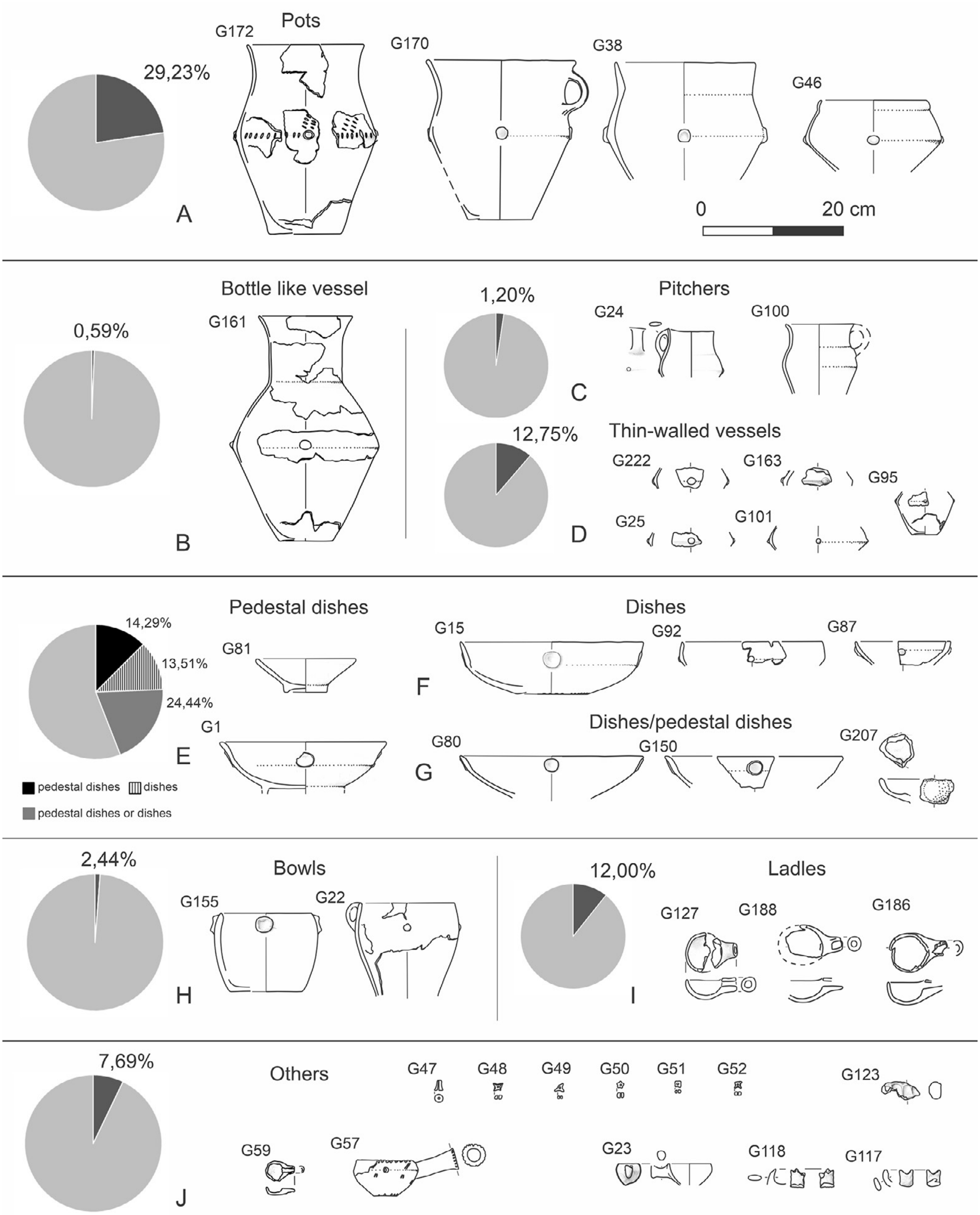

Fig. 8. Vessel shapes and their percentages within the typologically defined finds. Labels for the finds (*e.g., *G4...) are taken from the monographic publication of the site (*Kramberger in press, G1–G511*). Scale 1:8.

ger 2020). Pottery from Drulovka near Kranj, Ponikve near Trebnje and phases 4 and 5 in Moverna vas shows a similar decoration. Round appliqués do not appear on the largest circumference of the pots. The pots are decorated with regular bundles of incisions, often combined with impressions on the largest circumference and/or lip. The zig-zag incised decoration and the motif of horizontal incised lines are characteristic. All these motifs are also present at Ozalj – Stari grad (Fig. 1.19; *Težak-Gregl 2001; 2005*) in northern Croatia and at Spaha in Kočevsko region (Fig. 1.20; *Velušček 2011*). Small biconical vessels with a tubular attachment on the shoulder and a clay coating must also be mentioned as characteristic vessel type (see also

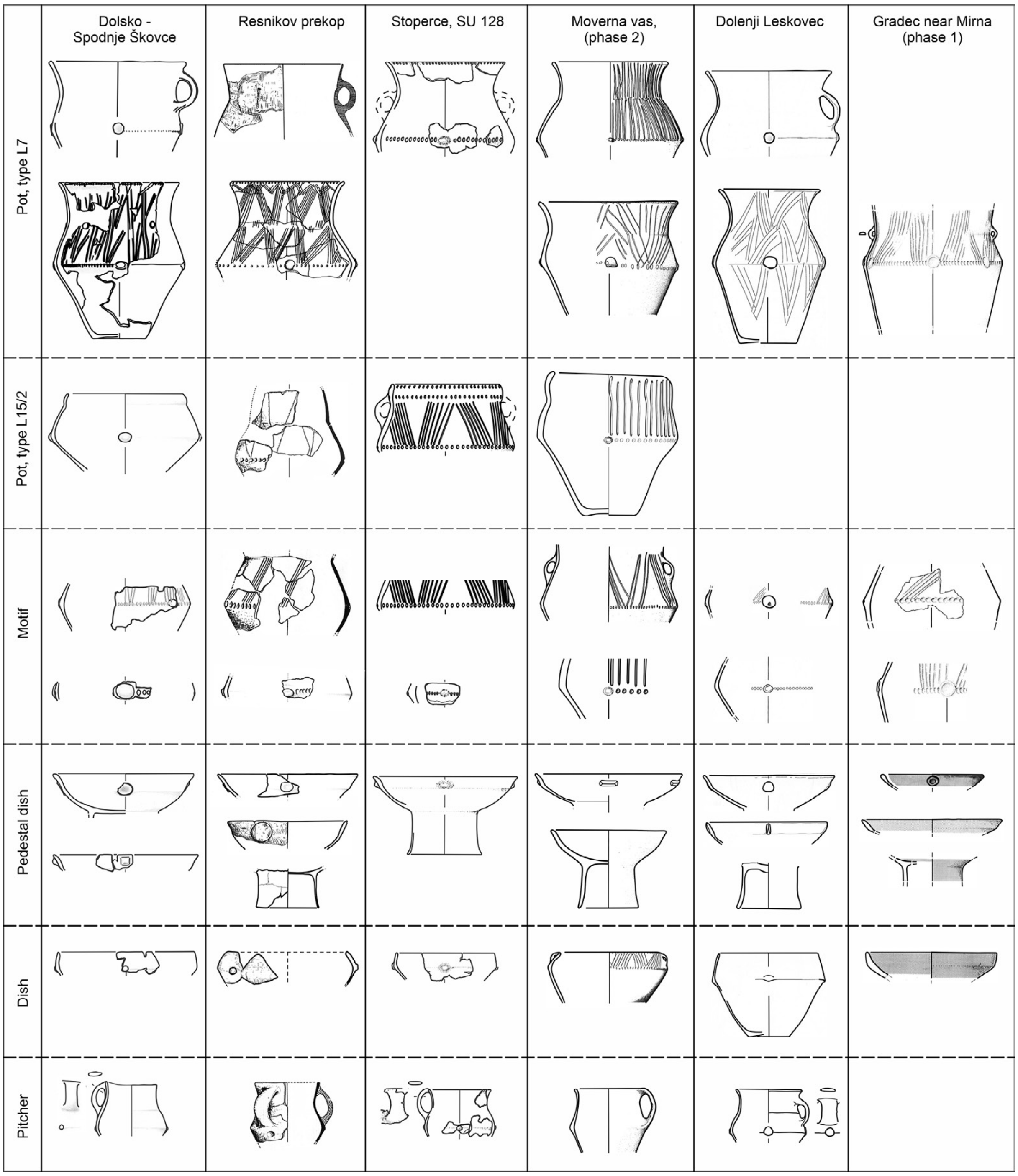

Fig. 9. Most important Late Neolithic pottery types at Dolsko – Spodnje Škovce and at sites Resnikov prekop, Stoperce (SU 128), Moverna vas (phase 2), Dolenji Leskovec, Gradec near Mirna (phase 1) representing Sava group Ib (after* Korošec 1964; Harej 1975; Budja 1995; Tomaž 1999; Dular *et al.* 1991; Hlad 2015; Kramberger 2020; Kramberger *et al.* 2023*). Not to scale.

here Fig. 14.15). They were found only at the sites of Ponikve near Trebnje (Fig. 1.10; *Ravnik, Tica 2018. find nos. 7,8,198,289,290,292*), Drulovka (Fig. 1.2; *Korošec 1960.Pl. 32: 5*), phases 4 and 5 of Moverna vas (Fig. 1.15; *Tomaž 1999.Pl. 21: 1; Pl. 26: 2*), and one in feature II at Ptuj – Šolski center in NE Slovenia (Fig. 1.23), where similar Late Neolithic pottery was found together with the Lasinja Culture ceramic forms (*Kramberger 2020.68–70, Fig. 6: 11*).

Overall, the pottery from Dolsko – Spodnje Škovce can be attributed to the Sava group, but with deviations in decoration compared to the nearby Dragomelj and Čatež – Sredno polje, and with significant differences compared to the pottery from Drulovka, Ponikve near Trebnje and phases 4 and 5 at Moverna vas. The pottery can be assigned to Sava group Ib according to the proposed terminology (*Kramberger 2020; cf. Tomaž 2022.151–152*).

Animal remains

The archaeozoological assemblage from Dolsko – Spodnje Škovce comprises 1645 animal remains from the Late Neolithic, Middle Copper Age, Late Bronze Age and Early Mediaeval periods (*Toškan in press*). The Late Neolithic material that is the subject of this study consists of several hundred tiny bone/tooth fragments (Fig. 10), most of which were recovered by wet sieving. Only 82 of these finds could be identified taxonomically, with tooth fragments clearly outnumbering bones ($NISP_{bones}$ = 3). This is not surprising considering that highly fragmented diaphyseal splinters are usually only identified at higher taxonomic levels or not at all (*cf. Morin* et al. *2017.921–923*; *McGrath* et al. *2019*). Cattle is by far the best represented species, with domestic pig, caprines and possibly wild boar being the remaining identified taxa (Tab. 1).

Bovine remains were all attributed to domestic cattle. This is due to the size of the better-preserved teeth and bone fragments, although the metrical separation between domestic cattle and aurochs is far from clear (*e.g., Wright, Viner-Daniels 2015*). Caprines are represented by two partially preserved teeth, neither of which allows a reliable differentiation between sheep and goat (*cf. Payne 1985*; *Zeder, Pilaar 2010*). In suines, the distinction between wild and domestic animals is probably the most complex. Apart from the question of interbreeding and/or feralization, studies combining genetics, geometric morphometrics and isotopic analysis show that large specimens traditionally assigned to wild boar may also contain feral individuals or domestic pig (*Evin* et al. *2015*; *Balasse* et al. *2016*; *Orton* et al. *2016*). Due to the highly fragmented nature of the archaeozoological material from Dolsko – Spodnje Škovce, no standard measurement data for suines could be collected. However, based on the general size of the best-preserved specimens, most have been tentatively assigned to domestic pig. A single fragmented lower second incisor may have come from a wild boar.

Most of the archaeozoological remains examined come from Pit 1 (Tab. 1). The vertical distribution of these finds in the pit is clearly uneven, with over 80% of them coming from the lowest fill SU 194 = 196 = 217. Interestingly, about 70% of these specimens are calcined, as evidenced by the predominantly white colour of the exposed surfaces, often in combination with heat-induced cracks (*Krap* et al. *2019.1–2*). Although specific sedimentological conditions (*e.g.,* well-drained, acidic, well-aerated soils) can also favour the rapid degradation of whole bones and teeth into small fragments (*Kendall* et al. *2018.12–13*), and sodium salts or carbonate-rich sediments can be responsible for white staining (*Dupras, Schultz 2013.323*), none of these factors contributed in any meaningful way to the taphonomic history of the archaeozoological material from Pit 1 in general, and SU 194 = 196 = 217 in particular. Having said that, a few specimens exhibit water-related abrasion, weathering or dark brown colou-

Fig. 10. Dolsko – Spodnje Škovce. A selection of highly fragmented, often calcined animal bones from Late Neolithic pit 1 (photo D. Valoh).

ration, the latter due to oxide staining in a waterlogged, anaerobic environment (*Stathopoulou* et al. *2019*).

The high proportion of calcined teeth and bones from SU 194 = 196 = 217 contrasts strikingly with the almost complete absence of such finds in other, similarly thick (Fig. 5.3) fills of the same pit (Tab. 1). This observation is even more remarkable as fill US 148, overlaying US 194 = 196 = 217, contained significantly more charcoal (up to 40% of the volume compared to <15% in SU 194 = 196 = 217 and <1% in the uppermost SU 113; *Kramberger in press*). No burnt/calcinated bones were found in any of the other features that yielded Late Neolithic archaeozoological material. Even unburned animal remains were only collected in pit 2 and paleochannel SU 218 (Tab. 1) (*Kramberger in press*).

Plant remains

Archaeobotanical analysis at Dolsko – Spodnje Škovce includes plant identification of seed/fruit remains and charcoal fragments. A stereomicroscope with up to 50x magnification, light microscope with up to 600x magnification, the reference collection of seeds, fruits, wood and charcoal at the Institute of Archaeology ZRC SAZU and specialized literature for seed/fruit and wood identification (*e.g., Berggren 1981; Schweingruber 1990; Anderberg 1994; Gale, Cutler 2000; Cappers* et al. *2006*) were used.

Among the archaeobotanical remains charcoal remains predominate. It was not always possible to identify them to the tree taxa level due to poor preservation. Charcoal was found in almost every sediment sample analysed (70 from all settlement phases). One to three randomly selected charcoal fragments per sample were analysed. In many cases, the charcoal fragments selected were from the same part (or piece) of wood, so there was no need to identify multiple fragments from the same sample. In several cases (32 samples) the species or even the genus of the taxa could not be determined due to poor preservation state, in these cases only DPW (diffuse porous wood), RPW (ring porous wood) or coniferous wood is indicated. Other plant macro-remains (*i.e.* seeds/fruits) were rarely found in the sediment samples from Dolsko. They were found in only 11 sediment samples: mostly (four) from the Copper Age, two from the Middle Ages and one from the Late Neolithic; other samples (four) were from unspecified contexts (*Tolar in press*).

In the sediments of the Late Neolithic contexts of the Dolsko site no macro-remains of cultivated or gathered plants were found. The only sample containing seed/fruit remains from the Late Neolithic is Flot. No. 34/1-4 (SU 194) with one non-carbonized seed of plantain (*Plantago lanceolata*) – most likely a contaminant, *i.e.* not archaeological (*Tolar in press*). Therefore, among the archaeobotanical remains from the Late Neolithic settlement, only charcoal remains are worth discussing (35 in total). The charcoal comes from different pits, most of them from pits 1 (28) and 2 (four). In general, species diversity is not high, with nine different tree taxa identified (Tab. 2). The identifications are dominated by oak (*Quercus* sp.; n = 12) and other ring-porous tree taxa (RPW; n=9; *i.e.* oak/ash (*Quercus* sp./*Fraxinus* sp.) or chestnut (*Castanea sativa*)). Conifers are identified in only three cases. They are probably represented by fir (*cf. Abies alba*) and pine (*cf. Pinus* sp.). Eleven charcoal fragments were identified as diffuse-porous tree taxa (DPW), among which *Cornus*, white hornbeam (*Carpinus betulus*) and maple (*Acer* sp.) are frequently identified (Tab. 2).

Feature	SU	*Bos taurus*	Caprinae	*Sus* cf. *domesticus*	Non-identified	Taphonomic observations
Pit 1	113	4 (4)				no traces of exposure to fire
	148	11 (11)	1 (1)		10++	two calcined fragments
	194 = 196 = 217	53 (50)	1 (1)	10 (10)	478 (6)	~70% of finds calcined
	190	2 (2)			2	no traces of exposure to fire
Pit 2	200	1			3	no traces of exposure to fire
Paleochannel	218				18	no traces of exposure to fire

Tab. 1. Dolsko – Spodnje Škovce. Late Neolithic animal remains per feature. The number of tooth fragments is given in brackets.

Results of radiocarbon dating

Six radiocarbon dates were obtained from the Late Neolithic settlement features at Dolsko – Spodnje Škovce as part of the research conducted as part of the rescue excavation project (see Acknowledgements). Five samples were radiocarbon dated in 2009 in the *Leibniz Laboratory for Radiometric Dating and Stable Isotope Research* in Kiel and one in the *Beta Analytic* Miami in 2021. All attempts to date collagen from animal bone were unsuccessful due to poor preservation of the collagen. In four cases, animal teeth, identified as *Bos taurus* from different fills of pit 1 (SUs 194, 196, 113, 148), from the bottom to the top, was dated. In addition, a charcoal sample of undetermined wood taxon from pit 1 (SU 194) and a charcoal sample from pit 2 (SU 200), identified as oak or chestnut (*Quercus* sp./*Castanea sativa*) were radiocarbon dated (Tab. 3). Charcoal samples were first examined under a microscope in laboratories to remove contaminants, then the appropriate amount of each charcoal sample was chemically treated (acid/alkali/acid) (*Grootes 2009b; Hatfield 2021*).

The dating of four teeth was based on enamel apatite (carbon from carbonate). The secondary calcite in the outer part of each individual tooth was removed. This was done by mechanically crushing the sample and dissolving it in HCl to a minimum of 28%. The remaining sample material was hydrolysed to CO_2 with 4ml of 60% phosphoric acid. To remove any sulphur compounds present, the CO_2 sample was placed in a quartz ampoule together with CuO and Ag wool, which was sealed and burned at 900°C for 4 hours. The resulting CO_2 sample was then converted to graphite with H_2 at 600°C using an iron catalyst, and finally the iron-graphite mixture was pressed into a tablet in the sample holder for AMS dating (*Grootes 2009a*).

The samples were then dated by AMS. The Conventional Radiocarbon Age was calculated using the Libby half-life (5568 years, *Stuiver, Polach 1977*), and this was then corrected for total isotopic fractionation. At the Leibniz Laboratory for Radiometric Dating and Stable Isotope Research the correction for isotopic fractionation was based on the $^{13}C/^{12}C$ ratio measured by AMS. These $\delta_{13}C$ values include isotope fractionation effects that occur during graphitization and in the AMS device and are therefore not directly comparable to $\delta_{13}C$ values measured in a CO_2 mass spectrometer. At Beta Analytic, these were measured separately in an IRMS (isotope ratio mass spectrometer), thus eliminating fractionation effects from natural, chemical and AMS induced sources. The radiocarbon age of the samples dated at Beta Analytic is rounded to the nearest 10 years and calculated sigmas less than 30 BP are conservatively rounded up to 30 (*Grootes 2009a; 2009b; Hatfield 2021*).

All samples contained more than the minimum recommended amount of carbon ^{14}C for accurate age determination. The earliest date was provided by a charcoal sample (*Quercus* sp./*Castanea sativa*) from pit 2. A charcoal sample from pit 1 yielded a later date, as did samples of enamel apatite from cattle teeth in pit 1. The apatite samples had $\delta_{13}C$ values typical of CO_2 apatite and showed very similar ages, which may support their reliability (*Grootes 2009a*): approx. 4500 and 4350 cal BC (95.4% probability).

Details of existing radiocarbon dates from Dolsko are listed in Table 3. Listed below are those from settlements associated with the most similar pottery (Sava group Ib) from the area of distribution of the Sava group as it was initially defined (*Guštin 2005*). These radiocarbon dates are compared in the following chapter with those of the Lengyel Culture, other dates from the Sava group in central Slovenia, dates from the subsequent Early Copper Age Lasinja Culture in the same area, and the radiocarbon sequence from Moverna vas in the Bela krajina.

Plant taxa	Amount of identified charcoal fragments
Quercus sp.	12
Quercus sp./*Castanea* sativa	3
Fraxinus sp.	1
Fraxinus/Castanea	1
RPW	4
Cornus sp.	4
Sorbus/Cornus	1
Acer sp.	1
Carpinis betulus	4
Coniferous; cf. *Abies alba*	2
Coniferous; cf. *Pinus* sp.	1
TOTAL	35 (28 pit 1; 4 pit 2; 3 SU 86; 1 SU 76; 1 SU 218)

***Tab. 2. Charcoal identifications (nos. of identified items) in Late Neolithic contexts at the site Dolsko – Spodnje Škovce (sum: 35 wood-anatomical identifications; items). For the results of plant macro-remain analyses for other periods at Dolsko – Spodnje Škovce site see* Tolar in press.**

Comparative analysis and evaluation of results in a regional and supra-regional context

Large pits filled with deposits containing ceramic fragments, stone implements, charcoal, animal remains and other finds showing evidence of human occupation have been found at various prehistoric sites and are also characteristic of 5th millennium BC settlements in central and south-eastern Europe (*e.g., Palečková 2008; Šavel, Karo 2012; Minichreiter, Marković 2013; Sava 2015; Barna 2017; Barna* et al. *2019; Tomaž 2022*). Two such pits found in the Late Neolithic settlement at Dolsko – Spodnje Škovce have been studied in terms of the archaeological excavation results, distribution of finds, technological and typological aspects of pottery, taxonomy of animal and plant

LAB number	Site	Material	Context	Age (BP)	$\delta^{13}C$ (‰)	PMC corrected*	Cal BC (68.3%)	Cal BC (95.4%)
KIA37347	Dolsko – Spodnje Škovce	Charcoal (*Quercus sp./Castanea sativa*)	Pit 2, SU 200	5837±32	-26.29±0.28	48.35±0.19	4770-4620	4788-4608
Beta-591316	Dolsko – Spodnje Škovce	Charcoal (n/a)	Pit 1, SU 194	5690±30	-28.9 o/oo	/	4547-4458	4609-4450
KIA37351	Dolsko – Spodnje Škovce	Tooth (enamel apatite, *Bos taurus*)	Pit 1, SU 194	5587±35	-13.36±0.23	49.88±0.22	4452-4369	4488-4352
KIA37350	Dolsko – Spodnje Škovce	Tooth (enamel apatite, *Bos taurus*)	Pit 1, SU 113	5602±32	-13.25±0.34	49.79±0.20	4459-4370	4493-4358
KIA37346	Dolsko – Spodnje Škovce	Tooth (enamel apatite, *Bos taurus*)	Pit 1, SU 148	5612±30	-11.49±0.22	49.73±0.18	4486-4371	4500-4360
KIA37349	Dolsko – Spodnje Škovce	Tooth (enamel apatite, *Bos taurus*)	Pit 1, SU 196	5563±30	-14.00±0.39	50.03±0.19	4446-4360	4454-4350
Poz-72746	Gradec near Mirna	Animal bone (n/a)	Phase 1, »below wall rubble« (assemblage 1)	5540±40	-24.00±0.5	/	4443-4345	4445-4331
Poz-72747	Gradec near Mirna	Bone (heel bone, *Bos taurus*)	Phase 1, »below wall rubble« (assemblage 2)	5570±40	-21.4±0.2	/	4445-4358	4491-4342
Poz-72751	Gradec near Mirna	Bone (mandible, *Bos taurus*)	Phase 1, »in the layer behind the wall« ((assemblage 3?)	5580±40	-26.1±1.2	/	4447-4363	4493-4345
Poz-66248	Dolenji Leskovec	Charred seed (*Cratageus* sp.)	Pit 3 (SU 1099)	5680±40	-25.9±0.1	/	4546-4454	4656-4371
Poz-66249	Dolenji Leskovec	Charred residues (pot; n/a)	Pit 3 (SU 1099)	5680±40	-27.8±0.1	/	4546-4454	4656-4371
Poz-66250	Dolenji Leskovec	Charcoal (n/a)	Pit 3 (SU 1099)	5880±35	-27.0±0.2	/	4790-4716	4841-4625
Beta-339594	Stoperce	Charcoal (n/a)	Pit SU 128	5690±30	-25.4 o/oo	/	4547-4458	4609-4450
Hd-24038	Resnikov prekop	Wood (*Alnus glutinosa*)	Pile with 10 rings	5718±23	/	/	4603-4501	4673-4459

Tab 3. List of ^{14}C AMS dated samples from Late Neolithic features at Dolsko – Spodnje Škovce and other sites with pottery of Sava group Ib (after **Velušček 2006; Sraka 2016; 2020; Kramberger 2014*****) in its distribution as defined (*****Guštin 2005; Tomaž 2022*****). The list does not include data affected by the possible hard water effect from Resnikov Prekop (*****Mlekuž et al. 2013*****). * "PMC corrected" refers to the percentage of modern (1950) carbon, corrected for mass fractionation by ^{13}C measurement. Samples were calibrated using OxCal v4.4 (*****Bronk Ramsey 2009*****) and the IntCal 20 calibration curve (*****Reimer et al. 2022*****).***

remains and radiocarbon measurements. The following section summarizes the results of comparing this data with that available from settlements of the 5th millennium BC in Slovenia and neighbouring regions.

The use of large pits of irregular plan

The largest pit at Dolsko – Spodnje Škovce (pit 1) did not yield any architectural elements, it was irregular in shape and filled with different layers in which ceramic fragments, bones, burnt clay, stone tools, implements and charcoal fragments were scattered. It was observed that fragments of individual vessels were distributed over an area of up to 4.5m, partly in fills in different stratigraphic positions. The distribution of fragments of certain vessels in different fills from the bottom to the top of pit 1 may to some extent be the result of post-depositional processes, partly it may reflect the accuracy of the excavation, but given the large number of such cases it seems likely that it is largely the result of the deposition process. It probably indicates that individual vessels were broken prior to deposition and that they came in the pit as fragments with different fills, together with charcoal, animal remains and stone implements.

The large amount and concentration of finds and two charcoal clusters suggest that pit 1 was probably filled by people, but some of the material may have been deposited naturally. This is indicated by the distribution of individual pot fragments found in pit 2 (SU 200) and pit 1 (SU 148). It can be assumed that a layer with Neolithic pottery running from northwest to southeast across pits 1 and 2 (Fig. 3.202,75) and consistent with the direction and orientation of the alluvial sediment in which the two pits were dug (Figs. 3.21 and 4), is related to this post-depositional process (*cf.* Fig. 2.4).

The situation where parts of a single vessel are distributed in different pits is not unique. In the Early Copper Age settlement at Zgornje Radvanje, parts of individual vessels were also distributed in different pits in several cases. One of the most significant examples is the distribution of ceramic fragments of a pot found in large pits 5 and 2 (*Kramberger 2021.342–343, find no. 235*). Alluvium and paleochannels were discovered above both pits, which may indicate that the upper parts of the pot were deposited by water from feature 5 to feature 2 (*Kramberger 2021.24–25, 149,137–139, Figs. 22,23,41a-b*).

Paleochannels found during the excavations at Dolsko with finds from different periods indicate the destruction of the archaeological record in the vicinity (Fig. 2.4). Similar phenomena can be observed at many other sites in Slovenia. In the Late Neolithic settlement of Dolenji Leskovec, for example, the Sava River completely washed away a part of the settlement, which was surrounded by two circular palisades (*Jovanović* et al. *2012.App. 7*). No post holes of possible houses could be identified in the area surrounded by ditches, only a few pits of irregular ground plan. Furthermore, at Dragomelj it was observed that the surface of less than half of the Late Neolithic ceramics was partially preserved, while the rest of the pottery had a completely destroyed surface (*Turk, Svetličič 2005.68; 2022. 37–38*). Redepositions of material are indicated by the finds from younger periods in the Late Neolithic pits and the results of radiocarbon dating (*e.g., Turk, Svetličič 2022.168,184–185, SU 402*). All these examples show that when interpreting large irregularly shaped pits and Late Neolithic settlements as a whole, we must consider site losses related not only to destruction during modern agriculture (*e.g., Guštin* et al. *2005.104; cf. Osztás* et al. *2012.386*), but also to post-depositional processes such as water, erosion and other sediment movements caused by natural factors.

Looking at the location of the sites where large, irregularly shaped pits were found, it can be concluded that they did not occur in the lakeside settlements, like Resnikov prekop and Verd (*Velušček 2006; Velušček* et al. *2023*). They are more widespread phenomenon of the Late Neolithic in the Carpathian Basin, south-eastern Alpine region and Northern Croatia, in regions with dry lands with thick layers of loam. The two larger pits at Dolsko were found on a clayey-loamy geological base (Fig. 4.21), which spread in a line from northwest to southeast over alluvial deposits of Sava gravel (Fig. 4.45; see also Fig. 3). Furthermore, it should be emphasized that the phenomenon of large irregularly shaped pits in Late Neolithic settlements represents a kind of change in comparison to Central European LBK settlements. Linear ditches next to the long houses, which were dug in the LBK settlements for the extraction of clay material (*e.g., Oross 2010; Oross, Bánffy 2009; Hofmann 2013; Bánffy 2013.131–137; Bickle 2013. 155–162, Fig. 7.2*), were almost completely (*e.g., Barna 2017.83–84, Fig. 16*) replaced by large pits in the Late Neolithic settlements.

Large-scale excavations over the last 25 years have uncovered many above-ground, timber-framed houses in Late Neolithic settlements in the Carpathian Basin, which required a reassessment of earlier theories. It became clear that large pits, previously interpreted as residential buildings, were temporary shelters or features used for a variety of activities (*Pávuk 2003.464; Raczky 2005.24; Osztás* et al. *2012.385; Barna* et al. *2019.126–128*). In most settlements, large pits of irregular ground plan were found near houses (*e.g.,* Fig. 11.A), and at Alsólnyék-Bátaszék, one of the largest Lengyel settlements in Transdanubia with more than 100 houses uncovered, some large pits extended along the edges of buildings, and these can in all probability be associated with these (*Bánffy* et al. *2016; Osztás* et al. *2016.192–196*). They were probably used to extract the clayey loam needed for construction, and later filled with household waste (*Osztás* et al. *2012.390, Fig. 12;* see also *Barna* et al. *2019.125*). In many settlements, rectangular houses and irregular large pits appear inside circular ditches, representing traces of defensive enclosures (Fig. 11.B,D), similar to those at Dolenji Leskovec (Fig. 1.12), where only two large pits and three smaller ones have survived in an area of 56x46m surrounded by ditches (*Jovanović* et al. *2012.App. 7*). However, in many other settlements the remains of palisades are not found, which may mean that they did not exist, or may be due to the state of research at individual sites. Such cases have been found in Transdanubia as well as in the neighbouring Croatia, in the Late Neolithic settlements attributed to the Sopot culture (Fig. 11.C). All these cases of better researched and preserved settlements with above-ground, timber-framed houses and large, irregularly shaped pits in their vicinity show that the latter were most likely not the remains of houses.

Pottery style(s) of the Late Neolithic Sava group

Analyses of the technological aspects of pottery production have been conducted at several Late Neolithic sites in Slovenia using the same analytical approach as at Dolsko (*Horvat 1999*), but the results have not been compared and evaluated since the recognition of the Sava group (*Guštin 2005*). These are Resnikov prekop (*Tomaž 1999.76–87; Tomaž, Velušček 2005.87–99*), Dragomelj (*Turk, Svetličič 2005; 2022.36–39*), Čatež – Sredno polje (*Tomaž 2005.113–129; 2022.62–73*) and Dolenji Leskovec (*Hlad 2015.15–29*), which were attributed to the Sava group of the Lengyel Culture (*Guštin 2005*), Moverna vas in the Bela krajina region (*Tomaž 1997; 1999.76–8*), Stoperce in Haloze (*Kramberger 2014.244–247; Kramberger* et al. *2023*) and Andrenci in northeastern Slovenia (*Kramberger 2014.244–247*), whose material culture has been attributed to the Late Lengyel Culture (*Bánffy 2002; Velušček 2006.33; Kavur 2010; Kramberger 2014*). The site Col 1 near Podgračeno was the first to be attributed to the Sava group (*Guštin 2005.8*) and the pottery found there was analysed using the same analytical approach. However, according to the excavator the pottery is later, contemporary with the pottery from SUs 43-44 in Ajdovska jama cemetery, Zgornje Radvanje and partly Ptuj–Šolski center (*Horvat 2005; 2020.120–121, Fig. 75, 59–62*), and a radiocarbon measurement also provided a later age (*Guštin 2005. Fig. 3; cf. Kramberger 2014; 2020; 2021*).

A comparison of pottery production methods between the above-mentioned sites has shown that the pottery from Dolsko – Spodnje Škovce differs significantly from the definition of the Sava group (*Guštin 2005.9–12*). The proportions of granularity groups, with the predominance of very fine (43%) and fine (36%) fabrics, contradict the definition in the first place, as it has been stated that the pottery of the Sava group was mainly made of medium-grained fabrics (Fig. 7.1). Similar proportions of granularity groups are found at Dolenji Leskovec, 50% of very fine-grained fabrics, 35.71% of fine grained and 14.28% of medium grained fabrics (*Hlad 2015.Fig. 19*). At the Late Lengyel site of Andrenci very fine grained pottery prevails (83%), at Stoperce – SU 128 very fine grained (42%) and fine-grained pottery (58%) were found in similar proportions (*Kramberger 2014.Fig. 27*). All other sites of the Sava group (*Tomaž, Velušček 2005.Fig. 1; Turk, Svetličič 2022.Fig. 46; Tomaž 2022.Fig. 42*) and phases 2, 4 and 5 of Moverna vas (*Tomaž 1997.Tab. 4*) yielded mostly medium grained pottery (see also Fig. 1).

The pottery from the Bela krajina region should have been coated with coloured clay slip significantly more often than that from the Sava group and from northeastern Slovenia (*Guštin 2005.20*). However, the pottery from Dolsko (27%) is more often coated with clay slip than the pottery from phases 2 (23.9%), 4 (22%) and 5 (12.3%) of Moverna vas (*Tomaž 1997.Tab. 7*). Very similar proportions of pottery with colour clay slip are also found at Dolenji Leskovec near the Sava in Posavje (29.03%; *Hlad 2015.21*) and SU 128 at Stoperce, in Haloze, northeastern Slovenia (32%; *Kramberger 2014.Fig. 29*). Only in the pottery from Dragomelj (*Turk, Svetličič 2005.68*), Čatež – Sredno polje (*Tomaž 2022.Fig. 45*), Andrenci (3%; *Kramberger 2014.Fig. 29*) and Resnikov prekop in the wetlands of the Ljubljansko barje (2.1%; *Tomaž, Velušček 2005. Fig. 3*) was colour clay slip rarely present (see also Fig. 1).

According to the definition, the pottery from the Sava group sites is mostly decorated with impressions, the rest with appliqués and incised decoration, which should be different from the pottery from northeastern Slovenia (predominant appliqués) and the Bela krajina region (predominant incised decoration) (*Guštin 2005.9–12;* see also Fig 1). In order to test this theory, we compared all sites with the available statistical data on decoration, and also conducted an analysis of published Late Neolithic finds from the sites of Drulovka near Kranj (*Korošec 1960.Pl. 9.1– Pl. 34.10; see also Guštin et al. 2005.43–47*), Ponikve near Trebnje (*Ravnik, Tica 2018.finds nos. 1–810*), Resnikov prekop (*Korošec 1964.Pls. 3–18; Harej 1975.Pls. 1–7;*

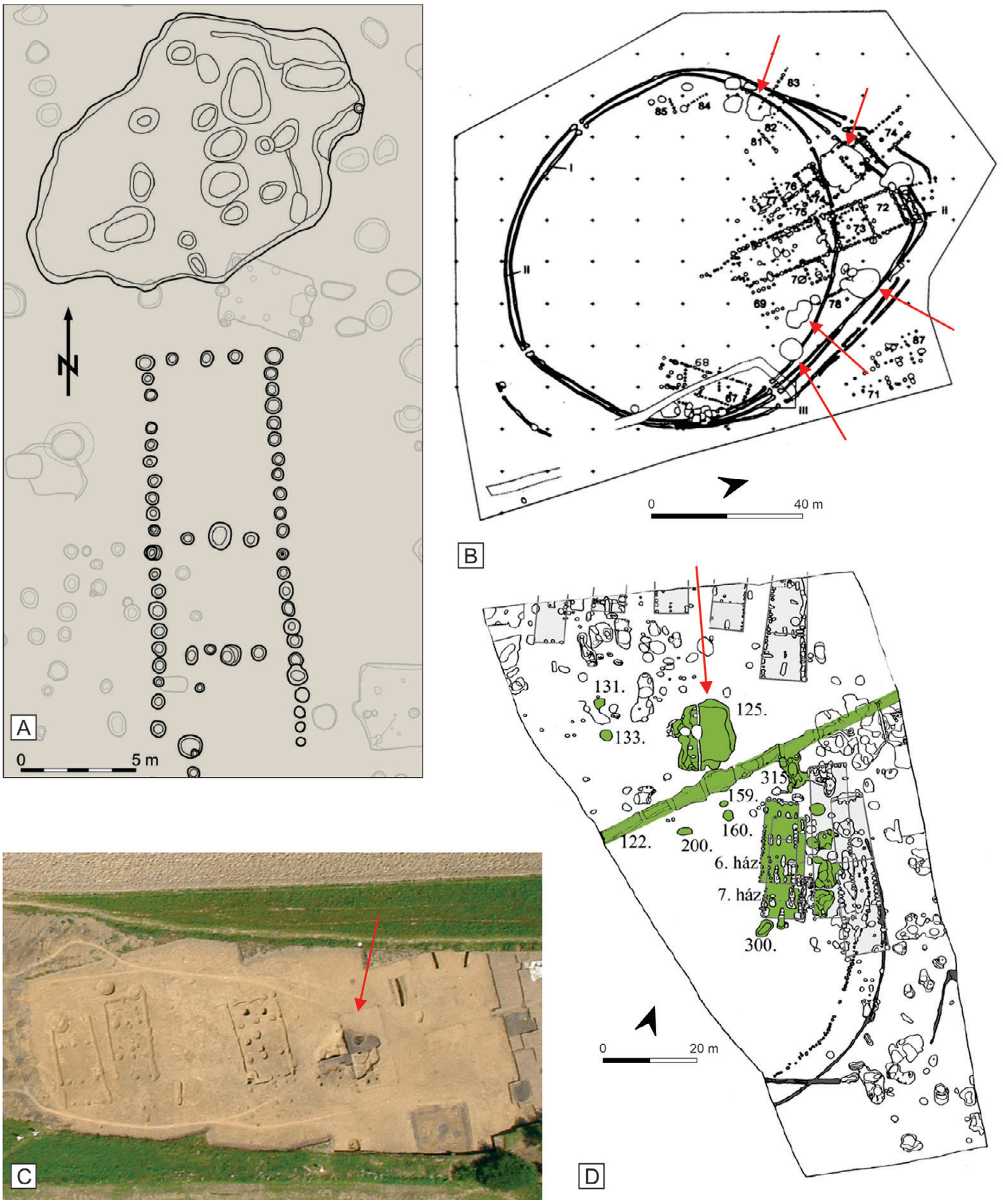

Fig. 11. Examples of above-ground rectangular houses and large pits in their vicinity at the Late Neolithic settlements of Lengyel and Sopot cultures.* A *Alsólnyék-Bátaszék (*Osztás *et al.* 2012.Fig. 6*),* B *Žlkovce (*Pávuk 1981*),* C *Kruševica – Njivice (*Balen, Čataj 2014*),* D *Veszprem – Jutasi út (*Regenye, Biró 2019.Fig. 1*).

Velušček 2006.Pls. 1–19), Dragomelj (*Turk* et al. *2022. finds nos. 1–447*), Late Neolithic finds from Moverna vas (*Tomaž 1999.Pls. 1–32*) and Bukovnica (*Šavel 1992.Pl. 1–6*) in northeastern Slovenia. It can be concluded that only at the sites of Dragomelj (62% and 9%; *Turk, Svetličič 2022.Fig. 54*) and Čatež – Sredno polje (68% and 13%; *Tomaž 2022.Fig. 34*) are impression and a combination of impressions and appliqués dominant as decoration techniques. At Dolsko, applied decoration predominates (62%; Fig. 7.3), similarly at the Late Lengyel settlements at Andrenci (80%; *Kramberger 2014.Fig. 31*) and Bukovnica (86%; *Šavel 1992*), and the Sava group site at Dolenji Leskovec (50%; *Hlad 2015.Fig. 31*) (for all of these see Fig. 12).

In the earliest phase of Moverna vas (phase 2) most ornaments on the pottery were made with a combination of impressions and incisions (37%), followed by applied decoration (30%) and impressions (20%), with the rest being decorated with incisions and other combinations. This was probably used to support the statement that most of the pottery at the sites in the Bela krajina region was decorated with incised decoration and a combination of incisions and impressions (*Guštin 2005.13; cf. Tomaž 1997; 1999*). However, at Resnikov Prekop (Fig. 12.4) and SU 128 in Stoperce (Fig. 12.9) the proportions of pottery decorated with incisions and impressions, and with applied decoration and impressions, are more similar to those from phase 2 at Moverna vas (Fig. 12.8) than to those at Dragomelj (Fig. 12.2) and Čatež – Sredno polje (Fig. 12.7). Moreover, if we consider the sites of Drulovka (Fig. 12.3), Ponikve near Trebnje (Fig. 12.5) and later phases of Moverna vas (phases 4 and 5; Fig. 12.8), we can notice that the pottery found there has a very similar proportion of individual decoration techniques as in phase 2 at Moverna vas, with incisions and a combination of incisions and impressions significantly predominant. Specifically, at Drulovka 36% of the pottery is decorated with incisions and impressions, 33% with incisions, 20% with impressions, only 5% with applied decoration and impressions, 4% with applied decoration and 2% with other combinations. At Ponikve near Trebnje 43% of the pottery is decorated with incisions and impressions, 41% with incisions, 16% with impressions and not a single fragment with applied decoration. Moreover, in phases 4 and 5 of Moverna vas the pottery was decorated with the same decoration techniques with some deviations in proportions: 69% with incisions and impressions, 17% with incisions, 14% with impressions and not a single fragment with applied decoration (for all of these see Fig. 12).

The analysis showed that the most common vessel type at Dolsko was a pot with an everted neck that is approximately the same length as the shoulders, decorated with appliqués (Fig. 6.G33, G34, G36, G38; Fig. 8.G170, G38; Fig. 13.1). A comparison of the proportions of types of pots at Late Neolithic sites in Slovenia (*Kramberger 2014; 2020*) shows that pots with a cylindrical neck dominate at only three sites (Fig. 13.d) – these are, again, Drulovka (65%; *e.g., Korošec 1960. Pls. 11.1, 19.1, 22.1,6,9*; Fig. 13.3), Ponikve near Trebnje (52%; *e.g., Ravnik, Tica 2018.finds nos. 1,178,181*; Fig. 13.5) and phases 4 and 5 (69%) at Moverna vas (*e.g., Tomaž 1999.Pls. 22.1–3, 24.1*; Fig. 13.8). At all other Late Neolithic sites pots with everted necks – similar to those at Dolsko – dominate (Fig. 13.a). At Resnikov prekop pots with cylindrical neck represent 10% of all pots (*e.g., Korošec 1964.Pl. 16.3; Harej 1975.Pl. 7.12*; Fig. 13.4), 2% at Čatež – Sredno polje (*e.g., Tomaž 2022. finds nos. 1758,1760*; Fig. 13.7), and at other sites no pots were found which could be described as having cylindrical necks (Fig. 13.d).

Pots with everted necks dominate at Dolsko – Spodnje Škovce (90%), followed by Čatež – Sredno polje (73%; *e.g., Tomaž 2022.finds nos. 251-253,1331*), Resnikov prekop (76%; *e.g., Korošec 1964.Pl. 5.5, Pl. 15.1. 3*), phase 2 at Moverna vas (65%; *e.g., Tomaž 1999.Pl. 11.1–2, 13.1*) and Dolenji Leskovec (63%; *e.g., Hlad 2015.finds nos. 16,17,19,20,23*). Fragments of everted neck of pots are rarely present at Drulovka (18%), Ponikve near Trebnje (24%) and in phases 4 and 5 at Moverna vas (25%). As it can be argued from the published material, they all belong to pots with short necks (*e.g., Tomaž 1999.Pl. 21.3, 23.1–2, 26.3; Korošec 1960.Pl. 10.1, 15.7, 19.6; Ravnik, Tica 2018.finds nos. 176–177,180,624,692*), which are rare or not present in other sites (Fig. 13.a).

In addition to pots with everted necks, a pot with a long sloping neck (5%; Fig. 13.b) and a pot with a short ellipsoid neck (5%; Fig. 13.c) were found at Dolsko – Spodnje Škovce (Fig. 13.1). Pots with a long sloping neck are also present at Dolenji Leskovec (26%; *e.g., Hlad 2015.finds nos. 4–6*; Fig. 13.6), Čatež – Sredno polje (21%; *e.g., Tomaž 2022.finds nos. 1329,759*; Fig. 13.7), Resnikov prekop (7%; *e.g., Harej 1975.Pl. 1.1*; Fig. 13.4), in the earliest (6%; *Tomaž 1999.Pl. 10.1*), as well as later (6%; *Tomaž 1999.Pl. 21.2*) Neolithic phases at Moverna vas (Fig. 13.8). Some pots with ellipsoid necks can also be found at Resnikov prekop (2%; *Harej 1975.Pl. 6.6*; Fig. 13.4), the earliest phase at Moverna vas (12%; *e.g., Tomaž 1999.Pl. 11.3*; Fig. 13.8)

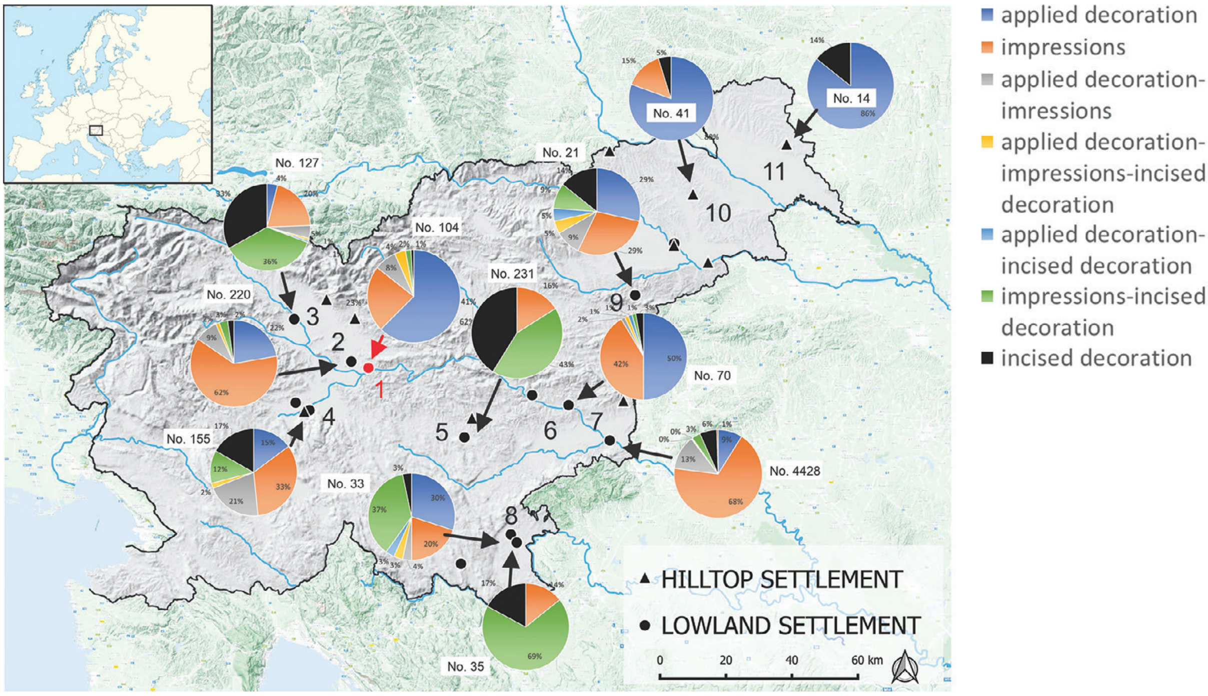

Fig. 12. Percentages of different decoration techniques in Late Neolithic settlements in Slovenia. Only sites with at least 50 typologically defined pottery fragments are included.* 1 *Dolsko – Spodnje Škovce,* 2 *Dragomelj,* 3 *Drulovka near Kranj (Late Neolithic finds),* 4 *Resnikov prekop,* 5 *Ponikve near Trebnje,* 6 *Dolenji Leskovec,* 7 *Čatež – Sredno polje,* 8 *Moverna vas (left phase 2, right phases 4 and 5),* 9 *Stoperce (SU 128),* 10 *Andrenci,* 11 *Bukovnica (Late Neolithic pit). The data from Dolsko – Spodnje Škovce are presented for the first time in this publication (Fig. 7) and are the result of the author's analysis. Data from Čatež – Sredne polje (*Tomaž 2022. Fig. 34*), Dolenji Leskovec (*Hlad 2015.Fig. 31*), Stoperce (SU 128) and Andrenci (*Kramberger 2014.Fig. 31*) are taken from the literature. Comprehensive analysis of finds from the Late Neolithic pile-dwelling at Resnikov prekop (*Korošec 1964.Pls. 3–18; Harej 1975.Pls. 1–7; Velušček 2006.Pls. 1–19*), Ponikve near Trebnje (*Ravnik, Tica 2018.finds nos. 1–810*), Drulovka (*Korošec 1960.Pls. 9–34*), Dragomelj (*Turk *et al.* 2022.finds nos. 1–447*), Late Neolithic finds from Bukovnica (*Šavel 1992*) and Moverna vas (*Tomaž 1999.Pls. 1–32*) were conducted by the author based on the published material.

and, as fragments, at Drulovka (4%; *Korošec 1965.Pl. 20.3*; Fig. 13.3) and Ponikve near Trebnje (5%; *Ravnik, Tica 2018.find no. 625*; Fig. 13.5). Much the same is true for pots without a neck (Fig. 13.f). They sparsely appear, in different variations, at the sites Čatež – Sredno polje (4%; *e.g., Tomaž 2022.find no. 1732*; Fig. 13.7), phase 2 at Moverna vas (17%; *e.g., Tomaž 1999. Pl. 7.1–2*; Fig. 13.8), Dolenji Leskovec (11%; *e.g., Hlad 2015.Pl. 1.3*; Fig. 13.6), Resnikov prekop (5%; *Harej 1975.Pl. 2.6*; Fig. 13.4) and Ponikve near Trebnje (10%; *e.g., Ravnik, Tica 2018.finds nos. 197–198*; Fig. 13.5). Pots with shoulders and sloping necks (Fig. 13.e) were identified only at Drulovka (13%; *Korošec 1960.Pl. 10.2*; Fig. 13.3) and Ponikve near Trebnje (9%; *Ravnik, Tica 2018.finds nos. 2, 179*; Fig. 13.5).

Overall, based on the results presented here, the sites in Bela krajina do not differ from the sites in Posavje, Savska ravan and Ljubljansko barje, either in terms of pottery production, decoration or ceramic forms, as has been suggested. On the contrary, a similar technology of pottery production was spread and used in Late Neolithic settlements throughout the southeastern Alpine region and northeastern Dinaric Carst, from Kranj in northwestern Slovenia, Bela krajina in southeastern Slovenia, to Stoperce in northeastern Slovenia, with some variations. The presence of coloured clay slip varies considerably from site to site, which may be largely due to local conditions, the characteristics of the soils in which the pottery is found, and taphonomic site loss. However, at Dolsko – Spodnje Škovce (Fig. 1.1) similar conditions could be assumed as at the neighbouring settlement at Dragomelj (Fig. 1.5; see also Fig. 2.1), yet there is still much more pottery with coloured slip at Dolsko. On this basis it cannot be excluded that the presence of coloured slip is to some extent related to the cultural variations within the pottery style, although not in the way that has been proposed (*Guštin 2005.13*). Similar proportions of coloured clay slip as at Dolsko – Spodnje Škovce are known from the phase 2 at Moverna vas, Dolenji Leskovec (southeastern Slovenia), and SU 128 in Stoperce (northeastern Slovenia). These are the sites which together with Resnikov prekop and Gradec near Mirna (phase 1) yielded the most similar vessel types and ornaments and were therefore attributed to the same variation of the style – Sava group Ib (Figs. 9, 14). Another variation of the pottery style is represented at Dragomelj and Čatež – Sredno polje (Sava group Ia; Fig. 1.5,14) and the third at Drulovka, Ponikve near Trebnje, phases 4 and 5 at Moverna vas and similar sites (Sava group II; Fig. 1.2,10,15; Fig. 14) (for all see also *Kramberger 2020*).

Absolute chronology

As mentioned above, the absolute dating of the Late Neolithic in Slovenia is based on charcoal samples and on samples of charred organic residues on the pottery. This is also due to the rare finds of charred seeds/fruits, missing human graves and often poor preservation of collagen in animal bones (*cf. Stadler, Ruttkay 2007; Oross* et al. *2010; Ilon 2004; Bánffy* et al. *2016; Regenye* et al. *2022*). The old wood effect is a common phenomenon (*e.g., Whittle 1990; Brock* et al. *2010; Nowak* et al. *2017.189*), but in the case of Slovenian sites it is difficult to assess its influence on the results of radiocarbon measurements, as tree species are rarely determined prior to dating and control dates are not available. In the case of Resnikov prekop in the wetlands of Ljubljansko barje, the dating of charred remains on pottery also proved problematic, with a large number of measurements yielding significantly older dates than expected (*Mlekuž* et al. *2013*).

As collagen leached from the dentine, four radiocarbon measurements on apatite from samples of cattle teeth from Dolsko – Spodnje Škovce were introduced in the present study. Carbonate exchange takes place between the apatite and burial environment, so pre-treatment is required, but as a comparison of 155 samples from more than 100 sites worldwide has shown, pretreatment is often inadequate (*Zazzo 2014*). This also applies to enamel, which has long been considered a more reliable dating material than bone apatite beca-

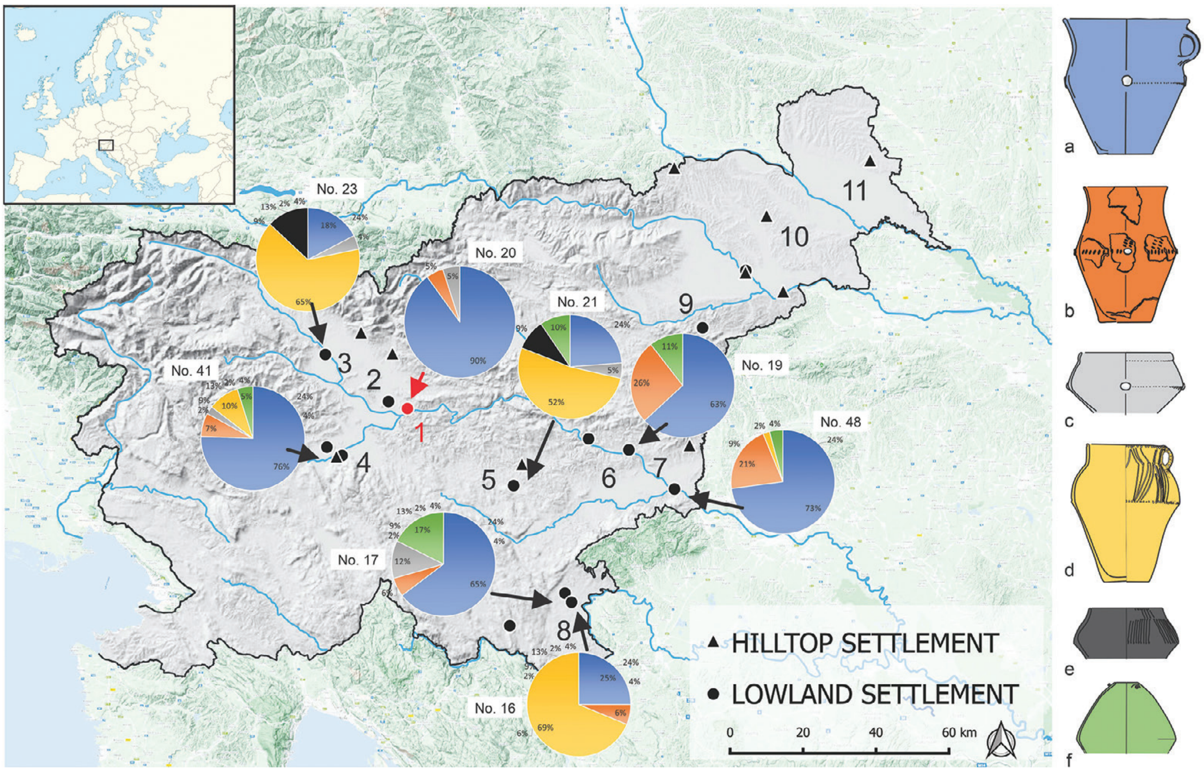

Fig. 13. Percentages of different types of pots in Late Neolithic settlements in Slovenia. Only sites with at least 15 definable pots are included.* 1 *Dolsko – Spodnje Škovce,* 2 *Dragomelj,* 3 *Drulovka near Kranj,* 4 *Resnikov prekop,* 5 *Ponikve near Trebnje,* 6 *Dolenji Leskovec,* 7 *Čatež – Sredno polje,* 8 *Moverna vas (left phase 2, right phases 4 and 5). All data were calculated from the finds published in the publications of individual sites (*Kramberger in press; Turk *et al.* 2022.finds nos. 1–447; Korošec 1960.Pls. 9–34; 1964.Pls. 3–18; Harej 1975. Pls. 1–7; Velušček 2006.Pls. 1–19; Ravnik, Tica 2018.finds nos. 1–810; Hlad 2015.finds nos. 1–248; Tomaž 2022. finds nos. 1–3522; 1999.Pls. 1–32*). The typological classification was based on the authors' typology (*Kramberger 2014; 2020*).

use of its lower porosity, smaller surface area, larger crystallites, and lower solubility due to its lower carbonate content (*Hedges* et al. *1995; Wood* et al. *2016.*).

Mechanical grinding can significantly increase the amount of carbonate contamination removed in an acid leach compared to hand grinding, although in many cases not all contamination is likely to be removed (*Wood* et al. *2016*). Within the mid-late Holocene, this level of contamination has resulted in radiocarbon age estimates within approximately 100 ^{14}C years of the true sample age, but sometimes more. A recent study suggests that decontamination of younger samples may be possible if higher concentrations of hydrochloric acid solution are used in the chemical pretreatment (*Hopkins* et al. *2016*). Samples of modern equine incisors, a Roman cattle molar, and a Palaeolithic rhino molar were taken and pretreated with different acid solutions, dated at the Oxford Radiocarbon Accelerator Unit (ORAU), and compared with control dated dentine collagen from the same individuals. Such control dates are not available from Dolsko – Spodnje Škovce. The only other radiocarbon date available from pit 1 is a charcoal sample from an unknown tree species. Consequently, despite radiocarbon dates of enamel apatite from different samples of cattle teeth from pit 1 overlap, they should be treated with caution. They can be understood as a minimum age for the cattle, while both charcoal samples (from pits 1 and 2) can be taken as a maximum age for tree felling (Tab. 3).

Among the sites with the most similar pottery finds, radiocarbon dates are available from Moverna vas, Dolenji Leskovec, Resnikov prekop, Stoperce – SU 128 and Gradec near Mirna (see Tab. 3, *cf.* Figs. 1, 9). Of particular importance are the dates from Gradec near Mirna, where samples of animal bones (*Cervus elaphus, Bos taurus, Sus* sp. and two samples of undefined animal species) were radiocarbon dated. According to Marko Sraka (*oral information*) collagen was dated and δ^{13}C values measured by AMS range from –21.05±0.5 to –28.07±02.

A total of ten samples were measured from the multiperiod settlement of Gradec near Mirna (*Dular* et al. *1991; Dular 2001*), six from the occupation layers of the Sava group, two from the Lasinja Culture oven above the Late Neolithic layer and two from the highest settlement layer attributed to the Furchenstich horizon (*Sraka 2020*). The results of the radiocarbon dating indicated that the samples collected as belonging to the lowest settlement layer were most likely from two different chronological phases, the Late Neolithic and the Lasinja Culture, indicating that the material from the lowest cultural layer may be partially mixed. Nevertheless, three radiocarbon dates from this layer (Gradec phase 1) can be recognized as older than the radiocarbon measurements from the layer above it (Gradec phase 2 – Lasinja Culture), which is in agreement with published pottery assemblages (*Dular* et al. *1991; Dular 2001*) (Tab. 3).

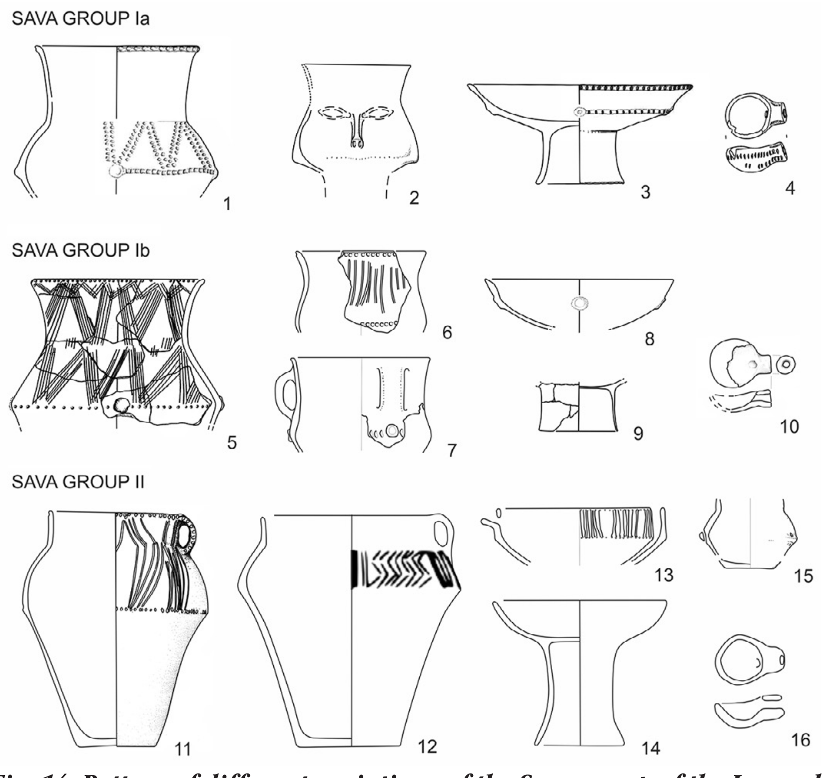

Fig. 14. Pottery of different variations of the Sava group of the Lengyel Culture.* 1–4 *Čatež – Sredno polje,* 5–10 *Resnikov prekop,* 11–16 *Moverna vas, phases 4 and 5 (after* Kramberger 2020; Tomaž 1999; 2022; Korošec 1964; Harej 1975; Velušček 2006*).

Another important group of samples was introduced from Dolenji Leskovec (Tab. 3*; Sraka 2016*). Three samples were measured, all from a single pit (SU 1099; *Hlad 2015*). The samples consist of different materials: charred seed, charred residues on pottery and a charcoal sample of unknown plant taxon. If we compare these measurements with those from Dolsko, we can see that the dates of the charcoal from pit 1 at Dolsko and the dates of the sample of charred seed (hawthorn seed) and charred remains from one of the pots at Dolenji Leskovec overlap, while the charcoal from the same pit at Dolenji Leskovec is older. This date overlaps with the measurement of a charcoal sample from pit 2 at Dolsko (Tab. 3), and with charcoal samples from Čatež – Sredno polje, Dragomelj and the earliest phase at Moverna vas.

Based on the above, the dates of charcoal differ from the dates of cattle teeth and charred seeds even when they come from the same settlement contexts. They proved to be earlier both, in the case of pit SU 1099 at Dolenji Leskovec and in the case of pit 1 at Dolsko, at least in the case of Dolenji Leskovec most likely due to the old wood effect. A date from the pile from Resnikov prekop, dates from collagen from animal bones from Gradec near Mirna and a date from the charred seed and charred residues from Dolenji Leskovec seem to be reliable. In addition to these dates, the dates from Verd are reliable because two samples of the pile (*Fraxinus* sp.) were measured, which made it possible to determine the age of a pile more precisely using the Wiggle matching method: 4674±42 cal BC (*Veluščček* et al. *2023*). Other currently available radiocarbon dates from Sava group sites are from charcoal, which should be regarded as the maximum possible age, with some also from the charred remains of pottery (Moverna vas, Resnikov prekop).

If we compare radiocarbon dates from the settlement context related to the Sava group Ib, we can see that they overlap, except for the dates of charcoal, charred residues from the phase 2 of Moverna vas (*Sraka 2012; 2016; 2020*) and the already mentioned problematic charred residues from Resnikov prekop (*Mlekuž* et al. *2013*), which are partly older. Comparable dates of collagen from animal bones are known from the Late Lengyel settlement of Zalaszentbalázs – Szőlőhegyi mező, and charcoal samples from this site again proved to be earlier (Fig. 15; *Bánffy 1995; Regenye* et al. *2022*). Radiocarbon dates of charred remains from the pottery from the Late Lengyel pits at Andrenci and Bukovnica, as well as those from animal bones from the Late Lengyel site Szombathely – metro and Szentgál-Teleki dűlő fall within a similar period (Fig. 15; *Ilon 2004; Regenye 2011; Kramberger 2014; Sraka 2014*). Finally, radiocarbon measurements of collagen from animal bones from Michelstetten (*Stadler, Ruttkay 2007*), and from horizons II-III at the Wildoner Schlossberg in Styria (*Tiefengraber 2018.Figs. 170–172,180–187*) are almost identical. All these dates indicate that Dolsko and related sites of the Sava group (Ib) in central Slovenia, Late Lengyel Culture in Transdanubia, regional variation of the Lengyel settlement in Styria and the MOG IIa phase in eastern Austria belong to the same horizon.

Two Bayesian models were then processed to compare the chronological sequences of the settlement at Moverna vas in Bela krajina (after *Sraka 2012; 2014*) and the ceramic sequences in the area of distribution of the Sava group in Posavje, Ljubljansko barje, Savska ravan, Krška ravan and Haloze (Figs. 16–17; see also Fig. 1). Dates from the entire period of the 5th millennium cal BC time range are included, *i.e.* the periods of the Late Neolithic and the Early Copper Age (Lasinja Culture). The first model assumes that sites with different variations of the Sava group pottery style were not contemporaneous (see also *Kramberger 2020*; Fig. 15). Čatež – Sredno polje (*Guštin 2005.Fig. 2; Tomaž 2022.135–141*) and Dragomelj (*Turk, Svetličič 2005; Turk* et al. *2022.14–144*) are representatives of the Sava group Ia, Dolsko – Spodnje Škovce (pit 1), Resnikov prekop, Dolenji Leskovec (SU 1099), Stoperce (SU 128) of the Sava group Ib (see Tab. 3) and Ponikve near Trebnje of the Sava group II (*Ravnik, Tica 2018.76–78*). The final phase of the sequence includes radiocarbon measurements from sites where finds can be chronologically correlated with the Lasinja Culture. The most important of these are samples of human bones and charred seeds from SUs 43 and 44 in Ajdovska jama cemetery (*Bonsall* et al. *2007; Sraka 2020*), where they were found together with typologically characteristic pottery (*e.g., Horvat 1989; 2009; Veluščček 2006.29–30; Kramberger 2018.81–96; 2020; 2021*) and dates of collagen and a charred seed from the oven at Gradec near Mirna (phase 2), which was found above the occupation layer of the Sava group (*Dular* et al. *1991; Dular 2001; Sraka 2020*). Dates of charcoal samples from the oldest phase at Gradišče above Dešen, 5km to the northeast of Dolsko (*Guštin 2005.Fig. 3; Pavlin, Dular 2007*), Col 1 near Podgračeno (*Guštin 2005.Fig. 3; Horvat 2005; 2020*) and a radiocarbon measurement of charred residues from pottery from pit SU 6508 at Obrežje (*Kramberger 2022*) also belong to this chronological phase (Fig. 16).

With this model (Fig. 16), the beginning of Sava group Ia, as we know it from Čatež – Sredno polje and Dragomelj, is estimated to between 4779-4731 cal BC (68.3% probability) and has a duration between 173-248 years (68.3% probability). This beginning and duration would probably be shorter if we had radiocarbon measurements on samples of short-lived materials. Settlements with the Sava group Ib pottery in Posavje, Ljubljansko barje and Savska ravan are dated to between 4568-4527 and 4403-4358 cal BC (68.3% probability) with the currently available set of radiocarbon measurements and lasted 133-198 years (68.3% probability). The settlement of Ponikve near Trebnje (Sava group II) is estimated to start 4403-4358 cal BC (68.3% probability) and lasted between 16-81 years or a median figure of 53 years (68.3% probability). The transition between Sava group II and the pottery style associated with human burials in Ajdovska jama (SUs 44 and 43), the oven at Gradec near Mirna (phase 2), Gradišče near Dešen, Col 1 and Obrežje is estimated to have been between 4353-4315 cal BC (68.3% probabi-

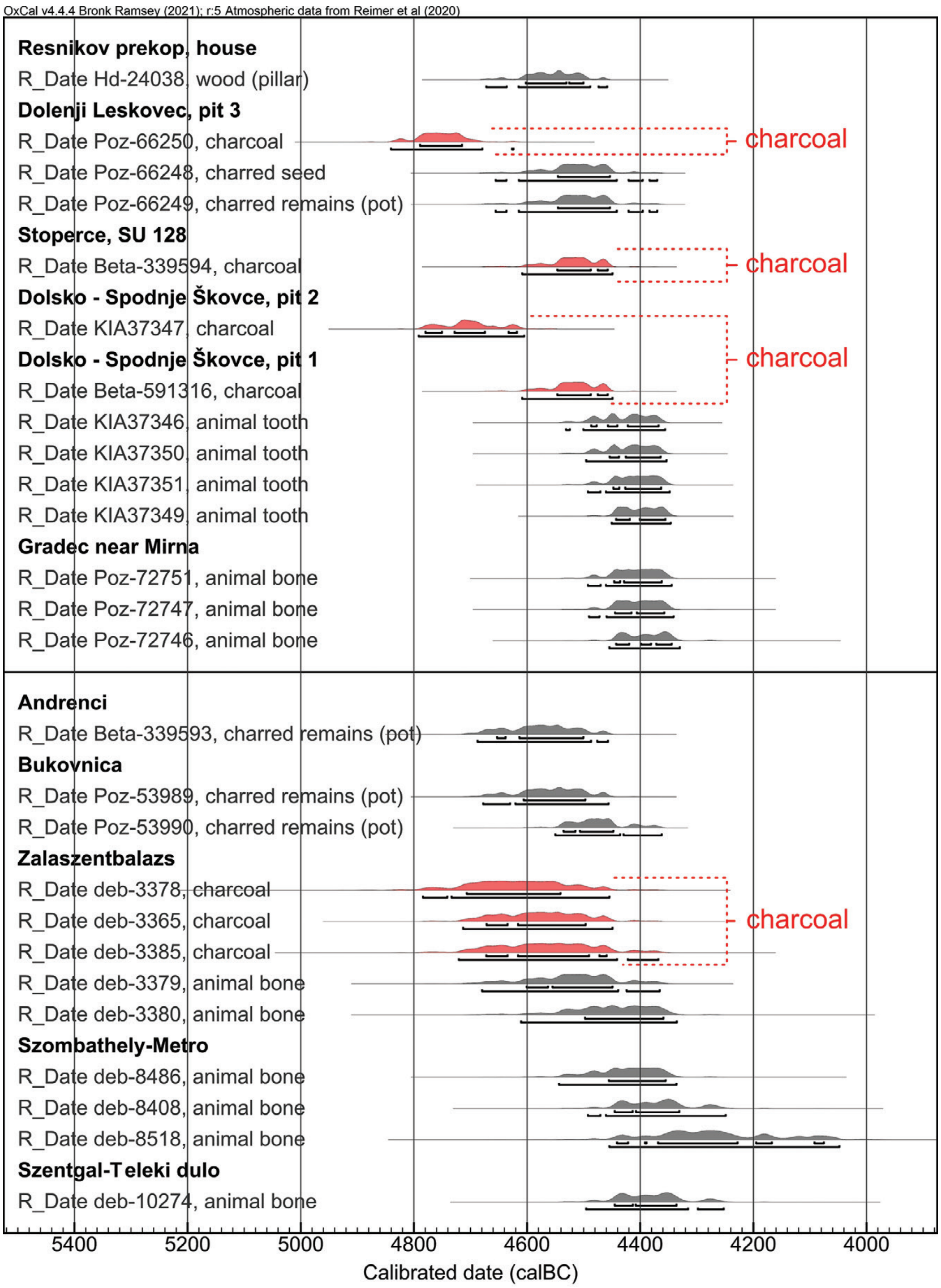

Fig. 15. Radiocarbon measurements from Dolsko – Spodnje Škovce and most similar sites of the Sava group (Ib) and the Late Lengyel Culture in Transdanubia. Charcoal dates are highlighted. Samples were calibrated using OxCal v4.4 (*Bronk Ramsey 2009*), and calibration curve IntCal 20 (*Reimer *et al.* 2022*).

lity), and the end of Lasinja Culture at these sites is estimated to have been between 4212-4118 cal BC (68.3% probability). Further details of the calculated Bayesian model are presented in Tables 4 and 5.

The median value for the beginning of the Čatež – Sredno polje and Dragomelj in the Bayesian chronological model presented here is 4758 cal BC. This is similar or slightly earlier than the age of the pile (*Fraxinus* sp.) from Verd, which was dated using the Wiggle matching method: 4674±42 cal BC (*Velušček* et al. *2023*). Unfortunately, the excavations in the trial trench yielded only a small number of ceramic fragments. In any case, from a broader perspective the date of the pile at Verd and the estimated beginning of the Sava group could correspond to the MOG Ia and Ib phases (*Stadler, Rutkay 2007*). Similar dates (collagen from animal bones) are known from the Lengyel II phase settlement of Nagykanizsa-Palin-Anyagnyerőhely in Transdanubia (*Barna* et al. *2016.319*) and a comparable time range was estimated for five Lengyel furnished burials at Veszprém-Jutasi út, which are supposedly later, from the Lengyel IIb phase, according to the typo-chronology (*Regenye* et al. *2022.288–290;* see also *Regenye 2007.392*).

The estimated time range for the beginning of phase 2 of Moverna vas is comparable, but slightly earlier than those from Čatež – Sredno polje and Dragomelj (*cf.* Figs. 16 and 17). This would mean that the settlement phase with finds of Sava group Ib at Moverna vas in Bela krajina was contemporary with the sites of Sava group Ia in Posavje, or even earlier (Fig. 1.16, 14, 5). However, due to the lack of radiocarbon measurements on short-lived material and the uncertainties associated with some dates on charred residues on pottery (*Mlekuž* et al. *2013.Tab. 1*), further research is needed to prove or disprove this. Dates similar to those from the Sava group Ib sites in Posavje are presented from phase 3 at Moverna vas (Fig. 17; *Sraka 2020. App.*), but so far no pottery finds from this settlement phase have been published.

The radiocarbon dates of charcoal samples from Ponikve near Trebnje and charcoal samples and charred remains on pottery from phases 4 and 5 at Moverna vas overlap and the estimated time spans in the Bayesian models are similar (*cf.* Figs. 16 and 17). In both cases, the occupation associated with the Sava group II pottery lasted for a rather short period, around 4400 cal BC. The calculated periods correspond to the later part of the Late Lengyel phase in Transdanubia, the later part of the MOG IIa and earlier part of the MOG IIb phases in eastern Austria (*cf. Oross* et al. *2010; Osztás* et al. *2016. 197–233; Regenye* et al. *2022; Stadler, Ruttkay 2007*). Both variations of pottery style – Sava group Ib with many similarities to that of Sava group Ia and Sava group II with more elements in common with the pottery of the subsequent Lasinja Culture (see *Kramberger 2020; 2021. 53,56–57*) – were thus parallel to the Lengyel III phase, and researchers in western Hungary have come to similar conclusions. The Late Lengyel horizon there can be divided into two subphases (Lengyel IIIa-b) and the researchers recognized that the settlements of the later subphase produced pottery with more elements of

Ceramic style sequence	Ranges with 68,3% probablity	Ranges with 95,4% probablity	Median
Start of Sava group Ia	4779-4731	4827-4726	4758
Sava group Ia-Ib transition	4568-4527	4598-4506	4548
Sava group Ib-II transition	4403-4358	4427-4348	4383
Sava group II – Lasinja	4353-4315	4366-4278	4332
End of Lasinja	4212-4118	4219-4004	4147

Tab. 4. List of values of probability distributions (in cal BC) of the ranges of transitions of ceramic sequences in the south-eastern Alpine region in Slovenia, derived from the chronological model in Fig. 16.

Ceramic style	Samples	Duration with 68,3% probablity	Duration with 95,4% probablity	Median
Sava group Ia	24 (all charcoal)	173-248	141-304	212
Sava group Ib	12 (3 collagen, 4 enamel apatite, 1 charred seed, 1 wood, 1 charred residue, 2 charcoal)	133-198	97-232	166
Sava group II	2 (charcoal)	16-81	0-114	53
Lasinja	26 (17 collagen, 6 charred seeds, 1 charred residues, 2 charcoal)	112-229	68-341	183

Tab. 5. List of values (in cal BC) of probability distributions of the durations of the Late Neolithic and Early Copper Age ceramic traditions in the southeastern Alpine region in Slovenia, derived from the chronological model in Fig. 16.

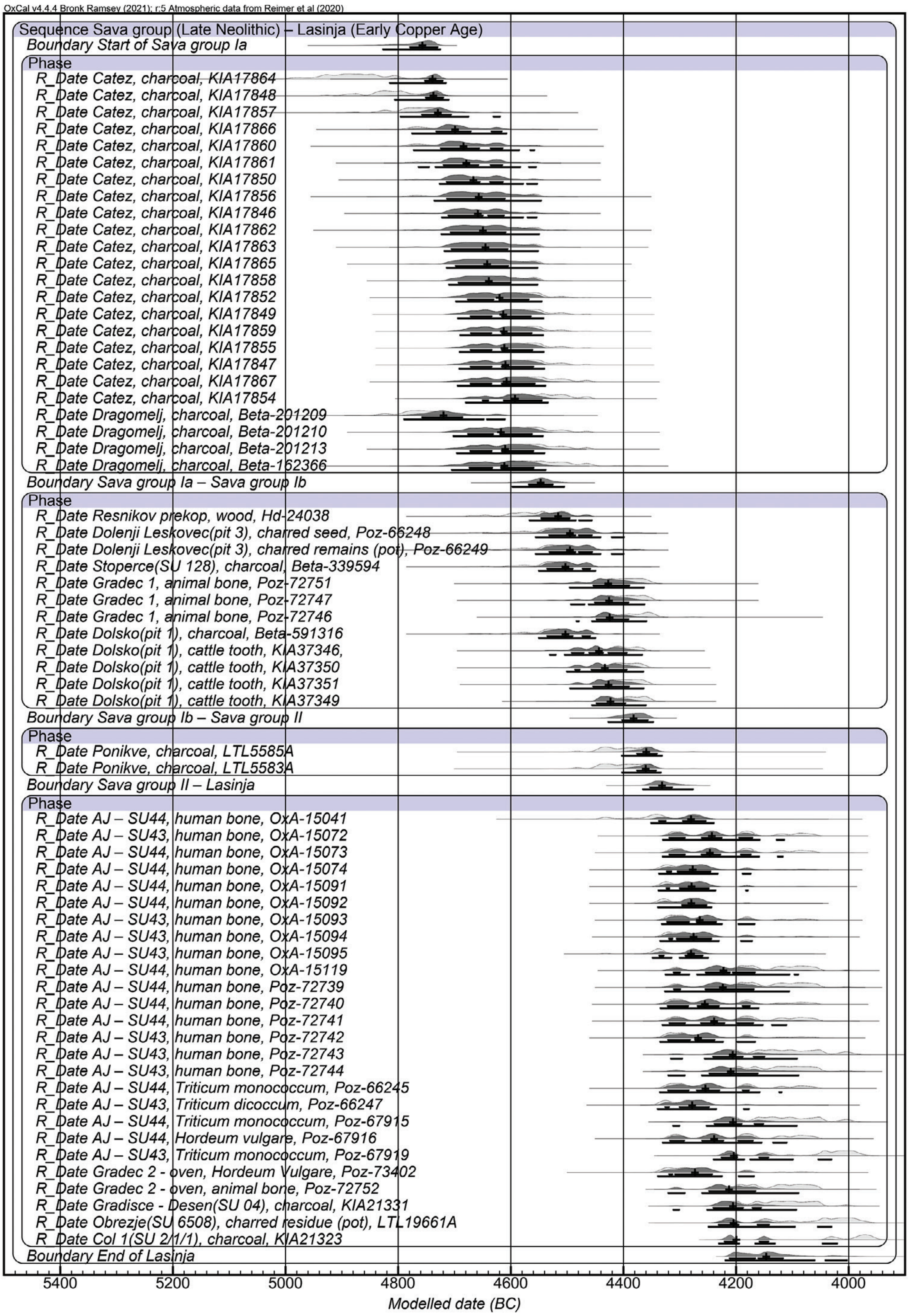

Fig. 16. Probability distributions of dates from the Late Neolithic and Early Copper Age ceramic sequence in southeastern Alpine region of Slovenia. In the model we estimate the dates of transition from one pottery style to another and no gaps. The Bayesian chronological modelling was carried out using OxCal v4.4 (*Bronk Ramsey 2009*) and the calibration curve IntCal 20 (*Reimer *et al.* 2022*).

the Lasinja (or Balaton-Lasinja) culture (*Kalicz 1991; Bánffy 1994; Regenye* et al. *2022.281*).

More significant changes in material culture, which can be associated with the Lasinja Culture (in Slovenian terminology representing the Early Copper Age), began in Posavje around 4350 cal BC according to the calculated chronological model (Fig. 16). This is similar to Moverna vas in Bela krajina (Fig. 17 – phase 7 and partly 6), northeastern Slovenia (*e.g., Sraka 2014; 2020*) and western Transdanubia (*Oross* et al. *2010; Regenye* et al. *2022*).

Archaeobotanical, archaeozoological data and subsistence strategies in the first half and beginning of the second half of the 5th millennium cal BC in the SE Alpine region

During the 7th and 6th millennia cal BC, agriculture gradually spread from southwestern Asia into nearby regions. Farming was first introduced into Mediterra-

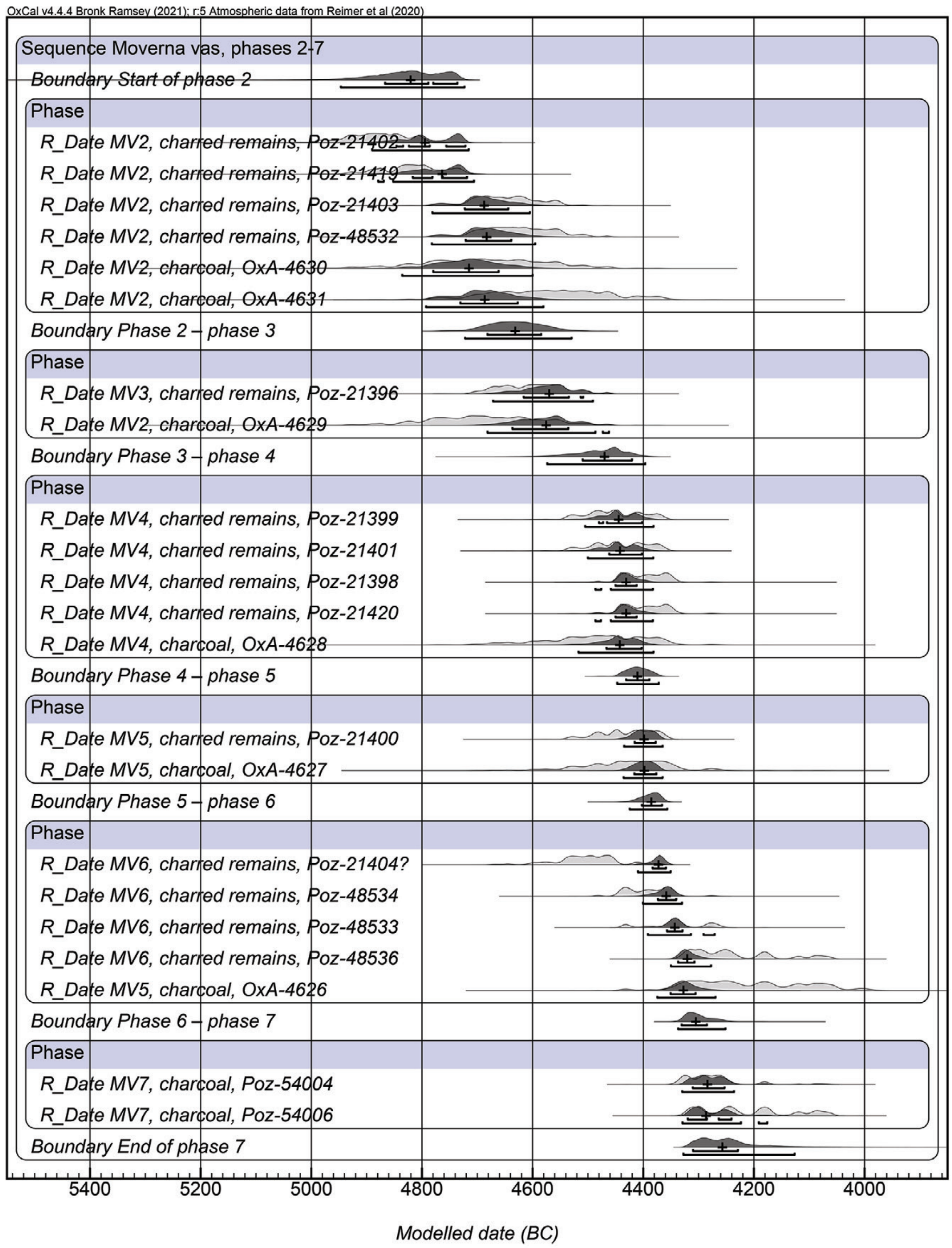

Fig. 17. Bayesian model of radiocarbon dates from Late Neolithic and Early Copper Age occupation layers at Moverna vas in Bela krajina (after **Sraka 2012.Fig. 2; 2014.Fig. 3*****). Type of program and calibration curve is the same as in Fig. 16.***

nean areas with climatic conditions similar to those in which it originated (*de Vareilles* et al. *2020*), and then progressively further north, starting in the Balkans. Archaeobotanical research on Early Neolithic sites in the Balkans has provided highly relevant data on the crop choices of early farmers. For example, some of the oldest directly dated cereal and pulse remains in Europe are from northern Greece (*e.g., Valamoti, Kotsakis 2007*), Bulgaria (*e.g., Marinova 2007; 2017*), Serbia (*e.g., Filipović 2014*) and North Macedonia, *i.e.* from *c.* 6400–5700 cal BC, where a wide range of crops has been found, with five cereal species and several varieties, two legumes and possibly two oil crops (*Sabanov* et al. *2024*). Some differences in the diversity and importance of certain crops were noted, probably depending on local environmental or cultural factors, *i.e.* early farmers adapted their crop choices.

The 5th millennium cal BC in Slovenia is characterized by the transition from the Neolithic to the Copper Age (*e.g., Budja 1995; Velušček 2011; Sraka 2020*). Archaeobotanical studies of Late Neolithic sites in Slovenia, including the site of Dolsko – Spodnje Škovce, are very scarce. There are several reasons for this, such as the limited and poor state of research, ineffective and insufficient sampling for archaeobotanical analyses, and poorly preserved cultural layers. The poor state of preservation of the plant macro-remains is certainly not the case for the pile-dwelling sites at Ljubljansko barje (*e.g., Culiberg 2006; Jeraj 2004; Tolar* et al. *2010; 2011; Velušček* et al. *2023*), the cave cemetery site in Ajdovska jama (*Culiberg, Šercelj 1986; Culiberg* et al. *1992; Sraka 2020*) or the hilltop settlement at Gradec near Mirna (*Dular* et al. *1991; Culiberg, Šercelj 1995; Sraka 2020*), where many macro-remains of cultivated plants were found, but all of them are younger (*i.e.* end of the 5th and 4th millennium cal BC).

The published archaeobotanical data on plant remains from Late Neolithic sites in Slovenia have been synthesized to expand the comparisons between sites in the area. In the next part of this paper, the archaeobotanical analyses of eight 5th millennium cal BC sites (dated around 4700-4400 cal BC) in Slovenia, from which at least some plant macro-remains (mostly charcoal) have been recovered, are presented to show the state-of-the-art, *i.e.* Dolsko – Spodnje Škovce, Čatež – Sredno polje (*Culiberg 2022*), Stoperce (*Kramberger* et al. *2023*), Dragomelj (*Tolar 2022*), Verd (*Velušček* et al. *2023*), Resnikov prekop (*Culiberg 2006; Čufar, Korenčič 2006*), Dolenji Leskovec (*Sraka 2016*) and Zamedvedica near Plešivica (*Turk, Vuga 1984*).

Very modest archaeobotanical investigations from the above listed sites have already been published (see references). This paper presents the first combined analysis of all of them. The oldest plant macro-remains recovered and analysed to date from the 5th millennium cal BC sites are listed and compared (seeds/fruits – Tab. 6; charcoal – Tab. 7; both tables see below). In most cases, the macro-remains compared were derived from the randomly and subjectively collected sediment samples. In some cases, the wash-over method (*Kenward* et al. *1980*) with a minimum sieve mesh size of 1 to 2mm was used to separate the plant macro-remains from the sediment sample material, and the macro-remains were then air-dried. Recognizable plant remains were then sorted out, but the volume of each sample varied according to the size of the approximate sediment sample value (*c.* 5–20 litres). In Tables 6 and 7, therefore, only the total number of recognized plant remains in an unknown volume are given, or only the presence/absence of plant taxa is marked. This methodological problem further limits comparisons between the sites. The context types for the sites compared are also given in Tables 6–7. Except for the pile-dwelling sites, most of the samples come from Neolithic secondary refuse deposits (*i.e.* pits). No large deposits of *in situ* preserved plant macro-remains have yet been recovered from the 5th mill. cal BC sites in Slovenia.

Tables 6–7 show that seed/fruit remains from Late Neolithic sites in Slovenia are less abundant than charcoal remains. Only four sites have at least one seed/fruit remain. Two of them (Dragomelj, Verd) may contain cereal remains, which could also be the remains of a wild plant of the Poaceae family, therefore the identification is uncertain. At two sites (Verd, Dol. Leskovec) the remains of wild edible fruits/nuts are preserved: *Fagus sylvatica* (beech), *Malus sylvestris/Pyrus pyraster* (wild apple/pear), *Crataegus monogyna* (hawthorn), *Rubus* sp. (blackberry/raspberry), *Trapa natans* (chestnut) – which point to a possible gathering economy. At three sites (Čatež, Dragomelj, Verd) the remains of other, nutritionally less important plant taxa are present, which provide information on the environmental conditions at the sites. The seed/fruit remains of Chenopodiaceae (goosefoot), *Polygonum* sp. (knotgrass), *Veronica* sp. (speedwell), *Setaria* sp. (foxtail), *Solanum nigrum* (black nightshade) found at the Čatež site confirm an anthropogenic, ruderal environment. The same is true for the remains of *Stellaria* sp. (chickweed) at the Dragomelj site. While the remains of various aquatic and marshy/

lakeshore plant taxa, identified at the Verd pile-dwelling site, such as *Sparganium* sp., *Alnus glutinosa*, *Betula pubescens*, *Nuphar luteum*, *Mentha aquatica*, *Schoenoplectus lacustris*, *Potamogeton* sp., *Alisma plantago aquatica, Euphatorium cannabinum*, *Ranunculus aquatilis*, *Oenanthe aquatica*, *Najas marina*, *Epilobium hirsutum*, *Trapa natans* and *Chara* sp., all attest to the existence of a water source and a marshy/lakeshore area at the site. The remains of *Urtica dioica*, *Acer* sp., *Abies alba*, *Cornus sanguinea*, Apiaceae and Poaceae at Verd could possibly be the remains of plant taxa that do not prefer moisture, and which could have been brought to the lakeshore settlement by the inhabitants.

The charcoal remains preserved at all eight considered Late Neolithic sites (Tab. 7) indicate palaeovegetational conditions in the surrounding forest and possible selection of wood for different purposes. At Dolsko – Spodnje Škovce a selection of mainly oak (*Quercus* sp.) and other RPW taxa (*Castanea*, *Fraxinus*) is shown, although five other tree taxa were also identified. Čatež – Sredno polje is the site with the most numerous charcoal fragments analysis among the sites considered (Tab. 7). The result shows that the forest vegetation of that time was quite similar to today's. In the lowland part of the wider area of the Čatež – Sredno polje, a floodplain oak forest still grows, in which hornbeam (*Carpinus betulus*) is also common. In addition to oak, elm (*Ulmus* sp.) and ash (*Fraxinus* sp.) are common, what is shown also by the analysed Late Neolithic charcoal. The elevated edges of the Gorjanci plain are now covered with light beech (*Fagus sylvatica*) forest, in which hornbeam and maple (*Acer* sp.) also thrive. The presence of vine (*Vitis vinifera* ssp.) charcoal at the Čatež – Sredno polje site is interesting, but it is not yet possible to say whether it is from the cultivated ssp. yet (*Culiberg 2022*). The result of charcoal analysis outline the natural environment from which people extracted natural resources, especially wood. Eighteen wooden piles of alder (*Alnus* sp.) used for construction at Resnikov prekop and seven of alder and willow (*Salix* sp.) at Verd pile-dwelling sites are of interest (Tab. 7), while mostly oak and ash wood is used at the younger Eneolithic pile-dwelling sites (*Čufar* et al. *2010*). In general, ash (*Fraxinus* sp.) charcoal has been found in five of the seven sites considered (Tab. 7); it seems to have been, along with oak (*Quercus* sp.), one of the tree taxa that was already selected by people in the Late Neolithic, not just in the Eneolithic (*Čufar* et al. *2010*). However, there are differences depending on the nearby forest vegetation and certainly also on the number of charcoal fragments and samples taken for analysis. The Čatež – Sredno polje site, with the largest number of charcoal identifications, clearly shows a relatively higher diversity (11 taxa) of the wood used, with a preference for beech, oak and maple – which probably grew in the vicinity of the settlement. In Dolsko – Spodnje Škovce, the oak charcoal can be interpreted in two ways: as natural oak wood or as selected oak wood. Today, almost two thirds of Posavsko hribovje is covered by forests, and the dolomite slopes of the Sava gorge are mainly beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) forests. Another important factor to be taken into account is the taphonomy and resistance of different types of wood/charcoal, which could also be the reason why oak charcoal is more often identified.

Archaeozoological knowledge about subsistence strategies in the settlements of the Sava group is limited (Tab. 8). This is mainly due to the lack of material caused by the poor preservation of bones in the often acidic sediments (*e.g., Hincak 2022*; *Kramberger* et al. *2023.71,108–109*) and/or the relatively small scale of the fieldwork (*e.g., Turk, Vuga 1984*; *Toškan, Dirjec 2006.Tab. 1; Veluščček* et al. *2023*). In Dolsko – Spodnje Škovce, too, the small number of taxonomically identified animal remains probably does not allow a reliable assessment of local subsistence strategies (*Davis 1987.46*; *Bartosiewicz 2005.58–59*), especially since most finds come from a single feature, *i.e.* pit 1. The latter circumstance precludes a serious analysis of spatial differentiation within the settlement, so that a comparison of local archaeozoological data with those from other sites is more likely to reflect (dis) similarities in spatial use within the settlement rather than the degree of congruence of general subsistence patterns at different sites. Further difficulties arise from the fact that the archaeozoological material is highly fragmented. This makes the calculation of the Minimum Number of Individuals (MNI) rather impractical, even when focusing on several dozen taxonomically identified teeth. Since it is practically impossible to identify the tiny enamel fragments belonging to the same tooth, the actual calculated value of MNI = 3 may be close to or significantly different from the actual number of animals represented in the pit.

Another stumbling block in the interpretation of the archaeozoological assemblage from Dolsko – Spodnje Škovce is the limited understanding of the formation process of the deposits in pit 1. The pit may have been formed by the extraction of clay material and later filled with waste, as is known from contemporary sites in the wider region, but it is unclear whether the pit was filled very quickly or much slower. Understanding the depositional processes associated with these features is crucial, as large pits may contain waste from a single building, from several households or possibly from the whole community; the deposits may be associated with ordinary daily activities, a special event (*e.g.,* a feast) or an exceptional situation (*e.g.,* the remains of a burnt-down house); they may contain primary or redeposited secondary waste, and so on (*Chapman 2000*; *Osztás* et al. *2012.388–390*; *Květina, Řídký 2017*; *Tóth* et al. *2020*; *Orton in press*). According to John Chapman (*2000.20,64*), in the Balkan Neolithic the "*…cultural material produced within, or domesticated into, the household was not subject to 20th century AD rules of refuse disposal but remained part of the household even after the end of its use.*" In other words, not everything that was deposited in pits can be considered as 'normal' waste, because there must have been a deliberate choice to dump certain materials in pits and not simply dispose them in backyards, along paths, between houses, *etc.* (*cf. Orton* in press). Such 'special' pits may include an above-average amount of dumped material, evidence of *in situ* firing, backfills with evidence of deliberate burning or inclusion of products of deliberate burning (charcoal, ash, burnt clay, lithics, vessels and organic remains with evidence of burning), a basal layer of special/rare and/or mixed finds, deliberate placement of animal bones, evidence of ritual breakage (*e.g.,* of vessels) and evidence of parts of the same vessel being scattered in different parts of the feature/site, and so on (*Chapman 2000.69–73,82–83*).

Interestingly, most of the listed clues were found in Pit 1 in Dolsko – Spodnje Škovce. The list includes large quantity of deposited ceramics, especially in the basal layer SU 194 = 196 = 217, the presence of fragments of individual vessels in different parts of the pit, the fill SU 148 with a large amount of charcoal, the presence (deposition?) of the only almost complete, unburnt bone – a cattle mandible – at the bottom of one of the depressions in the bottom of the pit (*i.e.* SU 217; Fig. 5.2), the presence of burnt clay and possibly two charcoal clusters (hearths?) directly above fill SU 194 = 196 = 217, the prevalence of calcined animal teeth and bones in SU 194 = 196 = 217, and the peculiarity that they were almost absent from fill SU 148, which contained by far the largest concentration of charcoal (*Kramberger in press*).

A pragmatic approach to the interpretation of the almost exclusive occurrence of cattle in the Late Neolithic archaeozoological assemblage from Dolsko – Spodnje Škovce would focus on the considerable importance of this animal at (roughly) contemporaneous Lengyel sites in Lower Austria, the Carpathian Basin and the Western Balkans (*e.g., Bökönyi 1986.Tab. 1, 3, Fig. 2–3*; *Bartosiewicz 1995.Tab. 2*; *Schmitzberger 2008.227–240*; *Nyerges, Biller 2015.4–6*; see also *Bartosiewicz 2005.57–58*), as this suggests that the Late Neolithic community under study often placed a strong emphasis on cattle herding. Of course, to confirm the hypothesis the archaeozoological material studied here

Site	NISP	*B. taurus*	Caprinae	*Sus* sp.	*C. familiaris*	*C. elaphus*	*C. capreolus*	*A. alces*	*B. primigenius*	Other taxa
Dolsko – Spodnje Škovce (Fig. 1.1)	511	71	2	10						
Resnikov prekop (Fig. 1.6)	108	14	5	19	2	37	4	20		7
Zamedvedica (Fig. 1.7)	15			3		10			1	1
Verd (Fig. 1.9)	5					4				1
Gradec near Mirna (Fig. 1.11)	8	3	1	1		3				
Čatež – Sredno polje (Fig. 1.14)	166	22	26	31		37	11		39	
Spaha (Fig. 1.20)	38	15	3	10		4			1	5

Tab. 8. Species representation at Dolsko and other sites of the Sava group of the Lengyel Culture. Notes on the contexts considered: Dolsko – Neolithic material (Tab. 1); Resnikov prekop – complete assemblage (*Toškan, Dirjec 2006*); Zamedvedica near Plešivica – complete assemblage (*Turk, Vuga 1984*); Verd – complete assemblage (*Veluščček *et al.* 2023*); Gradec near Mirna – phases 1a, 1b (Toškan, unpublished data); Čatež – Sredno polje – Neolithic material (*Hincak 2022; *unpublished data); Spaha – material from the 5th millennium cal BC (*Toškan 2011*). Explanation of abbreviation: NISP – Number of Identified Specimens (*Grayson 1984*).

would have to reflect subsistence strategies that go beyond the level of a single household or even a single event. Given the diversity of the material discarded in pit 1 and the considerable differences in the composition of different fills, this option is not to be ruled out completely (*cf. Osztás* et al. *2012.390*). The hypothesis that cattle breeding predominated in Late Neolithic Dolsko – Spodnje Škovce would indeed fit well with the local paleoenvironment, as the site is located on the edge of the agriculturally interesting lowlands of the Ljubljana Basin. On the other hand, for example, the nearby Resnikov prekop and Verd were located on the shores of the lake at Ljubljansko barje, with probably a less fertile soils, so the dominance of game at these sites (pile dwellings) is not surprising (Tab. 8).

On closer examination of the available data, however, the possibility seems realistic that the archaeozoological assemblage from the Late Neolithic contexts at Dolsko – Spodnje Škovce does not reflect 'average' subsistence practices, as the process of formation of the deposits from pit 1 appears to be peculiar in some respects. In this context, it is worth mentioning the taphonomic observations already highlighted in relation to the fillings of this pit. Also significant is the large discrepancy in the quantity of pottery, charcoal and animal remains between pit 1 and other pits discovered at this site, which is obvious even taking into account the differences in size between them (*Kramberger in press*). To mention only the number of animal remains (Tabs. 1, 8), several hundred specimens were collected from pit 1 (size: 11x7m; depth: up to 0.7m), no more than four from pit 2 (size: 10x5m; depth: 0.3m with deepenings in the floor up to a further 0.3m) and none from any of the other, indeed much smaller and shallower pits (N = 12; dimensions of the largest [SU 3029/3030]: 2.35x1.1m; depth: up to 0.35m; *Kramberger in press*). Finally, the preponderance of cattle in the various fills of Pit 1 is a remarkable circumstance. In fact, the sheer size of these animals implies that they were routinely consumed beyond the level of the individual household or nuclear family group, suggesting communal (and thus not 'ordinary'?) activity. Also worth mentioning is the possible social value of live animals of this domesticate as objects of prestige or exchange (*Orton 2012.27,32; Manning* et al. *2013a.250*).

Conclusions

Post-depositional processes related to the Sava River and smaller streams have shaped the found Late Neolithic archaeological record at Dolsko – Spodnje Škovce. Nevertheless, several smaller and two large pits (1 and 2), filled with material culture of the Sava group of the Lengyel Culture were found. Of particular interest is pit 1, which yielded most of the Late Neolithic pottery from the site. Based on its irregular shape, the distribution of parts of individual ceramic vessels in different fills of the pit and over large area, the large amount of very fragmented animal remains and the location of the pit on the 'island' of clayey alluvium, it may have been used for digging clay loam, which was used for construction activities, and in the later phase it was filled with waste. The same can be assumed for many other large pits of irregular shape at Late Neolithic sites in Slovenia. Lack of rectangular timber framed houses may be due to time-dependent site losses due to taphonomy.

Based on the analysis of the pottery, the definition of the Sava group of the Lengyel Culture needs to be supplemented. The sites in Bela Krajina do not differ from those in the Posavje, Ljubljansko barje and SU 128 in Stoperce (northeastern Slovenia) in terms of pottery production methods, decoration and ceramic forms. On the contrary, three variations of one pottery style (Sava group Ia-b, II) can be recognized. In Posavje and central Slovenia all three variations of one style are present, the only site of the Sava group in northeastern Slovenia (Stoperce, SU 128) has yielded pottery of the Sava group Ib style, and in the Bela krajina region so far only settlements with pottery of Sava group Ib and II were found, at Moverna vas in different occupation layers lying in stratigraphic superposition: settlement phases 2 (Sava group Ib), 4 and 5 (Sava group II).

According to the analysis, the material culture from pit 1 at Dolsko is attributed to the Sava group Ib and, based on radiocarbon measurements, it can be dated with caution to the middle and beginning of the second half of the 5th millennium cal BC. This period corresponds to a range of radiocarbon dates from short-lived material at other Late Neolithic sites with the Sava group Ib pottery in the Posavje region and Ljubljansko barje, as well as dates from the Late Lengyel Culture in Transdanubia and MOG IIa phase in Austria. It is later than the range of radiocarbon dates from Dragomelj and Čatež – Sredno polje, whose pottery can be attributed to Sava group Ia.

The Bayesian model presented in this study included a number of samples of short-lived materials related to Sava group Ib and Lasinja Culture of the Early Copper

Age from the area of central Slovenia and Posavje. According to the median value, the beginning of the Sava group (Ia) is estimated at 4758 cal BC and its end at 4548 cal BC, which could correspond to Lengyel II phase in Transdanubia and recently published dendrodata for the pile from Verd (*Velušček* et al. *2023*), but also to the time range estimated for five Lengyel furnished burials at Veszprém-Jutasi út, attributed to Lengyel IIb phase (*Regenye* et al. *2022.288–290*). The following part of the Sava group sequence (sites with pottery Sava group Ib and II) in Posavje was parallel to the Late Lengyel sequence in Transdanubia.

According to the chronological model presented here, the period of settlement phase 2 at Moverna vas overlaps with those from Čatež – Sredno polje and Dragomelj, or is even slightly earlier. This would mean that sites with pottery of Sava group Ia in central Slovenia and Posavje, and Sava group Ib in Bela Krajina were contemporary. However, since the radiocarbon dating at Dragomelj and Čatež – Sredno polje is based solely on charcoal, and at Moverna vas on charcoal and charred residues on the pottery, further research is needed to prove or disprove this. Later chronological sequence at Moverna vas (phases 3, 4, 5 and partly phase 6) is comparable with the later sequence in the here presented Bayesian chronological model for the Sava group in Posavje, and the beginning of the Lasinja Culture, which was part of a wider shift in settlement and society, is estimated in models for both regions to be around 4350 cal BC, which is similar to Transdanubia.

The synthesis of the scarce archaeobotanical results, especially no crop macro-remains (see Tab. 6), at Slovenian Late Neolithic (5th cal BC) sites to date aims to outline a regional gap in the study of the earliest agricultural communities and crop diversity among the early farmers in present-day Slovenia. The aim is to provoke a discussion about whether and why the potential botanical evidence for early agricultural decision-making at the local level is being dismissed, or indeed does not exist. The record of prehistoric crop cultivation in central Europe dates back to 5500 cal BC (*e.g., Baum* et al. *2016*). However, the synthesis presented in this article clearly shows that there is an urgent need for further revision and possible re-probing, which would allow us to expand the comparisons between the sites in the area and thus obtain more information about the first farmers in Slovenia. The discussion of cultural similarity and preferences in crop choice could then be developed, together with archaeological and archaeozoological evidences.

The oldest currently known finds of cultivated plants in Slovenia are therefore much younger, dating from the last third of the 5th and 4th mill. cal. BC or Early and Middle Copper Age; *e.g.,* form the sites: Pigl na Javorniku (*Tolar unpublished*), Ajdovska jama (*Culiberg, Šercelj 1986; Culiberg* et al. *1992; Sraka 2020*), Gradec near Mirna (2nd phase, *Culiberg, Šercelj 1995; Sraka 2020*), Stoperce (other pits than SU 128, *Kramberger* et al. *2023*), Zgornje Radvanje (*Kramberger 2021; Tolar 2021*). Strojanova voda and Maharski prekop (*Tolar 2018*), Stare gmajne (*Tolar* et al. *2011*), and Hočevarica (*Jeraj 2004*). The earliest crop taxa in Slovenia to date are represented by three species of cereals, barley (*Hordeum vulgare*), einkorn (*Triticum monococcum*) and emmer (*Triticum dicoccum*), one pulse, *i.e.* pea (*Pisum sativum*), and two or three oil crops: flax (*Linum usitatissimum*), poppy (*Papaver somniferum*), and possibly turnip (*Brassica rapa*; see *Tolar* et al. *2011*). The macro-remains of the listed taxa have all been found at the sites listed above and attest to the presence of the earliest cultivars in Slovenia. In addition to cereals grains and/or oilseeds, the remains of cereal or flax processings (*i.e.* chaff and capsulas remains) have been found at many of the above listed sites. At waterlogged sites (*i.e.* pile-dwellings) even the seeds of weeds are well preserved. All of these are evidences not only of the use of cultivated food plants (*i.e.* diet), but also of the cultivation practices (agriculture) directly at the archaeological site being investigated.

As far as the archaeozoological results are concerned, the first impression is that in the Late Neolithic in Dolsko – Spodnje Škovce cattle breeding played the main role in the supply of meat and fats. This is similar to other sites of the Lengyel Culture from Lower Austria and the Carpathian Basin (*Bökönyi 1986.Tabs. 1,3, Figs. 2–3*; *Bartosiewicz 1995.Tab. 2*; *Schmitzberger 2008.227–240*; *Nyerges, Biller 2015.4–6*), as well as most contemporaneous sites in the continental central Balkans (*Orton 2012; Manning* et al. *2013a; 2013b; Orton* et al. *2016; 2021*). However, it should not be forgotten that practically all the animal remains examined here came from a single, peculiar large pit. Moreover, since the general trend of increasing importance of large-scale cattle breeding in the Late Neolithic Balkans was neither universal nor synchronous (*Orton* et al. *2021* and references therein), it should not be taken for granted for the communities of the Lengyel Culture either. Heterogeneity in subsistence strategies is evident in the continued importance of wild species in the archaeofaunas of this period, suggesting that hunting was not consistently reduced to a sporadic, seasonal or purely opportunistic practice (*Gaastra, de Vareilles, Vander Linden 2022.52–57; Orton in press*).

Indeed, the archaeozoological data for the sites of the Sava group, although sparse, reflect the non-uniform supra-regional picture mentioned above quite well (Tab. 8). The high proportion of wild fauna at Čatež – Sredno polje and the pile-dwellings of Zamedvedica, Verd and Resnikov prekop is probably influenced by the location of these sites on/near a large lake/river with a forested, game-rich background (*Turk, Vuga 1984*; *Toškan, Dirjec 2006; Hincak 2022; Veluščček* et al. *2023.27–28*), but may not have been independent of a conscious, culturally determined decision to emphasize hunting (*cf. Bökönyi 1986*; *Gaastra* et al. *2022.56–57; Orton in press*). The relative abundance of cattle remains in the 5th millennium layers at the hilltop settlement of Spaha (*c.* 60km southeast of Dolsko – Spodnje Škovce), on the other hand, seems to reflect vertical transhumance as part of an already developed, large-scale cattle herding system. Since both extremes of subsistence strategy are found in the area occupied by the Sava group communities, the high prevalence of cattle remains in Dolsko – Spodnje Škovce could reflect either a strong emphasis on cattle herding by the local community or the holding of a special event in which cattle/beef played a notable role (*e.g.,* a feast).

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Tab. 6.* *5th millennium cal BC Late Neolithic sites in Slovenia with macro-remains of seeds/fruits, state-of-the-art (n.d. – no data). Quantitative proportions of samples apply to all analysed samples (seeds and wood charcoal). Source of data: Culiberg (2022); Kramberger* et al. *(2023); Tolar (2022); Velušček* et al. *(2023); Culiberg (2006); Čufar, Korenčič (2006); Sraka (2016); Hlad (2015) and unpublished data.

Site	**Dolsko – Spodnje Škovce (Fig. 1.1)**	**Dragomelj, SU 971 (Fig. 1.5)**	**Resnikov prekop (Fig. 1.6)**	**Zamedvedica (Fig. 1.7)**	**Verd (Fig. 1.9)**	**Dolenji Leskovec (Fig. 1.12)**	**Čatež – Sredno polje (Fig. 1.14)**	**Stoperce, SU 128 (Fig. 1.22)**
No. sediment samples	34	1	34 wood samples	n.d.	2	1	70	2
Context	Neolithic pits 1 and 2, SUs 87, 87, 218	Neolithic pit	Pile-dwelling	Surface finds	Pile-dwelling	Pit	Neolithic pits	Neolithic pit
Age cal BC / Plant taxa (seeds/fruits)	Charcoal and apatite: 4788-4350	Charcoal: 4840-4456	*Alnus* wood: 4675-4465	/	*Trapa natans:* 4611-4630; dendrochr.: 4674±42	*Crataegus*: 4656-4371	Charcoal: 4954-4460	Charcoal: 4609-4450
Cerealia		1						
Poaceae (?Cerealia)					x			
Stellaria sp.		1						
Chenopodiaceae							x	
Polygonum sp.							2	
Polygonum persicaria							1	
Veronica sp.							1	
Setaria sp.							2	
Urtica dioica					2			
Sparganium sp.					1			
Solanum nigrum							1	
Betula pubescens					1			
Acer sp.					2			
Fagus sylvatica					2			
Malus/Pyrus					1			
Crataegus monogyna					2	1		
Rubus sp.					1			
Cornus sanguinea					1			
Abies alba-needles					30			
Alnus sp.					5			
Nuphar luteum					2			
Mentha aquatica					29			
Schoenoplectus lacustris					13			
Potamogeton sp.					2			

Tab. 6. Continued

Alisma plantago aquatica					6			
Eupatorium cannabinum					7			
Ranunculus aquatilis					3			
Oenanthe aquatica					4			
Najas marina					3			
Epilobium hirsutum					3			
Apiaceae					1			
Trapa natans					8			
Chara sp.					33			

Tab. 7. 5th millennium cal BC Late Neolithic sites in Slovenia with charcoal (wood) remains, state-of-the-art (n.d. – no data). Quantitative proportions of samples apply to all analysed samples (seeds and wood charcoal). Source of data: Tab. 2 and same as in Tab. 6.

Site	**Dolsko – Spodnje Škovce (Fig. 1.1)**	**Dragomelj, SU 971 (Fig. 1.5)**	**Resnikov prekop (Fig. 1.6)**	**Zamedvedica (Fig. 1.7)**	**Verd (Fig. 1.9)**	**Dolenji Leskovec (Fig. 1.12)**	**Čatež – Sredno polje (Fig. 1.14)**	**Stoperce, SU 128 (Fig. 1.22)**
No. sediment samples	34	1	34 wood samples	n.d.	2	1	70	2
No. ID charcoals	35			n.d.		n.d.	190	4
Context	Neolithic pits 1 and 2, SUs 86, 76, 218	Neolithic pit	Pile-dwelling	Surface finds	Pile-dwelling	Pit	Neolithic pits	Neolithic pit
Age cal BC / Plant taxa (charcoal)	Charcoal and apatite: 4788-4350	Charcoal: 4840-4456	*Alnus* wood: 4675-4465	/	*Trapa natans:* 4611-4630; dendrochr.: 4674±42	*Crataegus*: 4656-4371	Charcoal: 4954-4460	Charcoal: 4609-4450
Quercus	12						6+10+6+11+3+1+5+7+26	
Quercus/Castanea	3							
Tilia							1	
Populus/Salix					3 (piles)		1+3+1	
Acer	1		1 (piles)				13+2+3+2+1+1+8+4	
Carpinus	5						1+5+1	
Fagus					1 (pile)		2+32+1+4+1+1+1+6+1+3+1+1+7+4+2+4	
Ulmus							4+4+2+3	
Vitis							17	

Tab. 7. Continued

Fraxinus	1		8 (piles)		x (charcoal); 2 (piles)		2+1+4+3	2
Fraxinus/Castanea	1							
Betula							1+1	
Sorbus							2	
Cornus	4							
Sorbus/Cornus	1							
Alnus sp.			18 (piles)		4 (piles)			
Corylus avellana				x				
Coniferous	3							2
DPW			7 (piles)				1	
RPW	4							
not determined		x			x (charcoal)	x (charcoal)	x	

Land-use and ceramics in the Andean highlands of Patagonia, Argentina

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ABSTRACT - *The aim of this paper is to study the use of ceramics of small-scale societies during the late Holocene in northern Patagonia. The technological investment model predicts that use-time and utility will determine the investment spent in ceramics. We explore how ceramics were used in short-term camps and aggregation sites during summer at high elevations, and residential camps during winter at lower elevations. To test the investment in ceramics we use four technological variables: temper size, average thickness, surface treatment and firing. Our results indicate that hunter-gatherers expected a short-term use in summer locations and therefore made a low investment in ceramics.*

KEY WORDS – *ceramic analysis; use of space; northwestern Patagonia; hunter-gatherers*

Raba prostora in lončenina v Andskem višavju Patagonije v Argentini

IZVLEČEK – *V prispevku proučujemo uporabo lončenine v manjših skupnostih v poznem holocenu v severni Patagoniji. Model tehnološke investicije predvideva, da čas uporabe in uporabnost določata naložbo v izdelavo keramičnih posod. V prispevku raziskujemo, kako se je lončenina uporabljala v kratkotrajnih poletnih taborih in zbirališčih na visokih nadmorskih višinah ter v zimskih bivalnih taborih na nižjih nadmorskih višinah. Za testiranje modela uporabljamo štiri tehnološke spremenljivke: velikost primesi, povprečno debelino, dodelavo površine in žganje. Rezultati kažejo, da so lovci in nabiralci načrtovali kratkotrajno uporabo posod na poletnih lokacijah, zato je bila naložba v izdelavo posod majhna.*

KLJUČNE BESEDE – *analiza keramike; raba prostora; severozahodna Patagonija; lovci in nabiralci*

Introduction

In mobile societies, the use of ceramics may be problematic if the manufacturing process interferes with residential movements and the acquisition of seasonal resources, such as when the vessel drying and firing process requires foragers to stay in places for longer periods. Yet the potential benefits of ceramics to the subsistence system may include improved return rates on seed crops and animal products, like bone, if cooking releases more calories relative to the time invested in their acquisition (*Bettinger* et al. *2006; Sturm* et al. *2016*). In this paper, we explore the following research question: How was ceramic technology used by small-scale mobile societies in the highlands of northwestern Patagonia?

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Hunter-gatherers face many constraints when considering the use of ceramic technology: (1) the utility and costs of similar technologies such as basketry and leather bags; (2) the fragility of the pots and whether or not they can be moved between residential and/or logistical camps; (3) scheduling conflicts between ceramic production and other activities such as seed gathering; (4) the small scale production does not take advantage of the opportunity to fire large amounts of pots in a single event (*Eerkens 2003; 2008*); and (5) the time needed to stay in a location and form, dry and fire a pot (*Arnold 1985*).

There are different strategies with regard to the use of ceramics among small-scale mobile societies: caching them at specific locations instead of moving them as the seasons change (*Eerkens 2008*), producing expedient pots for a single use and then discarding them (*Gibbs 2012*), and trading with nearby neighbours (*Beck 2009*). In addition to learning why and when this technology was acquired, we can explore how hunter-gatherers managed the costs of producing and transporting this technology in light of their seasonal constraints, movements, and needs. Variation in ceramic use across settlement systems permits investigation of patterns of mobility and seasonality. To interpret such variation, we need to consider the differences among the ecological zones and their limitations, the energy spent on manufacturing them, the utility of the vessels, and the duration of their use. Our objective is to investigate how hunter-gatherers from northwestern Patagonia complemented the use of land to mitigate risk with ceramic technology in the context of aridity and high elevation environments. Through the study of settlement patterns and the use of ceramics we determine how different strategies permitted the adaptation to different ecological zones, and especially the highlands.

Ceramics and land-use in mobile small-scale societies

There is a high correlation between ceramic technology and sedentism (*Arnold 1985*), mainly related to the different steps of the manufacturing sequence, which involves raw material acquisition, modelling, drying and firing. In 85% of the reported ethnographic cases, clays come from a radius within 1–5km (*Arnold 1985*). While vessel modelling can be a relatively fast activity, drying is often a step that does not take much effort but requires staying in one place until the process is complete, which can take days or weeks, depending on humidity and temperature. Moreover, firing is a step in which the whole process is at stake – it can go well and finish with a good production rate, or it can go wrong and be a great loss. Therefore potters often keep their firing know-how secret, with many myths surrounding the activity to ensure more security for the manufacturer (*Rice 1999*). Furthermore, since the firing stage is so important having an economy of scale is an advantage, and it pays off to produce a considerable number of pieces, such as more than 25 (*Eerkens* et al. *2002*).

We use the technological investment model (TIM) to explore how ceramics were used in the Diamante Valley (Fig. 1). The core concepts of the model derive from the Marginal Value Theorem (*Charnov 1976*). Andrew Ugan, Jason Bright, and Alan Rogers (*2003*) noted that the model considers different technologies along the same utility curve, which makes it difficult to compare variants of different categories, for example a porcelain teapot versus a Stanley thermos to keep water hot. Robert L. Bettinger, Bruce Winterhalder, and Richard McElreath (*2006*) thus improved the model by segregating each technological variant with its own utility curve, permitting independent comparisons for variants within the same technology (low or high investment ceramics), and variants of different technologies with the same function – *e.g.,* the use of leather bags, basketry, and ceramics.

For example, we can consider the use of baskets and ceramics as options for cooking or containers. The TIM application developed by Camilla Sturm, Julia K. Clark, and Loukas Barton (*2016*) allows us to identify the role of utility as a variable that may affect the adoption of ceramics. Specifically, direct-heat cooking provides greater returns because it requires less fuel and labour, facilitating the detoxification of certain plant products, degreasing bones, and processing small seeds that need long, slow cooking (*Sturm* et al. *2016*). These advantages solve scheduling problems related to subsistence practices, labour scarcity, and wood shortages. In addition, ceramics can be produced at scale more easily than baskets, and among hunter-gatherers this can be during an aggregation scenario. For the context of northwestern Patagonia, this is what we would expect for the high-elevation villages. In these locations wild plants are scarce, and therefore it is possible hunter gatherers brought domesticated plants with them to complement their diet, and ceramics may have helped with the storage and cooking of these. Moreover, cooking in pots may have boosted the calorific returns of the guanaco and bird meat available nearby. Despite a higher demand and scale in the highland villages, there is also a severe lack of wood, and therefore is very unlikely that ceramic production and firing occurred at such locations. The use of pots may also have helped to make more efficient use of wood in cooking. Finally, Sturm *et al.* (*2016*) explain that in a longer expected use-time scenario it would be more worthwhile to invest in ceramics.

According to Sturm *et al.* (*2016*), the core concept of the TIM is that the amount of time one would invest in a certain technology will depend on the expected use-time and the utility or benefits that can be obtained from it. Therefore, more expensive technologies that provide higher returns will replace cheaper and less beneficial technologies when their use-time outweighs the production cost.

One way to use ceramics within a high mobility culture is to produce cheap pots that can be easily discarded (*Gibbs 2012*). This is similar to expedient lithic technology performed on local raw materials. In contrast, curated pots with multiple functions might be suitable to transport among sites, allowing reliable and frequent use under an uncertain and patchy environment (*Sturm* et al. *2016*). In the context of northwestern Patagonia, we would expect to find low-investment ceramics used during summer in the highlands. These pots would be made with local clays and temper, mostly unsorted sands, and fired at low temperatures (*c.* 650°C) with uneven firing, represented by oxidized, incomplete firing. Conversely, we would expect to find high investment ceramics used during the rest of the year in the piedmont and the lowlands. These pots would be made with a preferred clay and prepared temper, designed to reduce thermal and physical stress, fired carefully to increase the pot strength, and with surface treatment designed to boost efficiency.

In the Diamante Valley we observe that ceramics were more important for subsistence activities in the intermediate valleys and the high-elevation villages (*Neme 2007; 2016; Morgan* et al. *2017; Franchetti 2019; 2022*). The model applied to foragers who use ceramics in summer predicts low investment related to the immediate and short-term expected use. However, a smaller proportion of the ceramics in the assemblages would have required a higher investment, as related to ceramics prepared for winter and therefore tied to long-term use. In addition, in summer a low proportion of locations could also have high investment ceramics related to longer use, such as rockshelters.

The Diamante Valley: archaeology and environment

Archaeological research over the past 20 years suggests that late Holocene people of northwestern Patagonia did not cultivate domestic crops, in spite of their proximity to farmers, but instead subsisted on wild camelids such as guanacos (*Lama guanicoe*), large flightless birds, small game, and seeds (*Otaola* et al. *2019; 2023*). Around 2000 years ago, demographic pressures, perhaps the result of human population growth, may have forced more intensive resource procurement and processing behaviours, as well as more regular and extensive interactions between individuals and groups over large areas (*Otaola* et al. *2023*). Gustavo Neme (*2007*) describes an intensification process that provoked a series of social changes, including the incorporation of new technologies, such as ceramics and the bow, and the increase of exchanges and territoriality.

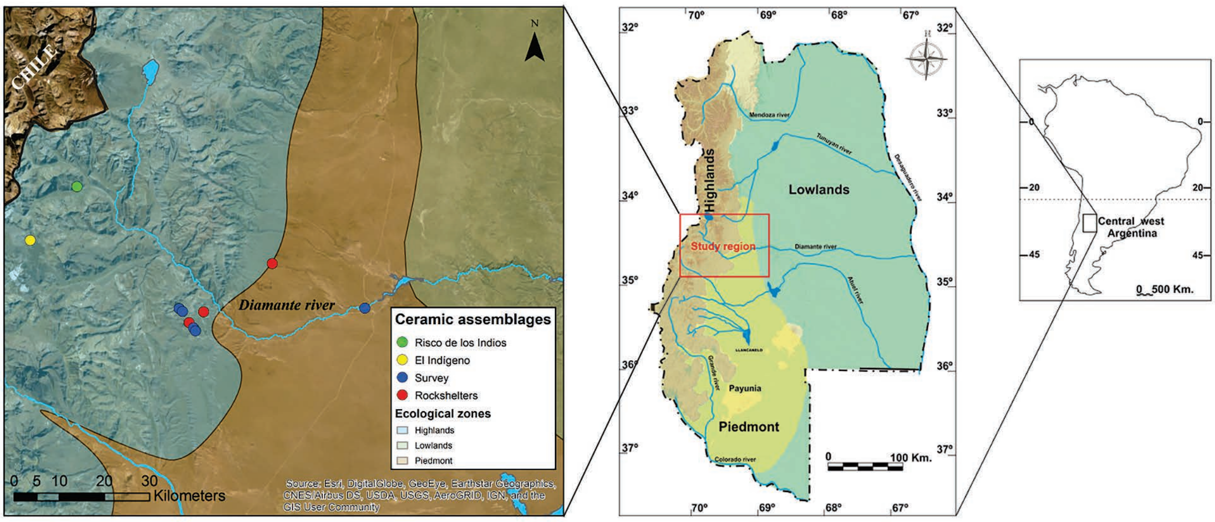
The data available from other areas of northwestern Patagonia (*Sugrañes 2017a*) indicates that ceramic technology played an important role in the subsistence system, without implying an important role in ritual activities. In fact, the forms studied from museum collections of the area reflect a wide variety of potential functions: pots, jars, bowls, vessels and cups (*Sugrañes 2017b*). This functional variability reflects the greater importance of pots linked to cooking and storage – reinforcing the idea that the technology is organized around subsistence and service. From reported radiocarbon dates associated with ceramics in sites of the Diamante Valley we can establish that ceramics were incorporated into the ways of life there around 2300 years BP (*Lagiglia 1997*). Furthermore, there is a higher frequency of radiocarbon dates associated with ceramics, indicating a more consistent occurrence between 1500 years BP until 500 years BP. It is plausible that beyond the earlier dates ceramics were more often used 1500 years BP, when the presence of different ceramic styles increased (*Sugrañes, Franchetti; 2012 Morgan* et al. *2017*).

In northwestern Patagonia, resource productivity and distribution varies in space owing to the enormous variability in average annual rainfall, topography, elevation, and the distribution of different soils across different ecological zones. Resources are therefore heterogeneously distributed and seasonally available. Average annual rainfall in the deserts of northwestern Patagonia is 250mm. Humans inhabit elevations from 700m above sea level in the lowlands to 3600m in the highlands (*Franchetti 2019*). Water is abundant in the highlands during the summer but scarce in the lowlands. While plants are more abundant in the lowlands, large animals are more abundant in the piedmont, though they move seasonally to the highlands in summer and to the lowlands in winter (Fig. 1).

The rockshelter sites are at an altitude between 2000 and 2300 masl. There are two sites excavated by Gambier in the 1970s, Alero Montiel and El Mallín, dated 1500 years BP (*Giardina* et al. *2017*), and one test pit excavated in Cave Manantial. The survey sample consists of ceramics from surface base camps in the highlands (altitude between 2000 and 3000 masl) and one surface base camp in the piedmont (altitude at 1600 masl) (*Franchetti 2019*).

During the last two decades, systematic excavations have been conducted at three high elevation sites with stone structures: El Indígeno, Laguna el Diamante, and Risco de los Indios. These sites date to the Late Holocene, and all of them share certain characteristics: (1) they are located between 2400 and 3400 masl, next to water courses and areas rich in flora and faunal resources called 'vegas'; (2) they are close to mountain passes and contain stone structures; (3) they were occupied within the last 2000 years BP and the people who lived there had a focus on camelid hunting with the complementary use of wild and domesticated plants; and finally (4), they all contain obsidian and ceramics from both sides of the Andes (*Lagiglia 1997; Durán* et al. *2006; Morgan* et al. *2017*).

On the basis of more than 200 stone structures, El Indígeno has been described as a summer occupation site linked to a pattern of vertical transhumance. Further evidence of this includes goods from both sides of the Andes: ceramics, shells, domesticated plants (maize), high proportions of guanacos and birds (*Franchetti* 2019). The importance of ceramics at El Indígeno is evident from the results of an index showing the amount of ceramics divided by the sum of other archaeological materials, with the highest ratio for the region (*Neme 2007*). In addition, some pots were found upside down and this was interpreted as a cache strategy for the reoccupation of the site (*Lagiglia 1997*). Neme (*2016*) argues that the structures were



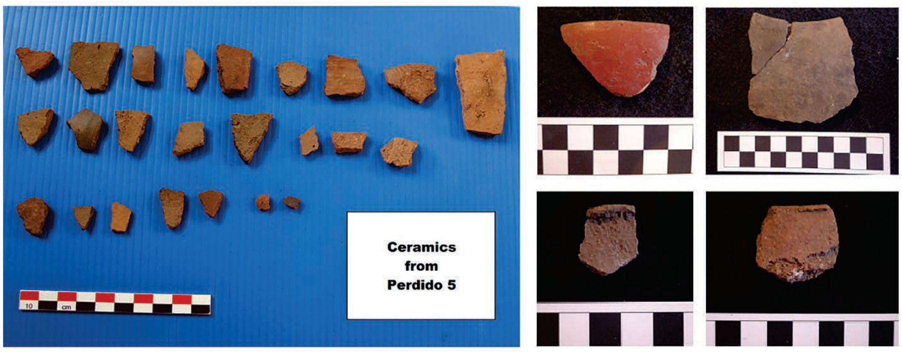


Fig. 1. Map of Mendoza province, Argentina, with ecological zones. Zoomed in to the study area with the ecological zones and the location of the ceramic assemblages from the Diamante Valley. Photography of ceramics from the Diamante Valley.

not occupied simultaneously, and some of the newest structures were built with rocks from the older ones. Guanacos were the main food resource consumed, supplemented with processed plants as suggested by the remains of both maize and grinding stones. Some remains that belong to the lowlands – such as *Zea mays, Lagenaria sp., Empetrum sp*., obsidian, silica, steatite, pottery, and mollusc shells – suggest the intention to minimize risk at high altitude. The amount and diversity of goods from both sides of the Andes have been interpreted as indicative of exchanges between communities from Chile and Argentina (*Neme 2016*).

Risco de Los Indios consists of 29 structures that are mainly circular or ovoid. The archaeological record presents local plants, animals, and lithic raw materials, although the obsidian, ceramics and *Phaseolus sp*. that have been found come from the lowlands or even as far away as Chile (*Morgan* et al. *2017*). The main difference between Risco de Los Indios and both El Indígeno and Laguna del Diamante is that it has fewer structures and was occupied later. Morgan *et al.* (2017) suggest that the use of high elevation villages began about 2100 years ago, peaked between 1500 and 600 years ago, and the population then shifted or moved to slightly lower altitudes thereafter.

Methodology

To test different degrees of investment across the high-altitude landscape of the Diamante Valley we compare four assemblages: (1) Surface survey (N=152), with locations between 1400–2600 masl; (2) Rockshelters (N=170), located between 2000–2300 masl; (3) Risco de los Indios (N=284), a highland village located at 2500 masl; and (4) El Indígeno (N=668), the largest highland village known at the time, located at 3400 masl.

Ceramic materials were cleaned and then subjected to low-power microscopic analysis with a binocular Nikon SMZ stereomicroscope 800 with an objective magnification of 1x and 10x (Fig. 2). We measured the maximum temper size in mm and the temper size in the categories Fine, Medium, and Large (*Orton* et al. *1993*). In the study area we consider local sands as inclusions, and we have detected several common minerals such as quartz, feldspar, and amphibole, among others. In contrast to other areas, we have not identified shells, fibers or grounded ceramics reused as inclusions. It is highly probable that some of the listed minerals are also mixed in with the clays. However, we interpret the proportions seen in the paste as intentionally added (Fig. 2).

Ceramic sherds were also analysed macroscopically and measured in mm with regard to width, length, and thickness. Different categories were recorded for surface treatment (polished, burnished, smoothed), decoration (painted, incised), and firing (oxidized, oxidized incomplete, reduced) (*Orton* et al. *1993; Simms* et al. *1997*).

To explore the degree of investment in ceramic production we will focus on four variables based on the following assumptions (*Simms* et al. *1997; Eerkens 2003; 2008; Roux 2019*): a finer wall thickness demands more work as the piece gets more fragile and unstable during manufacture; a finer and more homogenous temper size implies some extra work in the selection of temper before it is added to the clay; reduced firing implies special techniques and care to reduce the oxygen in the atmosphere during the process; and smoothing is the most common surface treatment (*Simms* et al. *1997; Rice 2015*), as opposed to brushing and polishing. Vessel thickness, temper size, firing and surface treatment should show low investment for the sites of summer aggregation in the highlands, and high investment for the sites in the piedmont. Table 1 presents the degree of investment expected for different

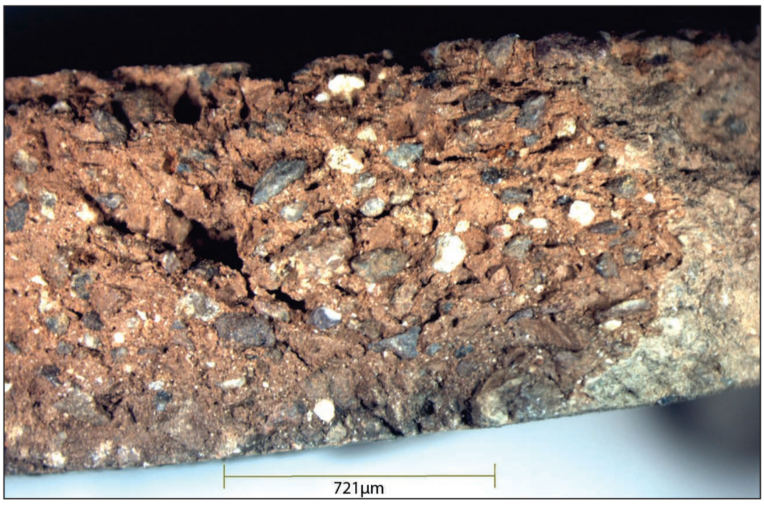


Fig. 2. Photo as an example of inclusions seen with a binocular Nikon SMZ stereomicroscope 800 with an objective magnification of 1x and 10x. Fragment from the Risco de los Indios site.

Degree of investment	Thickness	Temper Size	Surface Treatment	Firing
High Investment	5mm	Fine (0-0.2mm)	Polishing	Reduced
Moderate Investment	6mm	Medium (0.2-0.5mm)	Brushing	Oxidized incomplete
Low Investment	7mm	Large (+0.5mm)	Smoothing	Oxidized

Tab. 1. Degree of investment associated with different states of the variables.

states of the variables thickness, temper size, surface treatment, and firing.

Results

We grouped the findings of ceramics from a surface survey (N=152) and compared them to three other samples. We grouped the ceramics from the sites El Mallín and Alero Montiel, excavated by Gambier in the 1970s, together with a sample from Manantial cave, in the sample called rockshelters (N=170). Another sample includes the ceramic materials from an excavation at Risco de los Indios (N=284) (*Sugrañes 2016*), one of the high elevation villages previously described. The fourth sample are the surface collections materials from El Indígeno (N=668) (*Franchetti, Sugrañes 2012*).

The survey assemblage has an average thickness of 6.3±0.33mm; the rockshelter assemblage has an average thickness of 5.8±0.17mm; the Risco de los Indios assemblage has an average thickness of 6.8±0.19mm; and the El Indígeno assemblage has an average thickness of 5.4±0.13mm; all at a 95% confidence level. Figure 3 indicates that these assemblages are significantly different (at a 95% confidence level) with regard to the average thickness, evidencing an increasing investment for this variable from El Indígeno, then the rockshelters, the survey assemblage, and finally Risco de los Indios.

In Figure 4.A the black line that crosses the bullet graphs from the proportion value indicates that the differences in fine temper size proportions are significant for rockshelters and El Indígeno at 80% confidence level. In Figure 4.B the black line that crosses the bullet graphs from the proportion value shows that the differences in smoothed surface treatment proportions are significant for all the assemblages at 80% confidence level. In Figure 4.C the black line that crosses the bullet graphs from the proportion value indicates that the differences in reduced firing proportions are significant for rockshelters and Risco de los Indios at a 99% confidence level.

From these ceramic results, and beyond some variability among the assemblages, we observe a general pattern which consists of the following: average thickness suggests a low level of investment between 5 and 7mm; temper size percentages are mostly medium between 40–70%; firing technique is mostly oxidized, except for a 40% of reduced firing in the rockshelter assemblage; and the surface treatment is mostly smoothed with ranges of 60–90%. Overall, these assemblages for the Diamante Valley ceramics indicate a trend toward low investment.

Assemblage	Survey		Rockshelters		Risco de los Indios		El Indígeno	
Temper size	Percentage	ER	Percentage	ER	Percentage	ER	Percentage	ER
Fine	26.3	6.9	17.6	5.5	25.5	4.2	13	2.4
Medium	59.2	7.6	62.9	3.5	47.4	3.4	67.8	1.3
Large	13.2	5.3	14.7	5.6	27.1	4	8.7	2.5
Surface treatment	Percentage	ER	Percentage	ER	Percentage	ER	Percentage	ER
Smoothed	75	6.8	84.1	4.84	70.1	5.2	86.5	1.9
Polished	23.7	6.7	8.2	12.9	28.5	8.2	7.5	6.5
Firing	Percentage	ER	Percentage	ER	Percentage	ER	Percentage	ER
Oxidized	71.1	7.2	24.7	6.3	70.4	5.3	75	3.1
Oxidized incomplete	27	7	31.2	6	12.7	9.1	18.8	5.8
Reduced	2	2.2	40	5.5	16.9	8.8	3.29	6.4

Tab. 2. Percentages and error ranges (ER) at a 95% confidence level for temper size, surface treatment and firing among the assemblages from the Diamante Valley.

Discussion

Our research question was as follows: How was ceramic technology used by small-scale mobile societies in the highlands of northwestern Patagonia? We can answer that ceramics are more abundant in the highlands, and their use is also present and more important in high-elevation villages and some rockshelters. The investment in ceramic technology, beyond some internal variability, is low.

This is consistent with the idea proposed by Sturm *et al.* (*2016*) that when hunter-gatherers stay in summer camps they will tend to invest less in this technology because they do not expect to use it forvery long, and there is a conflict with other activities important to subsistence during this season. This contrasts sharply with previous expectations that related the higher investment in ceramics with increasing altitude (*Franchetti, Sugrañes 2012*). The application of the TIM model undermines the use of environmental determinism when we try to explain human decisions to adapt to marginal conditions. Even in those contexts, small-scale societies prove to have a myriad of strategies to manage risk and contingency.

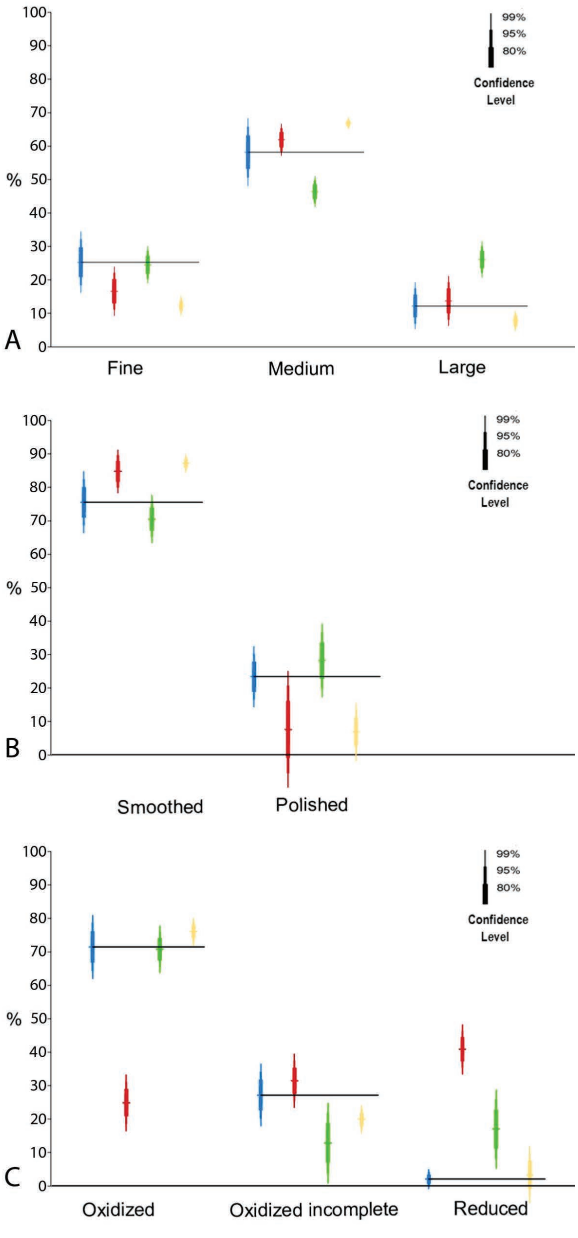


Fig. 4. Bullet graphs comparing temper size, surface treatment, and firing percentages in the survey (blue), rockshelters (red), Risco de los Indios (green) and El Indígeno (yellow) assemblages.

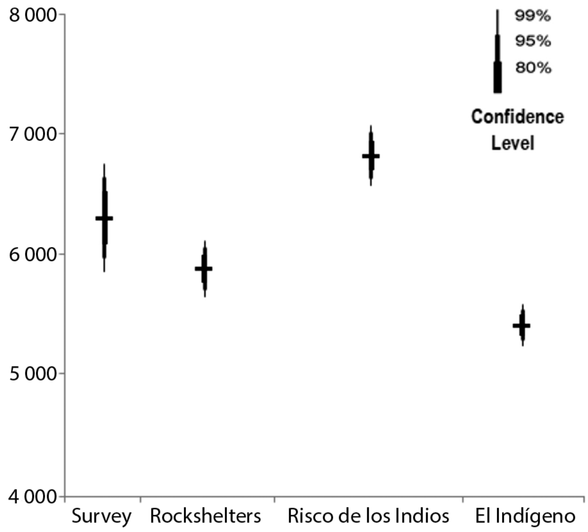


Fig. 3. Bullet graph comparing average thicknesses (in mm) at the survey, rockshelters, Risco de los Indios, and El Indígeno assemblages.

Hunter-gatherers of the Diamante Valley made decisions on how to incorporate ceramics considering the use-time at certain locations while evaluating the manufacturing time and the utility to be gained. Jelmer W. Eerkens (*2003*) suggests that a strategy hunter-gatherers use to engage in ceramic technology is through the re-occupation of settlements. By caching pots in the summer settlements in the highlands people reduce the cost of transport and increase the expected use-time. However, the low investment observed in the variables of thickness, temper size, surface treatment and firing suggest that human groups did not expect to use the pots for very long. This is consistent with the availability of the highlands and use of the highland villages only during summer. This could also suggest that there was not a reoccupation of these locations each year. This may imply that different locations were occupied across generations in the Perdido stream, although the re-occupation of these sites may not have been the norm. This secondary tributary of the

Diamante River was probably a pass through which people moved towards higher elevation patches and the high-elevation villages.

The discussion of trade or local production would require further exploration, but we can set a basic framework. It is very likely that ceramics were produced locally as is evidenced by the predominance of local styles in the Diamante Valley. The presence of other styles, even in very small frequencies, suggests that they were acquired through exchange or even visits from groups who spent the other months of the year living on the west side of the mountains. The exchange of gifts might have reinforced alliances that allowed the use of complementary regions and access to other territories when the groups from one or the other were under nutritional stress. A similar pattern has been proposed for southern Mendoza, with the high-altitude villages serving as aggregation areas for groups from different ecological regions (*Lagiglia 1997; Neme 2007*). In summary, ceramics were more prevalent in the highlands although investment in their production was low, as might be expected for summer camps in mobile societies, for which the expected use-time was low.

Hunter-gatherers face many challenges when incorporating ceramic technology. Mobility, the main strategy for buffering the heterogeneous distribution of resources both in time and space, implies serious constraints on the accumulation of goods. Ceramic technology competes with previous technologies such as basketry and leather manufacturing, which can be lighter and less fragile in transport (*Eerkens 2003; 2008*). However, when hunter-gatherers rely more on upland areas within their seasonal mobility range, the importance of new technologies such as ceramics played a key role in boosting the occupation of more risky environments (*Barton 2016*).

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Pottery vessels, technological knowledge, and potters at the Early Copper Age site of Polgár-Király-ér-part (Northeastern Hungary)

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ABSTRACT - *This paper investigates the long-debated issue of technological knowledge and potters in the Early Copper Age (4500–4000/3900 cal BC) through the analysis of the forming technology of a typical, small-scale settlement at Polgár-Király-ér-part (Northeastern Hungary). A complex technological knowledge of forming was identified, in which most of the vessel types have their own forming method. This technological knowledge presumably originated in the local Neolithic. However, a few smaller technological differences nuance this picture, raising the possibility of distinct learning networks and multiple potters at the settlement.*

KEY WORDS – *pottery* chaîne opératoire*; technological analysis; pottery forming; Great Hungarian Plain; Early Copper Age*

Lončene posode, tehnološko znanje in lončarji v zgodnji bakreni dobi v naselbini Polgár-Király-ér-part (severovzhodna Madžarska)

IZVLEČEK – *V članku s pomočjo analize tehnologij oblikovanja posod raziskujemo tehnološko znanje in delovanje lončarjev v majhnem naselju Polgár-Király-ér-part v severovzhodni Madžarski v zgodnji bakreni dobi (4500–4000/3900 pr. n. št.). Prepoznali smo kompleksno znanje tehnik oblikovanja, pri čemer ima večina tipov posod lastno tehniko oblikovanja. Tehnološko znanje najverjetneje izhaja iz lokalnega neolitika. Manjše tehnološke razlike nakazujejo različna učna omrežja in delovanje več lončarjev v naselju.*

KLJUČNE BESEDE – *operacijska sekvenca izdelave lončenine; analiza tehnik; oblikovanje lončenine; Velika madžarska ravnica; zgodnja bakrena doba*

Introduction

After the Late Neolithic, in the mid-5th millennium BC, many aspects of life were gradually transformed in the Early Copper Age on the Great Hungarian Plain (Eastern Hungary). The tells and large horizontal settlements were replaced by a network of small settlements (*Sherratt 1982; 1983a; 1983b; Parkinson 2006b; 2006a; Parkinson, Gyucha 2007*), the first formal cemeteries were established alongside the continuity of the tradition of burials on settlements (*Patay 1961; 1974; Bognár-Kutzián 1963; 1972; Raczky, Siklósi*

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2013; Raczky et al. *2014; Siklósi, Szilágyi 2021*), and the first appearance of heavy copper tools (*Bognár-Kutzián 1963; Patay 1974; 1984; Siklósi* et al. *2022*).

In previous chronological models, the Tiszapolgár culture was dated to the Early Copper Age, which was followed by the Middle Copper Age Bodrogkeresztúr culture (*Kalicz 1958; Banner, Bognár-Kutzián 1961; Patay 1961; 1974; Bognár- Kutzián 1963; 1972; 1985*). This distinction was mainly based on the analysis of cemeteries (*O.c.*) and supported by calibrated radiocarbon dates (*Raczky 1995*). However, from the very beginning it was difficult to separate the pottery of the two cultures despite the strict chronological distinction. Several vessel types – such as bowls, barrel-shaped vessels, or storage vessels – occur even at those Tiszapolgár and Bodrogkeresztúr sites, upon which the chronological separation of the two cultures was based (*Bognár-Kutzián 1963.236–294; 1972.119–135; Patay 1974.19–29*). Therefore, the focus was mainly on a few characteristic forms, for example the so-called 'milk jugs' or two-handled cups, both defined as 'culture-specific' vessel types of the Bodrogkeresztúr culture (*Bognár-Kutzián 1963.276–285; Patay 1974. 20–21,25–26*). This similarity could also be observed in the case of pottery decoration. Knobs and lugs dominated plastic applications in both pottery traditions (*Bognár-Kutzián 1963.300–306; 1972.118–135*). The typo-chronologically most distinctive features were the impressed and incised motifs that were mainly associated with the Bodrogkeresztúr culture (*Patay 1974.42–43*), but such motifs could also be observed in some assemblages considered to be from the Tiszapolgár culture (*Bognár-Kutzián 1972.172–182; Patay 1979.38–41*). The high degree of similarity of pottery often made it difficult to link assemblages to one culture or another.

It has recently become clear that the previous chronological and cultural models of this period need to be revised. Firstly, the new AMS data and Bayesian modelling challenged the absolute chronology of the two cultures by dating them both to the Early Copper Age. The appearance of the Tiszapolgár culture on the Great Hungarian Plain can be dated earlier, at least from 4435 (68.2%) 4385 cal BC to 4220 (68.2%) 4165 cal BC (*Siklósi, Szilágyi 2021.35*). The Bodrogkeresztúr culture appeared a little later, first in the Middle Tisza Region around 4400 (68.2%) 4325 cal BC. Then it can be observed throughout the whole Great Hungarian Plain until 4020 (68.2%) 3930 cal BC (*Siklósi, Szilágyi 2021.35,40*). Secondly, new studies on Early Copper Age settlements (*Parkinson 2006a; 2006b; Parkinson, Gyucha 2007; Raczky* et al. *2014; Gyucha 2015; Szilágyi 2015; Parkinson* et al. *2021*) shed light on the differences between the pottery assemblages of the settlements and those of the burials (*Siklósi* et al. *2022. 354–358*). Certain vessel types, such as 'milk jugs' or two-handled cups, which played an important role in the definition of the Bodrogkeresztúr culture, are primarily known from special ritual contexts, mostly graves (*Szilágyi 2015.316–319*). The stylistic analysis of the settlements proved that the Tiszapolgár and Bodrogkeresztúr pottery assemblages cannot be clearly separated (*Szilágyi 2015.289–296*).

These new studies demonstrate that the Tiszapolgár and Bodrogkeresztúr cultures cannot be described as different, well-defined, homogeneous entities, and that there is no sufficient explanation for the variability or homogeneity of the pottery styles (*Siklósi* et al. *2022. 351–352*). One possible way to explain either variability or homogeneity is to define the different characteristics at the level of individual vessels using bottom-up analytical approaches rather than broad cultural definitions.

Furthermore, recent settlement analyses highlighted the issue of social organization in the Early Copper Age. After the abandonment of the Late Neolithic tells and large horizontal settlements on the Great Hungarian Plain, the settlement structure was transformed into a network of considerably smaller settlements (*Parkinson* et al. *2010; 2021; Gyucha 2015; Szilágyi 2015*). William A. Parkinson and Attila Gyucha assumed that the small, single-roomed houses discovered in the Körös Region in the southern part of the Great Hungarian Plain were used by nuclear family groups (*Parkinson 2006a.151; Parkinson, Gyucha 2007.64*). According to the low number of buildings (mostly one to three), small-scale communities – probably extended families – inhabited these settlements (*Gyucha 2015.137; Parkinson* et al. *2021.183*). In terms of pottery, this raises the question about the number of potters who made the vessels in these communities and the pottery-making tradition they followed.

The present paper aims to investigate the issues listed above using the technological approach of pottery forming. One of the main advantages of this methodology is its capability to define real embedded knowledge and social patterns by a detailed analysis of the individual vessels. This method is based on the French school of the anthropological approach of techniques

(*Leroi-Gourhan 1943; 1945; 1964; 1965; Mauss 1947*) that describes the strong relation between the steps of a production process (*i.e. chaîne opératoire*) and the social identity of the producer (*Balfet 1975; 1991; Cresswell 1976; Lemonnier 1991; Latour, Lemonnier 1994*). In the case of pottery vessels, this link is to be found in the relation between the vessel fabrication steps and the social link(s) of the potter. The reason for this lies in the learning process, because the necessary motoric and cognitive skills of forming are acquired during a long learning period. During that time, the learner observes and copies the 'way of doing' of the tutor, *i.e.* tools or gestures. Once the learning process is complete, the learned motor and cognitive skills become fixed and difficult to change later (*Bril 2002*). The transmission of knowledge is always personal, where the tutor and the learner are socially related in some way (not necessarily biologically related). Thus, the learning process always takes place in social groups, connected by shared technical knowledge, *i.e.* communities of practice (*Lave, Wenger 1991; Wenger 1999*). The continuous transmission of the 'ways of doing' over a long period creates technical traditions of pottery forming, that can be studied in space and time (*Gosselain 2002.26; Gelbert 2003.53–59; Gosselain, Livingstone Smith 2005.41–42; Roux 2010.6; Gomart 2014a.154; Giligny 2015.73*).

The focus of this paper, Polgár-Király-ér-part, is an ideal case study for exploring these issues, as it is a typical, small Early Copper Age settlement, which is extremely homogeneous in terms of pottery style (*Szilágyi 2015. 140–141*). Thus, the technological analysis of pottery forming could clarify the technological variability behind the uniform repertoire of pottery forms and decorations. Moreover, the technological diversity can reflect the number of potters in this small-scale settlement and their learning networks.

Material

Polgár-Király-ér-part lies on the so-called Polgár island, which is a well-studied region in the Northern Great Hungarian Plain, in Northeastern Hungary (Fig. 1). Many archaeological sites are known in this region, from which 24 can be dated to the Early Copper Age (*Raczky* et al. *2014.328*). The Király-ér-part site is situated on the bank of the Király (or Selypes) Creek, and was revealed in 1995 during the preventive excavations of the M3 Motorway construction (*Hajdú, Nagy 1999.144–146*). Altogether 22 archaeological features could be dated to the Early Copper Age: eight graves and 11 settlement pits (Fig. 2; Tab.1 see below). The remaining three features[1] cannot be categorized due to the insufficient documentation.[2] According to the traditional stylistic classification, the assemblage was dated to the Tiszapolgár culture (*Szilágyi 2015. 130–141*). As the features were situated in the southwestern part of the excavated area, we can assume that the settlement was only partially unearthed. No trace of buildings or ditches could be observed, and therefore the settlement structure remained unclear. According to the most recent AMS dating, the Early Copper Age site of Polgár-Király-ér-part can be dated between 4370 (68.2%) 4120 cal BC and 4235 (68.2%) 4015 cal BC and the span of use can be estimated to 0 (68.2%) 100 years (*Siklósi, Szilágyi 2021.600*).

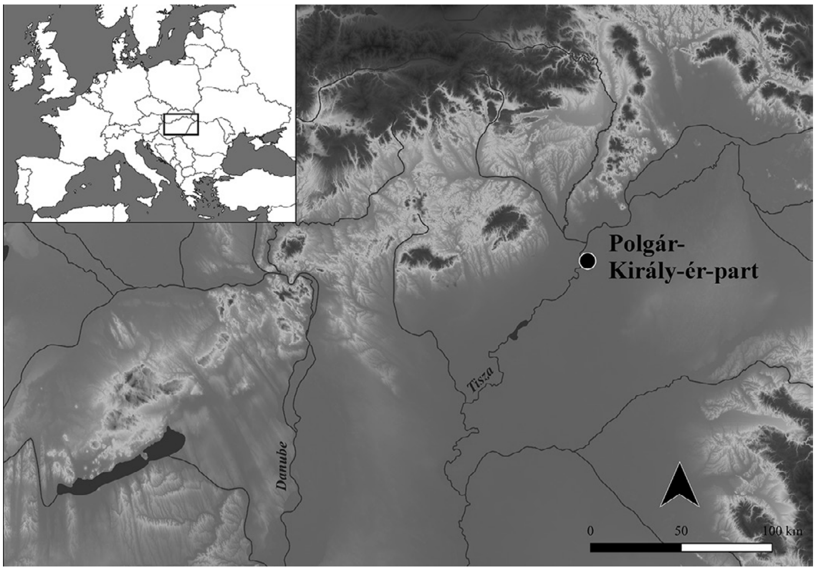

Fig. 1. Location of the analysed site.

Overall, 470 pottery sherds were analysed, belonging to at least 338 vessels. The small and non-diagnostic sherds were most likely discarded undocumented shortly after the excavation (*Szilágyi 2015.134*). Of

1 Presumably two archaeological features were also given the number 139. However, due to lack of documentation, it is not possible to separate them.

2 Zsuzsanna Siklósi and Márton Szilágyi (*2021.591*) defined nine graves and 13 settlement features on the site, classifying one uncertain feature among the burials and two among the settlement features.

the 338 vessels that were preserved in the museum, 69 vessels from 11 settlement pits, three graves, and the two undefined features were suitable for technological analysis. That is because these vessels contained macroscopically identifiable traces of forming.

The most common vessel category among the 69 examined vessels was the different types of bowls, either pedestalled or flat-based: conical, wide conical, hemispherical, carinated, and gently S-profiled (Fig. 3). Barrel-shaped vessels, jars, and storage vessels also occurred frequently, and some tumblers were also found (Fig. 4). Besides, the exact type of some vessels cannot be defined, and thus these were classified into three categories: bases,[3] fine wares, and coarse wares[4]. Plastic applied decoration was dominant in the material, and only a few simple geometric patterns of impressed dots were identified (*e.g.,* two impressed dots). The pottery style of the vessels in the settlement features and the burials cannot be clearly separated.

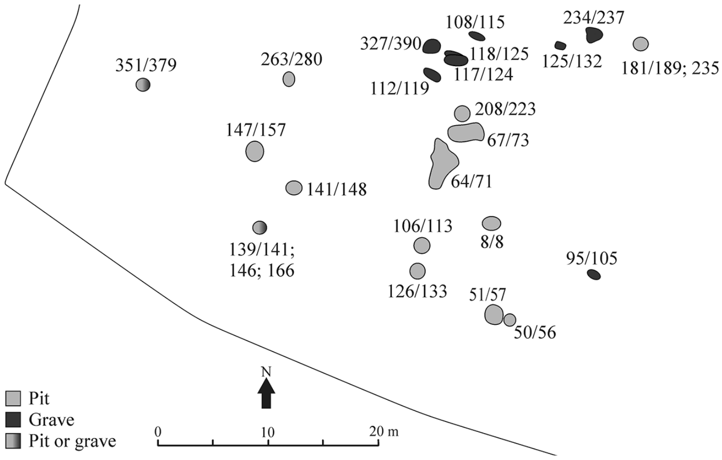

Fig. 2. Map of the excavation at Polgár-Király-ér-part highlighting the Early Copper Age archaeological features.

Method

Although the methodological basis for the technological study of the forming of pottery vessels has been laid down in many significant works (among others *Rye 1981; Rice 1987; Roux 1994; 2010; 2016; 2019; Pierret 1995; Martineau 2000; Gosselain 2002; Gelbert 2003; Livingstone Smith 2007; Giligny 2010; Gomart 2014b*), the methodology is not strictly standardized and unchanging (*Pyzel, Gomart 2023.118*). The reason for this lies in the great diversity of pottery assemblages, and therefore the general rules and application of this approach must be adapted to the studied assemblage(s), as will be shown in this paper.

Macroscopical analyses were carried out on the inner and outer vessel surfaces were assessed visually to study the wall thickness, the lines of fractures, and the internal structure of the vessel walls to identify macrotraces – *i.e.* discernible forming traces (*Pierret 1995.59; Livingstone Smith 2010.112–129; Van Doosselaere 2010.180–222; Gomart 2014b.44–45; Roux 2016.179–187; Solnay 2021.201*). All identifiable forming phases of all diagnostic vessels were recorded, described, and drawn and/or photographed following the method of François Giligny (*2010.2*) and Louise Gomart (*2014.45*). The observations were then coded and recorded in a database. As a result of a systematic analysis of macrotraces, forming methods can be reconstructed, which can be defined as an ordered sequence of certain functional operations from the beginning of the forming to the creation of the final vessel form (*Roux 2019.41*).

Potters used a variety of forming techniques, *i.e.* physical modalities of clay transformation, for the successful realization of a forming method (*Roux 2019.41–42*). These techniques can be classified into two large categories: the roughing-out, during which the vessel gets its basic shape, and the preforming, during which the vessel gets its final shape (*Rye 1981.62; Roux 1994; 2019.41; Pierret 1995.16–17; Martineau 2000.116; Gosselain 2002.80; Livingstone Smith 2007.94–95; Gallay 2012.61*). For the identification of the different forming techniques, many ethnographic, archaeological, and experimental collections have provided comparative references (*Smith, Crépeau 1983; Gelbert 2003.15; Giligny 2010.21; Van Doosselaere 2010.223; Gomart 2014a.146; Solnay 2021.203*).

In this Early Copper Age pottery assemblage, only the roughing-out techniques could be systematically identified and preforming techniques with characteristic macrotraces appear only sporadically on a few vessels. Therefore, the determination of the forming method is only based on the roughing-out technique of the five

3 In the case of these vessels, only the base was known. Therefore, it is often not possible to classify it clearly into any of the other categories.

4 For fine and coarse vessels, not only the base but also a large part of the vessel was known (*e.g.,* the body), but the exact shape could not be determined.

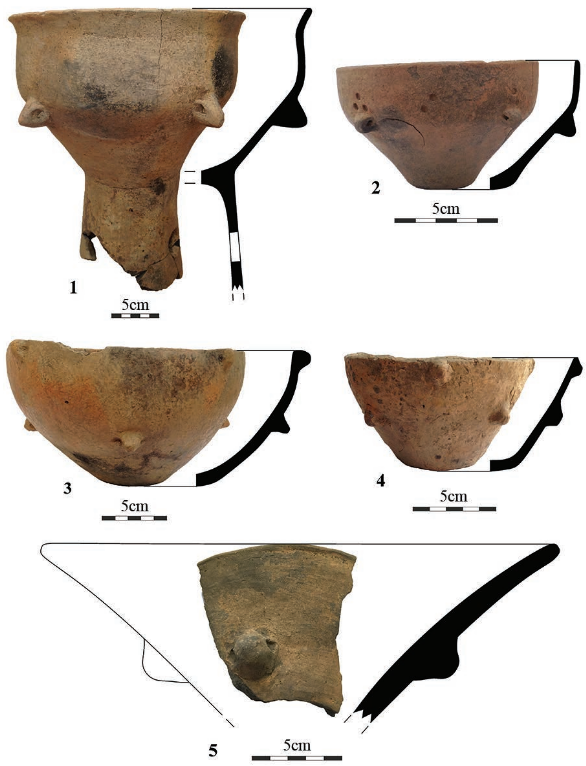

Fig. 3. Different main bowl types from the site. **1** ***gently S-profiled bowl (with pedestal) (grave 112/119);*** **2** ***carinated bowl (grave 327/390);*** **3** ***hemispherical bowl (grave 327/390);*** **4** ***conical bowl (grave 327/390);*** **5** ***wide conical bowl (pit 147/157).***

distinct sections of the vessels: (1) pedestal, (2) base, (3) body, (4) neck, and (5) rim. Although, due to the fragmentation of the material, it was not possible to observe the whole forming method on every vessel. Besides, it was also important to describe the preforming techniques separately but, at the same time, avoid the creation of further subgroups based on only a few sherds. Preformed vessels are thus always presented within the relevant method and are not defined as separate variants. In that way, the data that might be important after the technological analysis of further sites in this period and/or region are preserved.

Results

Forming technology

Overall, three forming methods were identified in the assemblage (Forming method 1–3), with Forming method 1 having two variants (Variants 1.1 and 1.2) based on the differences in the making of one section of the vessel.

Forming method 1

In Forming method 1, the bodies of most of the vessels – 43 in total – were shaped with the same technique (Figs. 5–7). Undulations, bulges of clay, as well as horizontal lines of fractures and fissures could be observed on the outer and/or inner surface of the bodies. These indicate a bottom-up coiling technique when the vessels were built from coils from the bottom towards the rim. Besides, in the case of one vessel, the absence of a characteristic fracture in the profile between the base and body raises the possibility of coiling in/on a support (Fig. 6.2).

The configuration and size of the coils are very diverse, they can be varied even on the same vessel. The configuration can be inward oblique (Fig. 6.2), S-Z-shaped (Figs. 5.4, 6.1), mixed inward oblique and S-Z-shaped (Fig. 7.1), as well as O-shaped (Fig. 6.1). The size of coils cannot be clearly grouped, even if we are taking the configuration into account.[5] Coils are generally between 2–5cm. The macrotraces of coils indicate two different procedures: the usage of superposed or

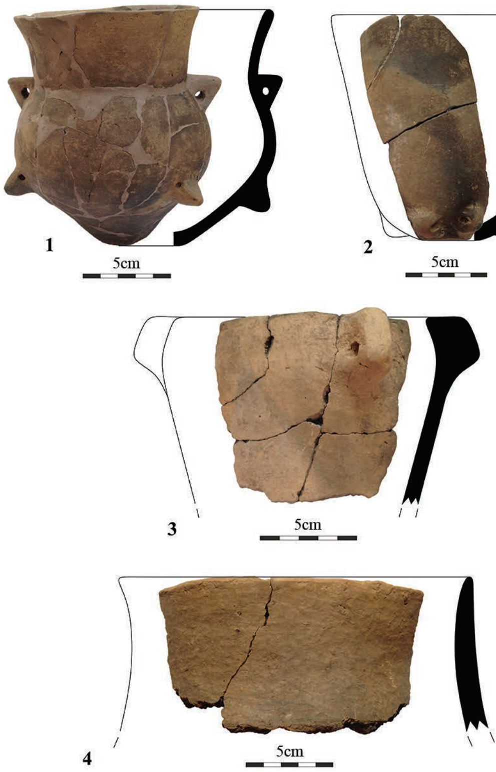

Fig. 4. Main vessel categories from the site, other than bowls. **1** ***jar (grave 112/119);*** **2** ***tumbler (pit 106/113);*** **3** ***barrel-shaped vessel (pit 67/73);*** **4** ***storage vessel (pit 64/71).***

5 The only exception is one O-shaped coil (1cm) that is observed on an otherwise S-Z-shaped configuration. However, in the present context, we do not consider it necessary to group the whole assemblage on the basis of this single vessel.

elongated coils. In the latter case, the coils have been attached together in several different ways from the inside, the outside or in alternating directions. Due to the high degree of variability of procedures of coiling and ways of attachment, even on a single vessel, (Figs. 6.1, 7.1), it was not possible to make relevant categories of the different ways of coiling in this assemblage.

In Forming method 1, two variants can be separated based on the shaping of the base. In Variant 1.1 (Fig. 5.1–3), oval and rounded depressions were found on the inner and/or outer surfaces of six vessels. The lines of fractures are occasionally laminar. The internal structure was homogeneous or linear fissures can be observed. This suggests that the base was built from

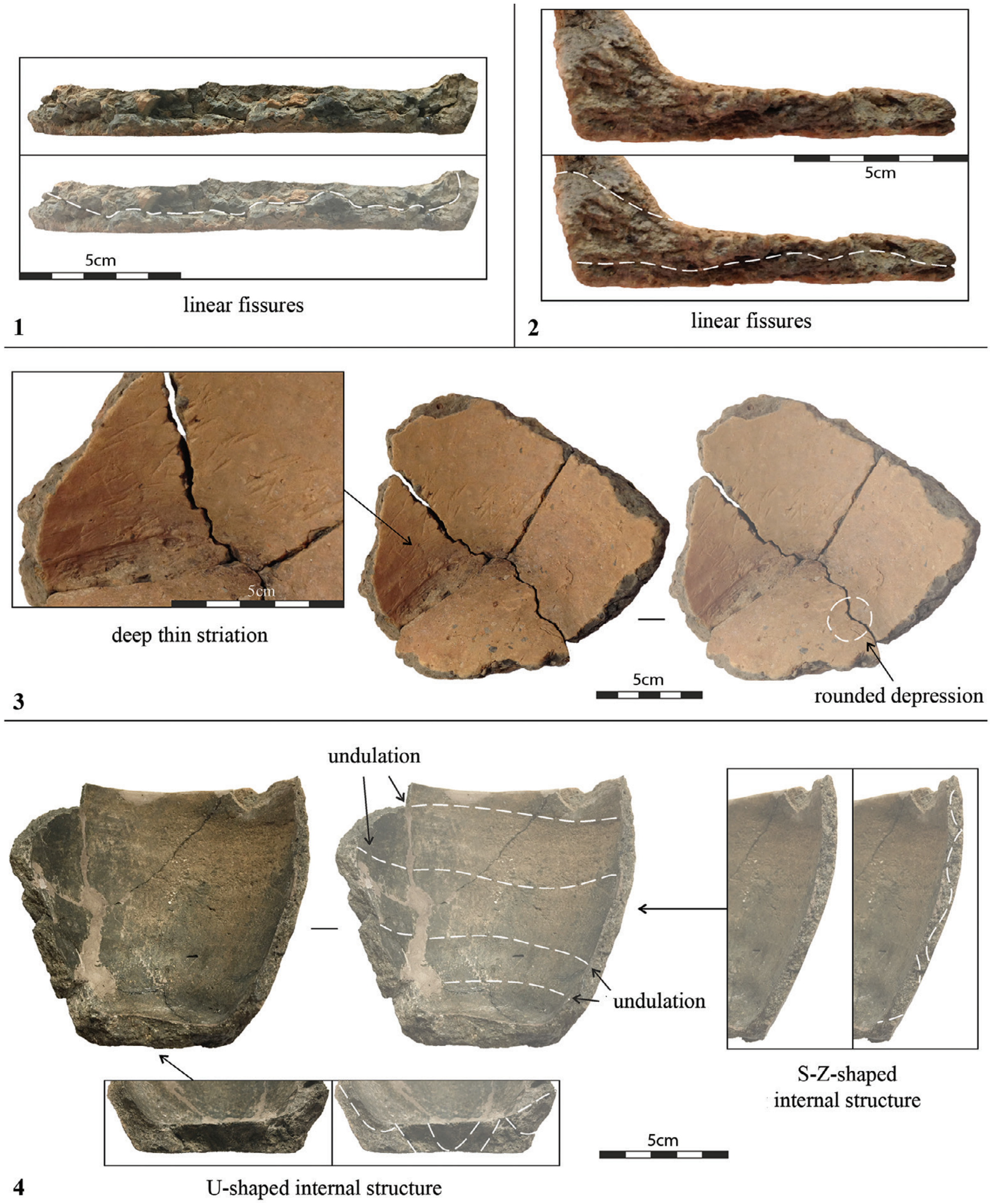

Fig. 5. Macrotraces of Forming method 1. 1 ***Variant 1.1 (grave 112/119);*** 2 ***Variant 1.1 (pit 64/71);*** 3 ***Variant 1.1 (pit 64/71);*** 4 ***Variant 1.2 (pit 51/57).***

one or more (mainly one) superposed clay disks, followed by a body built with coils.

Moreover, in the case of one vessel in Variant 1.1, horizontal, deep, thin striation can be observed at the inner surface of the joint of the base and the body (Fig. 5.3). This could be an indication of scraping, when a vessel is preformed using a rigid tool to profile the inner surface.

In the case of Variant 1.2 (Fig. 5.4), undulation can be observed on the inner surface of three vessels. The

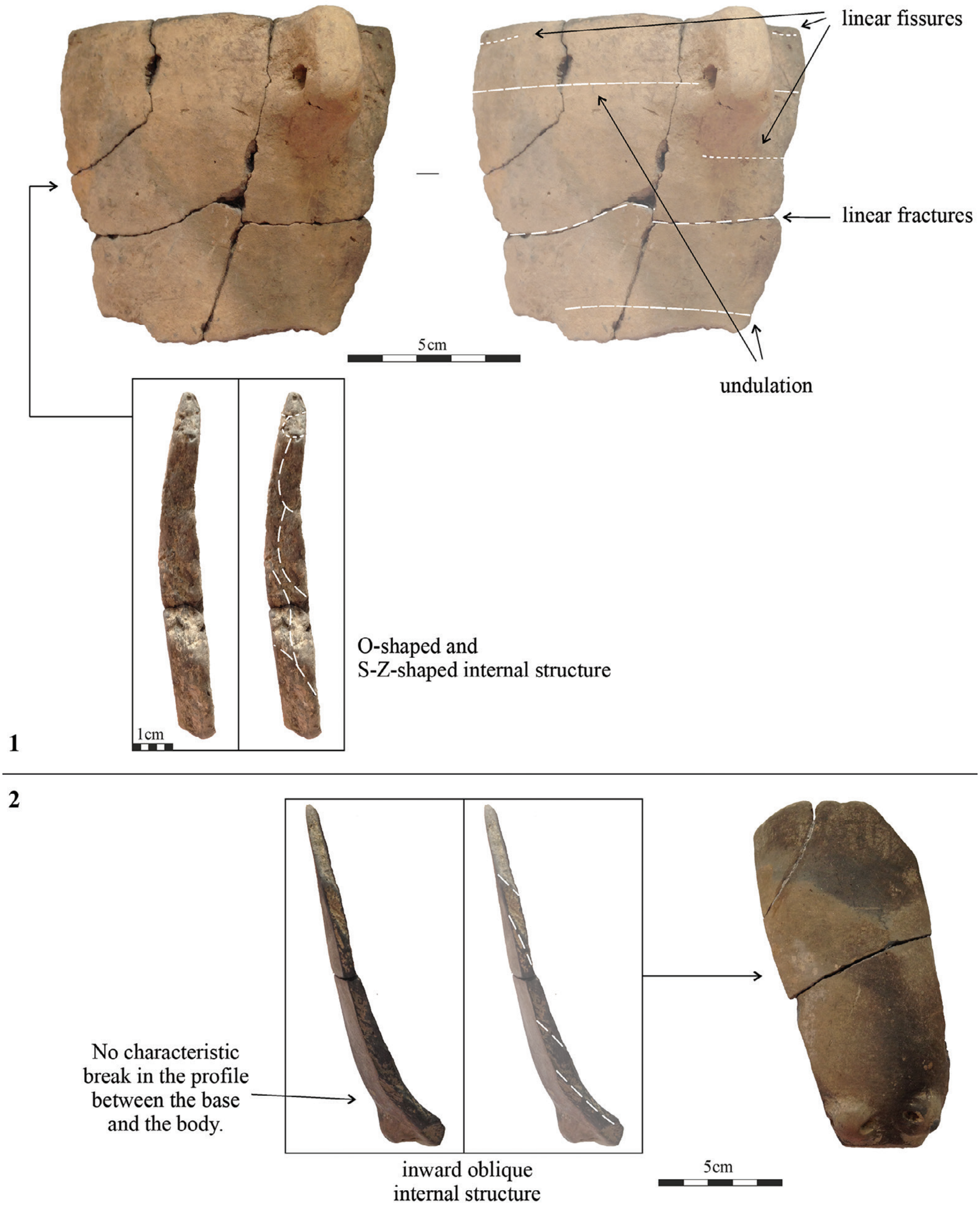

Fig. 6. Macrotraces of Forming method 1. **1** ***vessel with unknown base (pit 67/73);*** **2** ***vessel with unknown base (pit 106/113).***

lines of fractures are circular. The internal structure of the base is C/U-shaped. This refers to a base made of a spiral or rings of coils.

Furthermore, the base of 30 vessels is missing (Fig. 6), only the bottom-up coiled bodies were found. Thus, they cannot be classified into a variant. In the case of one vessel, the wall of the body was thinned towards the base and there is no characteristic fracture in the profile between the base and the body, which might indicate that support may have been used while joining the coils (Fig. 6.2). Since there is only a single vessel, in case of which the possibility (not certainty) of using a support emerged, it was not considered as a separate variant at this stage of the study. Furthermore, if the form required it, a neck was added to the body. The macrotrace of the neck is similar to that of the body (Fig. 7.1), and thus it could have been formed with coils.

Moreover, preforming techniques were identified in the case of four vessels whose bases were unknown. On the one hand, horizontal, deep, thin striation can be observed at the inner surface and/or outer surface of the body or neck (Fig. 7.1) of three vessels. Similarly to the previous pot in Variant 1.1, this suggests preforming with scraping. On the other hand, longitudinal flat stripes were found on the inner surface of a pottery neck (Fig. 7.2). This indicates that the inner part of the vessel was profiled with a sharp tool that can be defined as shaving. Furthermore, horizontal, deep, thin striation was found above the longitudinal flat stripes that might refer to scraping after shaving.

Forming method 2

In total, seven vessels can be categorized into Forming method 2 (Fig. 8). Characteristic oval and circular depressions were found on the outer surface of the base. The internal structure of the base showed continuity with the body and the profile of the vessel is continuous. It is thus possible that the base and the body were formed together. The inner and outer surfaces of the body were mainly homogeneous with slight undulations on the outer surface. The internal structure of the body was inward oblique, almost parallel to the wall. This suggests strongly elongated coils (6– 9cm) on the whole body.

However, the wall of the body was relatively thin (1–2cm), and the size of the body was comparatively large (the diameter of the rim was approximately 20–25cm and the height of the body was around 15cm). These parameters imply that it would be difficult to build such vessels from coils of this size and shape without a support (*Gomart 2014a.157*). Given that the inner surface of the vessels is homogeneous and macrotraces can only be found on the outer surface, concave support can be presumed (when the vessel was built on – not in – the support) in the case of these vessels. This hypothesis can be reinforced by the observed oval and circular depressions in the outer surface of the base. These traces can only be created when the paste is still wet, possibly when the joint of the coils is worked together with the fingers. Presumably, the easiest way to do this is to turn the vessel upside down. Therefore, the base and body of the vessels in Forming method 2 are probably shaped with the reverse coiling technique.

Depending on the form of the vessels, other parts were also shaped and subsequently added to the main body. First, pedestals can be formed where strong undulation occurs on the outer surface. Besides, the internal structure is exclusively S-Z-shaped, suggesting a coiling technique with elongated coils (4–6cm).

Rims could also be made separately from the body with bottom-up coiling, based on the thinning of the wall of the rim and the horizontal lines of fissures between the body and the rim. Only one internal structure can be studied that shows an O-shaped configuration. This refers to superposed coils, even though the body was formed with elongated coils.

Forming method 3

Nineteen vessels can be categorized into Forming method 3 (Fig. 9). The base of these vessels is never sharply separated from the body, and thus it could have been formed from one clay mass. The inner and outer surfaces of these forming phases are generally homogeneous, only a few shallow depressions were found. The lines of fractures can be central, from the rim towards the base in a relatively straight line. The internal structure was homogeneous. This evidence indicates the use of a moulding technique that consists of a clay mass that was pushed on/in a form to take its shape.

The rim of these vessels was shaped separately with a bottom-up coiling technique based on the oval and longitudinal depressions on the inner and outer surfaces (working together the body and the rim with fingers), the thickening of the rim, as well as the inward oblique or S-Z-shaped internal structure. The size of the coils is generally between 1–3cm. This suggests that some of these were probably superposed coils but are aligned in alternate directions (Fig. 9.2), and others are elongated coils (Fig. 9.1). However, in many cases the size and gradient of the coils do not allow us to separate these procedures on the vessels. Therefore, in this paper, no classification was made based on the coils, as with Forming method 1.

Forming technology and pottery types

The variability of forming technology cannot be investigated without the comparison of the forming techniques and the pottery types (Fig. 10). Certain types cannot be made with a given technique or require a large effort. Therefore, the shape of the vessels may have a strong influence on the technique that is applied (*Arnold 1989.34*).

Barrel-shaped vessels – one of the most common vessel types at the site – were always formed with Forming method 1, *i.e.* bottom-up coiling. However, the base can be built in different ways. Superposing one or more clay discs was the most common base-building technique (Variant 1.1), but it could also be made of

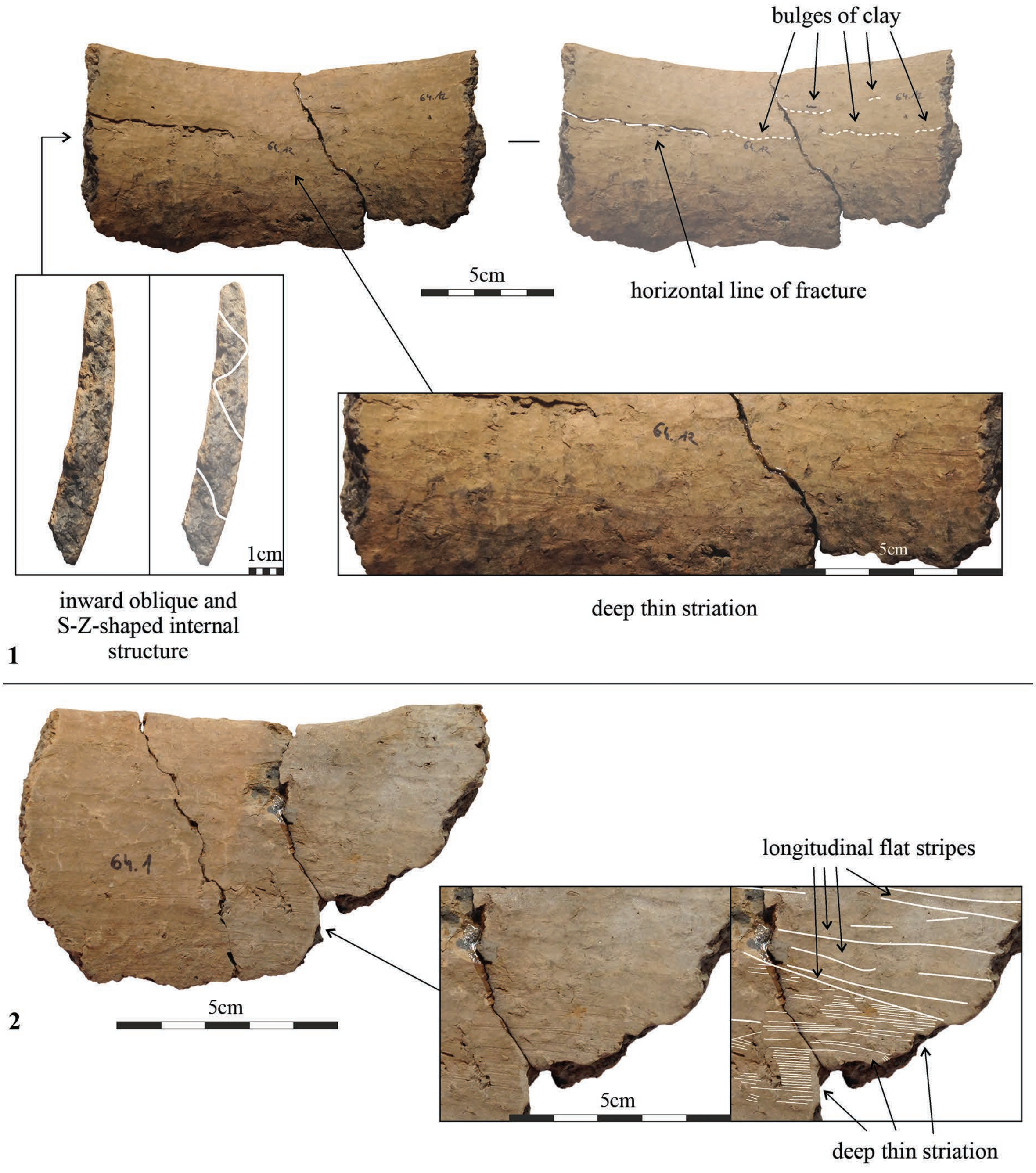

Fig. 7. Macrotraces of Forming method 1. 1 ***Variant 1.3 (pit 64/71);*** 2 ***Variant 1.3 (pit 64/71).***

coil rings or spirals (Variant 1.2). Thus, in the case of barrel-shaped vessels, we can reckon with a certain technological variability within the similar forming technique.

Storage vessels were also made by Forming method 1. However, the forming of the base is not known.

The two analysed tumblers were also made with Forming method 1. Only the shaping of one base can be defined, it was made of coil rings or spirals (Variant 1.2). The others cannot be classified into any of the variants because the bases were unknown. Besides, the macrotraces of one latter vessel (with unknown base) raise the possibility of coiling in/on a support, which would be an important technological difference.

Jars were also exclusively made by Forming method 1. All the known bases are made with one or more superposing clay discs (Variant 1.1). However, in many jars, the fragment of the base was not found, or it was not-enough to determine the forming technique.

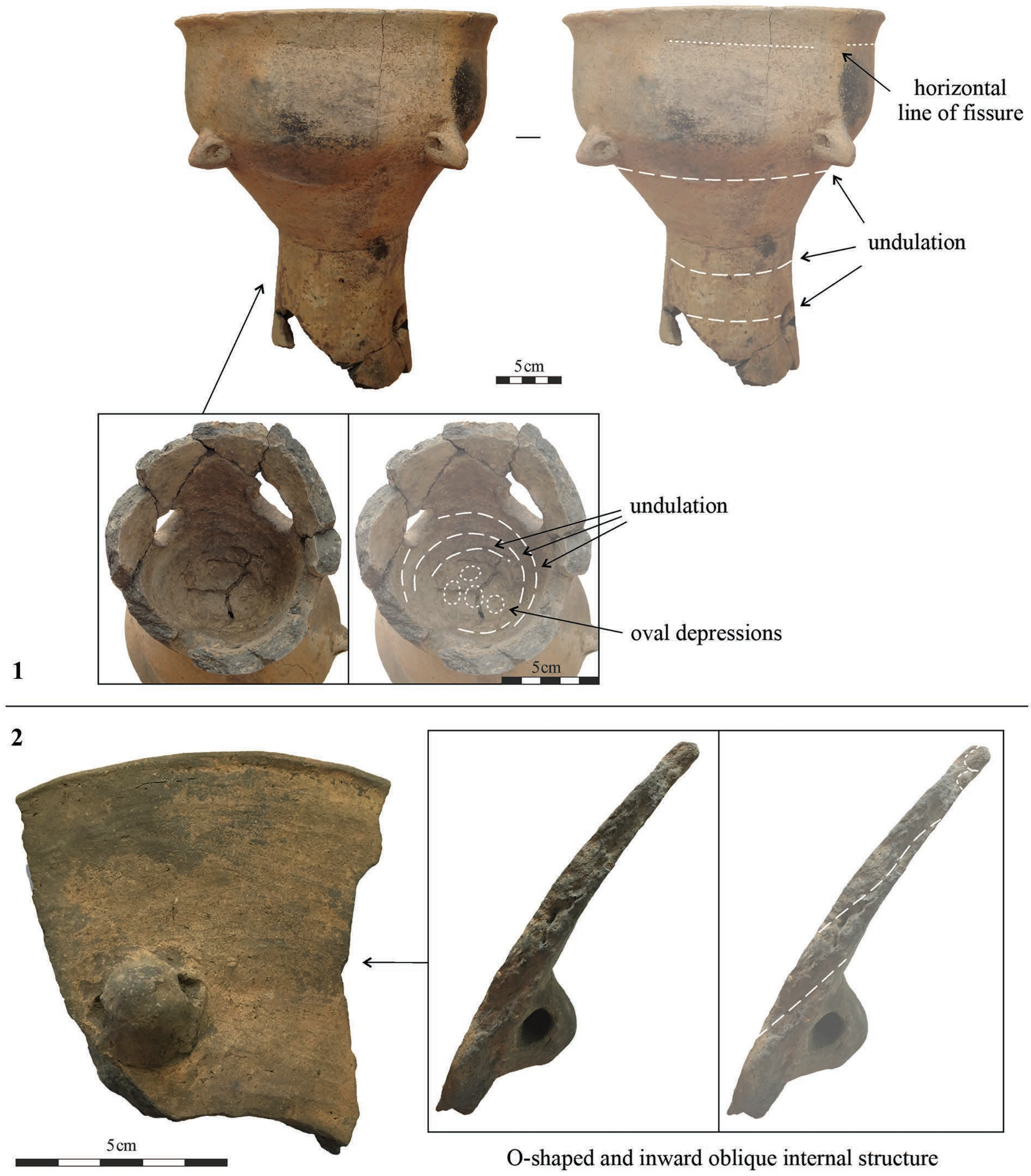

Fig. 8. Macrotraces of Forming method 2. **1** *(grave 112/119);* **2** *(pit 147/157).*

All the different bowls had their own way of forming. Deviations from this rule are very rare, indicating a high degree of technological homogeneity. The wide conical bowls (either pedestalled or flat-based) and S-profiled bowls with a pedestal were always shaped with Forming method 2, *i.e.* reverse coiled body occasionally with bottom-up coiled pedestal and rim. The hemispherical, S-profiled, and carinated bowls (both flat-based) were exclusively built using Forming method 3, *i.e.* a moulded body and rim made from coils. Conical bowls were the only bowl type where some level of forming variability was detected. The majority of these were also made with Forming method 3, yet two of them were formed with Forming method 1 (the base was unknown).

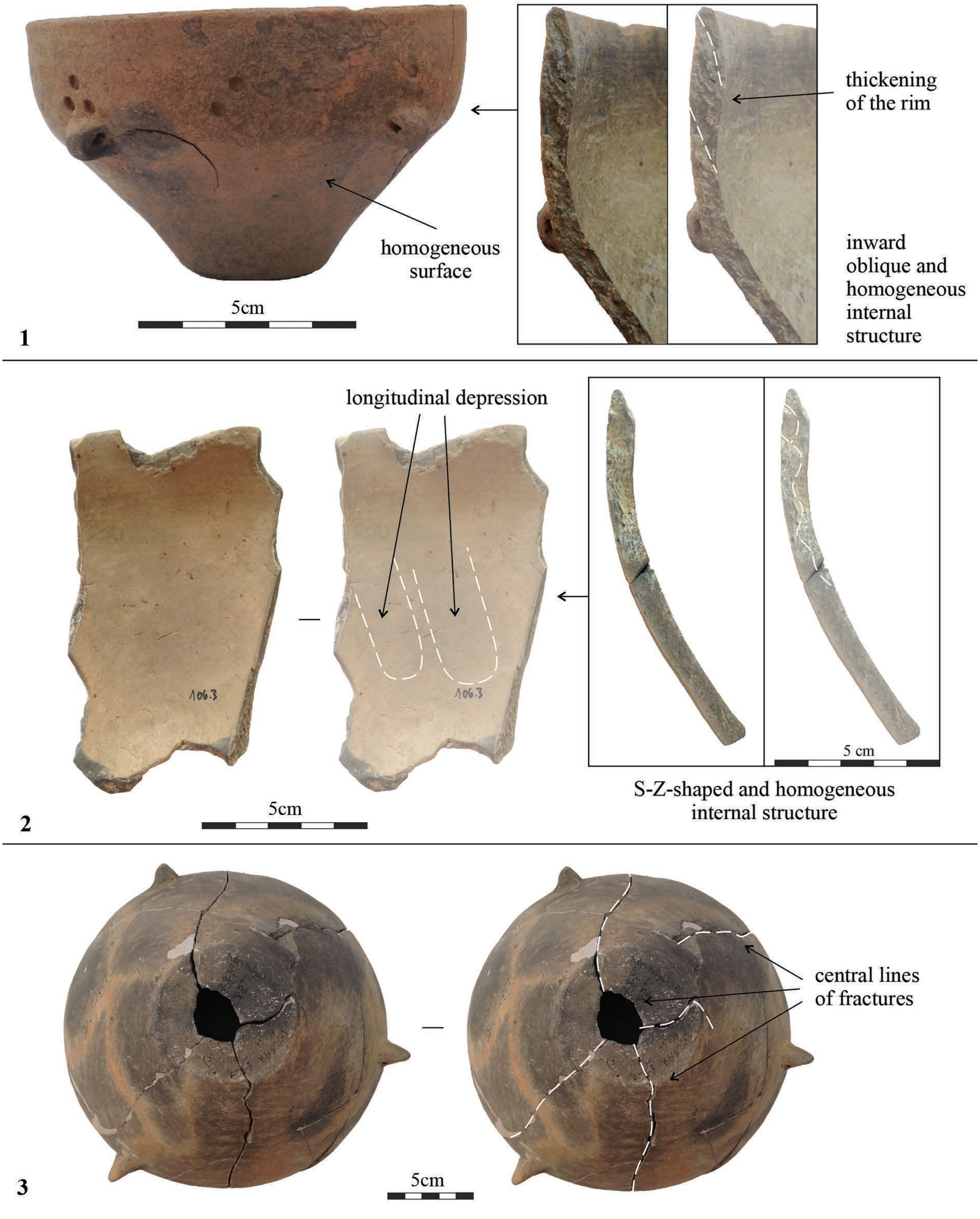

Fig. 9. Macrotraces of forming method 3.* 1 *(grave 327/390);* 2 *(pit 106/113);* 3 *(grave 108/115).

Discussion

Contextualization of the forming methods

Technological analyses conducted at the site of Polgár-Király-ér-part revealed three pottery forming methods and three variants. These strongly correlate with different vessel types.

First, it is important to explore the presence of these forming methods at other Early Copper Age sites and sites from earlier Neolithic periods in the Carpathian Basin to understand the origin of this technical knowledge. There have been only a few publications on the forming technology of the Neolithic (*Gomart 2014a; Kreiter* et al. *2017; Füzesi 2019; 2023; Gomart* et al. *2020*) and Early Copper Age (*Gucsi 2006; Solnay 2021; Solnay* et al. *2023*) pottery vessels in the Carpathian Basin so far, and only one of those is located on the Polgár island (*Gomart 2014a; Gomart* et al. *2020*). However, these studies provide crucial information for contextualizing the pottery assemblage of Polgár-Király-ér-part.

Most of these ways of forming can be found in the Carpathian Basin since the Neolithic. The coiling technique was one of the most frequent ways of roughing-out the body that has been continuously observed in the region since the Early Neolithic until at least the studied period (*Gomart 2014a.156–157; Kreiter* et al. *2017.120; Füzesi 2019.91; 2023.171,173; Gomart* et al. *2020.53–55*). It was also identified on two Early Copper Age sites – one at Tiszagyenda-Vágott-halom on the Great Hungarian Plain (*Solnay 2021.216; Solnay* et al. *2023.6–7, Tab. 1*), and another at Zamárdi-Kútvölgyi dűlő in Transdanubia (Western Hungary) (*Gucsi 2006.9*).

Regarding the base shaping of these coil-bodied vessels, one or multiple superposed clay discs had been common since the Early Neolithic (*Gomart 2014a.156–157; Kreiter* et al. *2017.120; Füzesi 2019.91; 2023.176; Gomart* et al. *2020.53–55*). However, based on the already published data, no separate foot-ring shaped from coil rings or spirals was known from the Neolithic.

The earliest examples of the combination of moulding (the base and body) and coiling (the upper part of the vessel) were observed in the Middle Neolithic in the Carpathian Basin, and interestingly from the other

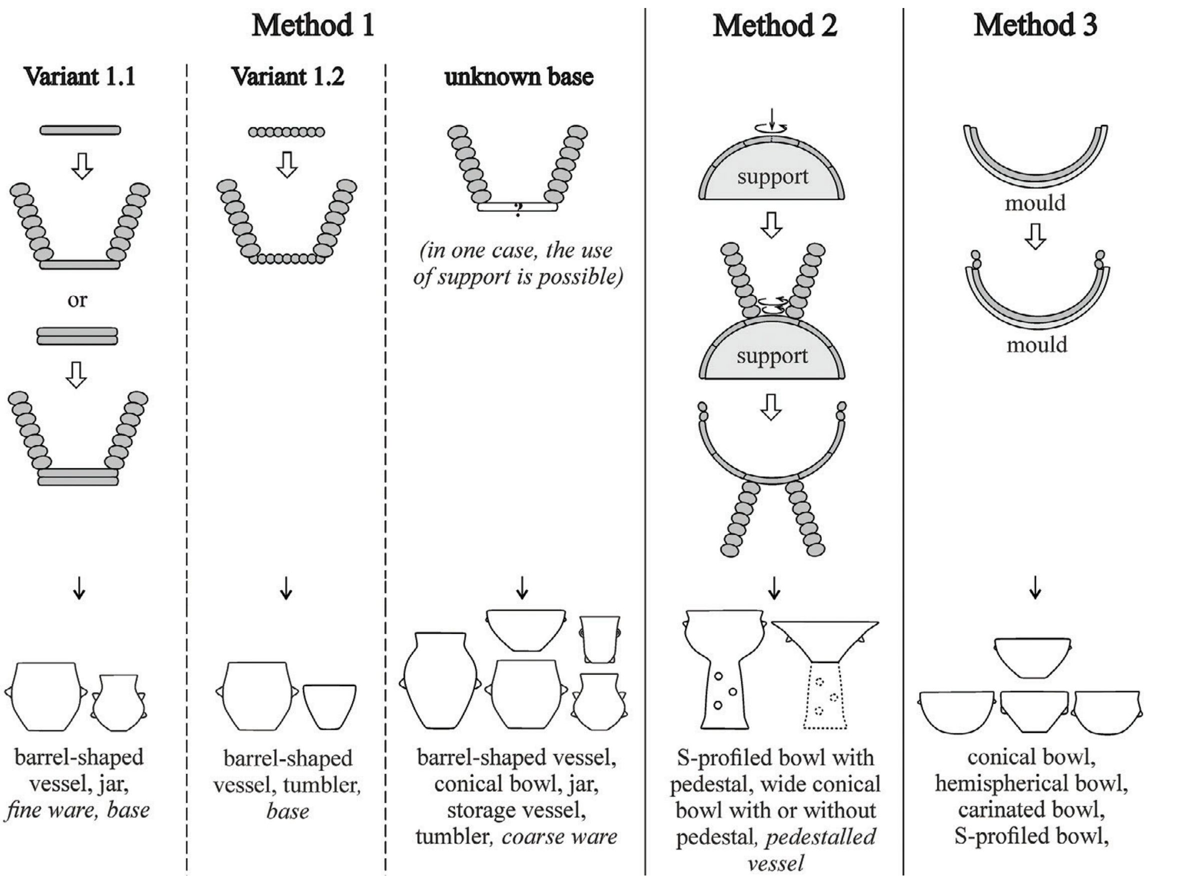

Fig. 10. **Chaîne opératoire** ***of every forming method and variant, as well as the resulting vessel forms.***

analysed site on the Polgár island: Polgár-Ferenci-hát (*Gomart 2014a.157; Gomart* et al. *2020.55*). This method also existed in the Late Neolithic (*Füzesi 2023. 173–174*) and it was observed at the Early Copper Age site of Tiszagyenda-Vágott-halom, where this was also one of the most common methods to form a bowl (*Solnay 2021.216; Solnay* et al. *2023.15*).

The reverse coiling method was first detected in the Early Neolithic on the Great Hungarian Plain (*Gomart 2014a.157; Gomart* et al. *2020.55*). However, its continuity into the Early Copper Age is not yet clarified.

Previous studies have demonstrated the continuous presence of certain techniques over very long periods of time in other regions and periods (*Vandiver 1987; Roux 2019*). The contextualization of the results of Polgár-Király-ér-part possibly suggests a similar pattern. Most of the observed forming methods and variants at the site existed in other Early Copper Age sites and had their roots in the Neolithic. However, it is also essential to consider the relationship between forming technology and vessel shapes to understand the transformation of the technological repertoires.

So far, there is little published data on this topic. Until now, no correlation has been detected between the forming techniques and pottery shapes in the Early and Middle Neolithic (*Kreiter* et al. *2017.122*). At that time, the different forming methods presumably indicate different technical traditions, that probably signify multiple communities of practice (*Gomart 2014a. 159–160; Kreiter* et al. *2017.128–129; Gomart* et al. *2020.60–62*). However, similarly to Polgár-Király-ér-part, the pottery assemblage of the Late Neolithic site of Öcsöd-Kovácshalom shows that certain forming methods are limited to certain vessel shapes (*Füzesi 2023.170.Fig. 6*). In the Early Copper Age, this phenomenon was also observed at Tiszagyenda-Vágott-halom (*Solnay 2021.216; Solnay* et al. *2023.15*).

Technological knowledge and potters

This study has demonstrated that at Polgár-Király-ér-part no clear pattern can be observed regarding the spatial distribution of forming methods and variants. Furthermore, there is no definitive technological difference between the material of the settlement features and that of burials.

However, a strong connection between the forming methods and vessel shapes suggests a clear regularity in the pottery-making practice at Polgár-Király-ér-part. At this point of the research, it is highly unlikely that the Early Copper Age potters specialized in only one pottery form in this small-scale site. Therefore, the different forming methods at Polgár were probably part of shared technological knowledge, in which most of the vessel shapes had its own forming method: jars, barrel-shaped vessels, storage vessels, and tumblers were made with a bottom-up coiled body (Forming method 1), wide conical bowls (either pedestalled or flat-based) and S-profiled bowls with a pedestal were shaped with a reverse coiled body and additional, coiled rim (Forming method 2), as well as hemispherical, S-profiled, and carinated bowls (both flat-based) were made with a moulded body and coiled rim (Forming method 3). Based on the previously cited studies, this complex technological knowledge probably already existed in the local Late Neolithic (*Füzesi 2019; 2023*), and was possibly followed by other Early Copper Age potters on the Great Hungarian Plain, not only in Polgár (*Solnay 2021; Solnay* et al. *2023*).

However, taking a closer look at this shared technological knowledge reveals some minor technological differences. Although the body of the barrel-shaped bowls were made always made with a bottom-up coiling technique (Forming method 1), their bases could be fabricated both with one or multiple superposed clay discs (Variant 1.1), as well as coil rings or spirals (Variant 1.2). Conical bowls can also be formed with moulding and a coiled rim (Forming method 3), or bottom-up coiling (Forming method 1). Besides, coiling in/on a support is possible in the case of one tumbler. These findings suggest that a certain degree of technological diversity must be considered. This assumption is further supported by the fact that traces of preforming (namely scraping and/or shaving) were also found on a few vessels. Based on these data, a hypothesis can be established to interpret these small technological diversities.

The similar pottery shapes that were made by different forming techniques, as well as preformed and non-preformed vessels, probably would not have been made by the same potter. Some of these techniques, like the fabrication of the base with one or multiple superposed clay discs, had their roots in the Early and Middle Neolithic, where they can be understood as part of separate technical traditions (*Gomart 2014a; Kreiter* et al. *2017; Gomart* et al. *2020*). Therefore, it is possible that these minor differences in the shared technological knowledge are the signs of distinct learning networks in Polgár-Király-ér-part. This suggests that the vessels found in this site could have been made by more than one potter. This is a surprising result given the small size and presumably short life span of the settlement. Further studies of other Early Copper Age sites are necessary to explore this hypothesis.

Conclusion

The technological approach of pottery assemblages reveals the pottery making practices in the Early Copper Age settlement of Polgár-Király-ér-part. As a result, a very complex technological knowledge of pottery forming was identified in which almost all the vessel types have their own forming methods. Although most of the forming techniques originated in the local Neolithic, the examples considered above indicate that there might have been some level of change in the process of the transmission of knowledge in the Early Copper Age.

However, some minor technological differences imply different pottery learning networks, which suggest that more than one potters made the vessels at Polgár. This result raises many issues about the social organization of this small-scale settlement with a relatively short life span, such as the spatial and temporal relationship of the potters and the number of households.

Besides, the extremely homogeneous pottery style of the site is not entirely in harmony with the forming technology. Although there is evidence of shared technological knowledge at the site, the observed minor differences may suggest the existence of different learning networks. This, however, cannot be observed in the pottery style.

Therefore, the paper demonstrates the importance of the technological approach to pottery forming and proves the usefulness of the combination of the results of both technological and stylistic analyses. This methodology reveals the complexity of pottery production and sheds light on the network of technological knowledge and the potters following them.

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Tab. 1. Early Copper Age archaeological features at Polgár-Király-ér-part.

Number of the archaeolo-gical feature	Description of the archaeological feature	Number of sherds	Number of vessels	Number of analysed vessels	Type of every analysed vessel	Forming method and variant of every analysed vessel	Configuration of the coils on different forming phases	Traces of preforming technique	References
50/56	Pit with round shape, straight side, and flat bottom.	14	10	7	Fine ware	Forming method 1, Variant 1.1	Body: inward oblique	–	*Szilágyi 2015.130–131*
					Base	Forming method 1, Variant 1.2	Neck: S-Z-shaped	–	
					Jar	Forming method 1, unknown base	Rim: inward oblique	–	
					Conical bowl	Forming method 3	Rim: S-Z shaped	–	
					S-profiled bowl	Forming method 3	Rim: S-Z shaped	–	
					S-profiled bowl	Forming method 3	Rim: S-Z shaped	–	
					S-profiled bowl	Forming method 3	Rim: S-Z shaped	–	
51/57	Pit with round shape, straight side, and flat bottom.	33	30	3	Jar	Forming method 1, unknown base	Body: inward oblique	–	*Szilágyi 2015.131*
					Hemispherical bowl	Forming method 3	Rim: inward oblique	–	
					S-profiled bowl	Forming method 3	Rim: inward oblique	–	
64/71	Pit with amor-phous shape and uneven bottom.	50	26	11	Fine ware	Forming method 1, Variant 1.1	Body: S-Z shaped	–	*Szilágyi 2015.131*
					Jar	Forming method 1, Variant 1.1	Unknown	–	
					Base	Forming method 1, Variant 1.1	Body: inward oblique	Horizontal, deep, thin striation	
					Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z	–	
					Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped and inward oblique	–	
					Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped and inward oblique	–	
					Coarse ware	Forming method 1, unknown base	Body: inward oblique	–	
					Coarse ware	Forming method 1, unknown base	Body: S-Z-shaped	–	
					Jar	Forming method 1, unknown base	Neck: inward oblique	–	

Tab. 1. Continued

					Storage vessel	Forming method 1, unknown base	Neck S-Z-shaped and inward oblique	Horizontal, deep, thin striation	
					Storage vessel	Forming method 1, unknown base	Neck: inward oblique	Longitudinal flat stripes and horizontal, deep, thin striation	
67/73	Pit with amor-phous shape and uneven bottom.	119	99	6	Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped, rim: O-shaped	–	*Szilágyi 2015.131*
					Barrel-shaped vessel	Forming method 1, unknown base	Body: inward oblique	–	
					Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped	–	
					Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped	–	
					Storage vessel	Forming method 1, unknown base	Body: S-Z-shaped	–	
					Storage vessel	Forming method 1, unknown base	Neck: inward oblique	–	
95/105	Grave with an east-west orient-ed skeleton on the left side in crouched positi-on. No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave good.	–	*Szilágyi 2015.132*
106/113	Pit with round shape, straight side, and flat bottom.	96	52	5	Barrel-shaped vessel	Forming method 1, Variant 1.1	Body: S-Z-shaped	–	*Szilágyi 2015.132*
					Coarse ware	Forming method 1, unknown base	Body: S-Z-shaped and inward oblique	–	
					Tumbler	Forming method 1, unknown base	Body: inward oblique	–	
					Storage vessel	Forming method 1, unknown base	Neck: S-Z-shaped	–	
					Carinated bowl	Forming method 3	Rim: S-Z-shaped	–	

Tab. 1. Continued

108/115	Grave with an east-west oriented skeleton on the right side in gently crouch-ed position. Grave-goods: vessels and pig's mandi-ble. AMS radiocarbon dates from an ulna of a Homo sapiens: 4330 (68.2%) 4170 cal BC.	4	4	3	Tumbler	Forming method 1, Variant 1.2	Body: S-Z-shaped	–	*Siklósi, Szilágyi 2021.593, Tab. 1; Szilágyi 2015.132*
					Barrel-shaped vessel	Forming method 1, Variant 1.2	Unknown	–	
					S-profiled bowl	Forming method 3	Rim: S-Z	–	
112/119	Grave with three skeletons, one adult laid supine in an extended position, two children skeleton in crouched po-sition. Grave-goods: vessels. AMS radiocarbon dates from a costa frg., phalanx of a Homo sapiens: 4240 (68.2%) 4060 cal BC	3	3	3	Barrel-shaped vessel	Forming method 1, Variant 1.1	Body: S-Z-shaped	–	*Siklósi, Szilá-gyi 2021.593. Tab. 1; Szilágyi 2015.132*
					Jar	Forming method 1, unknown base	Body: S-Z-shaped, neck: inward oblique	–	
					S-profiled bowl with hollow-pedestal	Forming method 2	Pedestal: inward oblique	–	
117/124	Grave with an east-west orient-ed skeleton laid supine in an ex-tended position. No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	–	–

Tab. 1. Continued

118/125	Disturbed grave, cut by grave 117/124. No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	–	–
125/133	Grave with an east-west oriented skeleton on the left side in crouched positi-on. No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	–	*Szilágyi 2015.132*
126/133	Pit with round shape, straight side, and flat bottom.	8	7	2	Coarse ware	Forming method 1, unknown base	Body: S-Z-shaped	–	*Szilágyi 2015.132–133*
					Vessel with pedestal	Forming method 2	Pedestal: S-Z-shaped	–	
139/141; 146; 166	Two archaeolo-gical features have been given this number, presumably a grave and a pit, which cannot be separated due to lack of document-tation. Three stratigraphical numbers (141, 146, and 166) have been assigned to the feature number 139, but their relationship is unclear.	39	30	7	Jar	Forming method 1, unknown base	Body: S-Z-shaped, neck: inward oblique	–	*Szilágyi 2015.133*
					Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped	Horizontal, deep, thin striation	
					Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped	Horizontal, deep, thin striation	
					Vessel with pedestal	Forming method 2	Pedestal: S-Z-shaped	–	
					Vessel with pedestal	Forming method 2	Pedestal: S-Z-shaped	–	
					Vessel with pedestal	Forming method 2	Pedestal: S-Z-shaped	–	
					Carinated bowl	Forming method 3	Rim: S-Z-shaped	–	

Tab. 1. Continued

141/148	Pit with round shape, straight side, and flat bottom. AMS radiocarbon dates from a calcaneus dextra of a juvenis Sus scrofa: 4255 (68.2%) 4065 cal BC.	71	67	8	Barrel-shaped vessel	Forming method 1, unknown base	Body: S-Z-shaped	–	*Siklósi, Szilágyi 2021.593. Tab. 1; Szilágyi 2015.133*
					Storage vessel	Forming method 1, unknown base	Neck: inward oblique	–	
					Carinated bowl	Forming method 3	Rim: inward oblique	–	
					Carinated bowl	Forming method 3	Rim: O-shaped	–	
					S-profiled bowl	Forming method 3	Rim: inward oblique	–	
					S-profiled bowl	Forming method 3	Rim: inward oblique	–	
					S-profiled bowl	Forming method 3	Rim: S-Z-shaped	–	
					Conical bowl	Forming method 3	Unknown	–	
147/157	Pit with round shape.	2	2	2	Wide conical bowl	Forming method 2	Body: inward oblique, rim: O-shaped	–	*Szilágyi 2015.133*
					Wide conical bowl	Forming method 2	Unknown	–	
181/189; 235	Pit with amorphous shape and uneven bottom. Two stratigraphical numbers have been assigned to feature 181, 189 for the surface of the feature and 235 for its infill. AMS radiocarbon dates from a large ungulate vertebra frg.? 5030 (68.2%) 4900 cal BC.	51	40	3	Coarse ware	Forming method 1, unknown base	Body: S-Z-shaped and inward oblique	–	*Siklósi, Szilágyi 2021.593. Tab. 1; Szilágyi 2015.133*
					Jar	Forming method 1, unknown base	Neck: S-Z-shaped	–	
					Jar	Forming method 1, unknown base	Body and neck: S-Z-shaped	–	
208/223	Pit with round shape.	5	3	1	S-profiled bowl	Forming method 3	Unknown	–	*Szilágyi 2015.133–134*
234/237	Disturbed grave in crouched position. No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	No grave goods.	–	–

Tab. 1. Continued

263/280	Pit with round shape.	3	3	3	Coarse ware	Forming method 1, unknown base	Body: S-Z-shaped	–	*Szilágyi 2015.134*
					Coarse ware	Forming method 1, unknown base	Body: S-Z-shaped	–	
					Conical bowl	Forming method 1, unknown base	Body: S-Z-shaped	–	
327/390	Grave with a west-east oriented skeleton on the left side in crouched position. Grave-goods: vessels.	3	3	3	Conical bowl	Forming method 1, unknown base	Unknown	–	*Szilágyi 2015.134*
					Carinated bowl	Forming method 3	Rim: inward oblique	–	
					Conical bowl	Forming method 3	Unknown	–	
351/379	Probably a grave in a pit, but the	9	9	2	Coarse ware	Forming method 1, unknown base	Body: S-Z-shaped	–	*Szilágyi 2015.134*

Investigating the pottery firing techniques in western Slovenia during the Late Bronze and Early Iron Ages using FTIR and petrographic analysis

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ABSTRACT - *This study focuses on the analysis of pottery firing techniques during the Late Bronze and Early Iron Ages in the Karst region of Slovenia. Given the absence of archaeological structures, we adopted an alternative research approach, employing FTIR and ceramic thin-section analysis. The archaeological material underwent study using a model derived from archaeological experiments, which encompassed firing techniques in both pits and pottery kilns. Our research successfully identified that various firing structures were utilized during the Late Bronze and Early Iron Ages.*

KEY WORDS – *pottery; firing techniques; experimental archaeology; petrographic analysis; FTIR - Fourier Transform Infrared Spectroscopy analysis; Karst; Slovenia*

Raziskovanje tehnik žganja keramike v zahodni Sloveniji v pozni bronasti in starejši železni dobi na podlagi FTIR in petrografskih analiz

IZVLEČEK – *Študija je usmerjena v analizo tehnik žganja keramike v pozni bronasti in starejši železni dobi na Krasu v Sloveniji. Zaradi odsotnosti arheološki struktur smo uporabili alternativni raziskovalni pristop, in sicer FTIR in keramične petrografske analize. Arheološki material smo analizirali s pomočjo modela, ki smo ga razvili pri arheološkem raziskovalnem delu, žganju v jami in žganju v peči. S pomočjo raziskave smo uspešno prepoznali različne tehnike žganja, ki so bile v uporabi v pozni bronasti in starejši železni dobi.*

KLJUČNE BESEDE – *keramika; tehnike žganja keramike; eksperimentalna arheologija; petrografska analiza; FTIR - infrardeča spektroskopija s Fourierovo transformacijo; Kras; Slovenija*

Introduction

Archaeological research has yielded compelling evidence for pottery firing techniques during the Late Bronze and Early Iron Ages in western Slovenia. These resulted from Fourier Transform Infrared Reflectance Spectroscopy (FTIR) analysis conducted on ceramic samples obtained through archaeological experiments and archaeological excavations. As there are no archaeological structures such as pottery kilns in the area that could contribute to the understanding of firing techniques during this period, an alternative approach to the investigation is required. This paper presents the results of an investigation that sought to identify indirect evidence for Late Bronze and Early Iron Age firing practices in western Slovenia.

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The existing knowledge of pottery technology and production during this period in the study area derives from limited research, primarily from a macroscopic point of view and focusing solely on settlement material, such as storage, cooking, and serving types of vessels. The pottery is locally produced and handmade, fired in bonfires/pit-fires and single-chamber kilns. Typological analysis indicates a clear influence from the west, particularly from the Veneto and Friuli regions in northern Italy.

The application of the Fourier Transform Infrared Reflectance Spectroscopy (FTIR) has been proven as an excellent method for identifying the mineralogical composition of archaeological ceramics and estimating firing temperatures (*Shoval, Paz 2015; Shoval 2016*). Such information can contribute significantly to the reconstruction of firing structures and to a more nuanced comprehension of firing techniques. This research comprises an interdisciplinary study of ceramics from two hillforts: (a) the Tabor site, spanning the Late Bronze to Early Iron Age, situated near Vrabče, and (b) the Štanjel site, representative of the Early Iron Age site (Fig. 1).

In addition to the aforementioned FTIR analyses, ceramic petrographic thin-section analyses were conducted on ceramic materials procured from both sites, focusing on forms presumed to be of local production. The validation of local pottery production serves to draw conclusions about the firing structures in the examined area.

Furthermore, an archaeological experiment-based model was built to facilitate the comparison with the archaeological material. This involved the recreation of probable firing techniques and conditions from the Late Bronze and Early Iron Ages, accomplished through the construction of a one-chamber kiln and the replication of vessels using local clays.

Archaeological background

The prehistoric Karst Plateau

The Karst Plateau is a landscape between the Gulf of Trieste and the Vipava Valley. In the northwest, it is connected with the Soča Plain, in the southwest with the Brkini Hills, the Podgorje Karst Plateau with the Čičarija Plateau, and the Podgraje Lowland (*Perko, Kladnik 1998*). The Karst Plateau is famous for the so-called hillforts (sl. g*radišča*, it. *castellieri*), which are dated to the Bronze and/or Early Iron Ages (*Marchesetti 1903*). Most of these hillforts were poorly excavated and the stratigraphy was preserved only in a few cases (*Canarella 1975–1977; Moretti 1978; Novaković*, *Turk 1991; Bratina 2014; 2021; Zupančič*, *Vinazza 2015; Maggi* et al. *2017; Borgna* et al. *2018; Bernardini* et al. *2023*).

The archaeological material under consideration was collected from two hillforts, Tabor near Vrabče and Štanjel. The chronological framework for both sites was established through stratigraphic analysis, and confirmed by both archaeological evidence and absolute data (*Vinazza 2021.Fig. 5*). The Tabor near Vrabče site with a double dry-wall has two occupational phases. The initial phase is dated to the end of the Late Bronze Age (10th century BC), while the second corresponds to the Early Iron Age (8th and 7th centuries BC). In contrast, the Štanjel site contains the foundations of a cellar dug into the limestone bedrock, dating to the conclusion of the end of the Early Iron Age (6th and 5th centuries BC) (*Vinazza 2021.429,442, Fig. 5*).

Pottery firing in the Late Bronze and Early Iron Ages in Slovenia

The first archaeometric study about Bronze and Iron Age firing techniques on Slovenian pottery was conducted in 2021 (*Vinazza, Dolenec 2021*). Existing research in Slovenia has been limited to individual archaeological sites, as evidenced by studies such as Janez Dular (*1982*), Matija Črešnar (*2006*), Andreja Žibrat Gašparič *et al*. (*2018*), with macroscopic analysis of ceramic technology still dominating the literature. Since we are dealing with both direct and indirect data pertaining to pottery firing at this time in Slovenia, a comprehensive understanding is possible through an overview of the current state of research.

Macroscopic and microscopic examinations of pottery technologies, constituting indirect data, suggest the utilization of both bonfires/pit fires and kilns. Notable examples include the Poštela and Novine sites in northeastern Slovenia, as well Štanjel, Tabor near Vrabče, and Tomaj in the Karst region (*Žibrat, Dolenec 2015; Žibrat* et al. *2018.188; Vinazza, Dolenec 2021.401; Vinazza 2022*).

Meanwhile, only a limited number of archaeologically excavated kilns, serving as direct data, have been identified for pottery production. Regardless of the type, these kilns are predominantly of the one-chamber type, as documented by Irena Horvat Šavel (*1988–1989. 130–131*) and Draško Josipović *et al*. (*2016*). Although the two-chamber kiln, excavated archaeologically, is dated to the Late Iron Age (*Tomanič Jevremov, Guštin 1996*), evidence from neighbouring northern Italian sites suggests its use in the Late Bronze Age (*Levi 2010. 117*), but most examples of such kilns are known from the Early Iron Age (*Poggiani Keller 1994.76; Iaia, Moroni Lanfredini 2009.65,68,70; Gasparini, Miari 2017.24; Rapi* et al. *2019.107*).

The absence of archaeologically excavated kilns is notable at the Late Bronze and Early Iron Age sites in the Karst, yet indirect data allude to their probable existence (see *Vinazza 2021; Vinazza, Dolenec 2022*). Moreover, an analysis of the *chaíne opératoire* of certain locally produced vessel types, exemplified by the ceramic situlae from the Štanjel site, suggests the use of two-chamber kilns. This specific pottery requires an oxidation-reduction-oxidation (ORO) firing atmosphere, achievable only in such kilns. By analysing the provenance based on petrographic thin-section analysis we can distinguish between local and non-local production and foresee the use of this kind of firing technique in the area under study. This research aims to compare the firing model derived from archaeological experiments using FTIR analyses, which is based on temperature estimation. Additionally, the study seeks to ascertain whether the results of FTIR analyses of

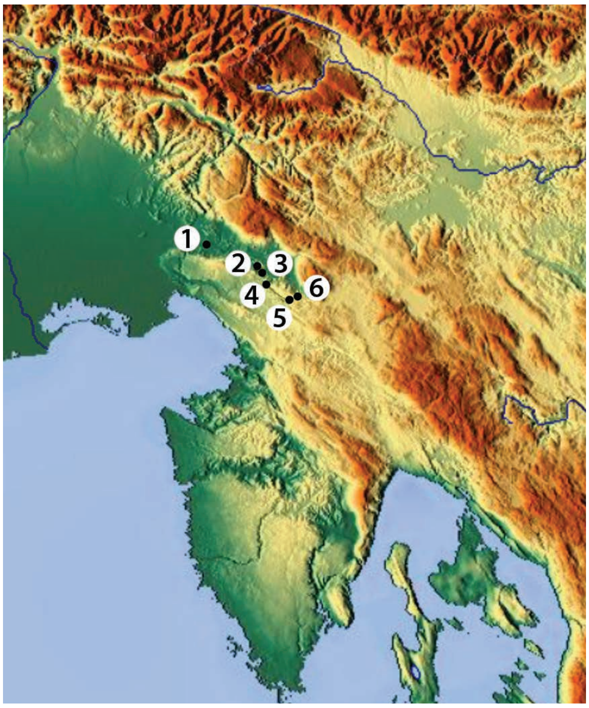

Fig. 1. A map showing the location of the clay sources (1 Renče, 2 Ostri vrh, 4 Veliki Dul, 5 Griže) and the archaeological sites (3 Štanjel, 6 Tabor near Vrabče). Source: https://maps-for-free.com/

archaeological material can effectively differentiate between pottery fired in a bonfire/pit fire and that fired in a kiln.

Geological background of the Karst Plateau

The Karst Plateau is a flat plain with conical hills, small elevations, denuded karst areas, sinkholes, caves and the average altitude above sea level is 300 to 600 metres above sea level. Despite the absence of surface streams, the plateau harbours a significant underground stream system, one that gathers available water and directs it towards the spring of Timav (*Jurkovšek* et al. *1996.21*).

Tabor near Vrabče

The archaeological site of Tabor near Vrabče (Fig. 2) encompasses two main lithostratigraphic units: the Lipica Formation and the Flysch. The Lipica Formation locally contains the Tomaj limestone, a platy and laminated limestone with chert. The limestone is bedded and massive with rudist biostromes and bioherms (*Jurkovšek* et al. *1996.25, App*.). Cherts occur in the Tomaj limestone as nodules and thin lenses and have a microcrystalline texture (*Jurkovšek* et al. *1996.47*). The Flysch unit results from the alteration of marl, sandy siltstone and coarse-grained carbonate sandstone, with intercalations of breccia and conglomerate, which consist mainly of fragments and pebbles of older carbonate platform formation. The breccia and conglomerate varieties encompass basalt conglomerate and calcite-cemented breccia, featuring limestone fragments of diverse sizes (*Jurkovšek* et al. *1996.63*).

Štanjel

The archaeological site of Štanjel lies in an even more dynamic area (Fig. 2), between four lithostratigraphic units: the Lipica Formation, the Flysch, the Liburnian Formation, the Lower Trstelj, and the Upper Trstelj beds. The Liburnian Formation comprises marly limestone and limestone breccia, while the Upper Trstelj beds, which primarily consist of miliolid limestone, exhibit calcarenite with foraminifers and Coral-algal limestone (*Jurkovšek 2010.27,40*).

Clays

Fieldwork in the wider area of interest identified various clay sources potentially suitable for pottery production. The selection of clays focused on proximity to archaeological sites (*i.e*. Tabor near Vrabče and Štanjel) and suitability for pottery production. Therefore, samples were collected from the Renče source in the

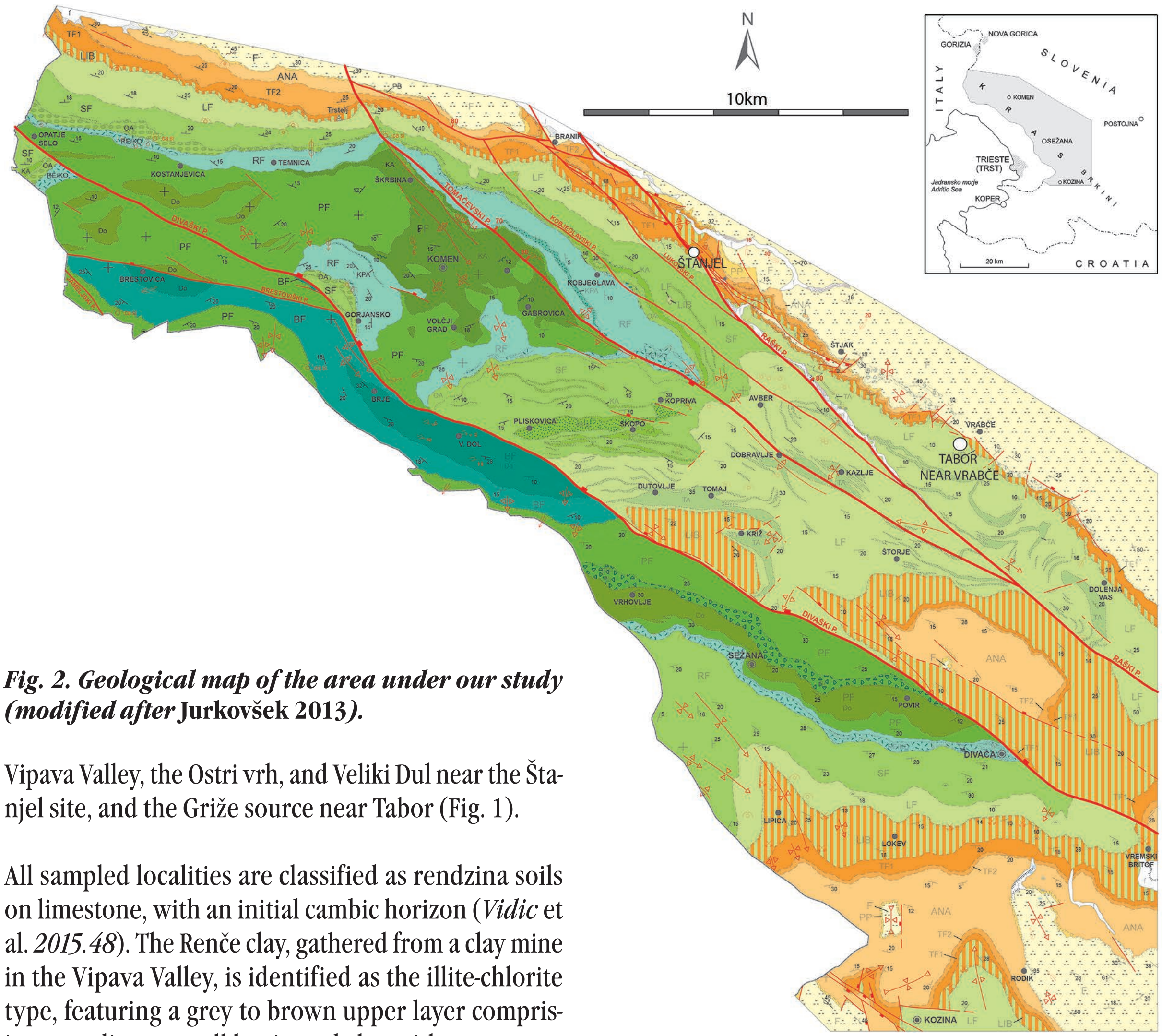

Fig. 2. Geological map of the area under our study (modified after* Jurkovšek 2013*).

Vipava Valley, the Ostri vrh, and Veliki Dul near the Štanjel site, and the Griže source near Tabor (Fig. 1).

All sampled localities are classified as rendzina soils on limestone, with an initial cambic horizon (*Vidic* et al. *2015.48*). The Renče clay, gathered from a clay mine in the Vipava Valley, is identified as the illite-chlorite type, featuring a grey to brown upper layer comprising a medium to well-laminated clay with an average thickness of 5m. The mineral composition encompasses chlorite, quartz, albite, montmorillonite, carbonate, and iron minerals (*Rokavec 2014.32,35,54*). Clays from Ostri vrh and Griže were collected on the hillsides, while the samples from Veliki Dul were collected in a valley (Fig. 1).

They fall under the terra rossa type (*Šušteršič* et al. *2009.Tab. 1*).

Materials and methods

Archaeological experiments, as detailed in Manca Vinazza (*2021a; 2021b.183–184*) and Vinazza and Matej Dolenec (*2022.392*), were conducted in the courtyard of the Department of Archaeology at the University of Ljubljana in the years 2020 and 2021. The initial phase involved the construction of a one-chamber kiln, utilizing Renče clay. Subsequently, ceramic vessels were made from the examined clay sources, which were fired in a replicated one-chamber kiln, in a pit fire and an electric laboratory kiln.

Archaeological pottery was sampled from two sites, Tabor near Vrabče and Štanjel, from which we obtained stratified material with absolute ^{14}C dates. We selected material that we were confident was locally produced, including storage and cooking vessels, as well as a locally made ceramic situla fired in ORO conditions. We sampled local clay sources in the vicinity of both archaeological sites: Griže near Tabor, and Veliki Dul and Ostri vrh near Štanjel.

Furthermore, the experimental pottery served for comparisons with archaeological pottery. To achieve this, samples from both the experimental and archaeological pottery were taken and analysed through FTIR spectroscopy (*Parish* et al*. 2013*) and petrographic study of ceramic thin sections (*Quinn 2022*). Additionally, the findings from these techniques were complemented by previously acquired X-ray Diffraction (XRD) results (see Tab. 1).

FTIR Spectroscopy

The FTIR equipment employed for this research was located in the Charles McBurney Laboratory for Geoarchaeology, based in the Department of Archaeology at the University of Cambridge. Representative FTIR spectra were obtained from all the clay and ceramic samples (n=21) by grinding a few tens of micrograms of the sample using an agate mortar and pestle (*Smith 2011*). About 0.1mg or less of the sample was mixed with about 80mg of KBr (IR-grade). A 7mm pellet was then made using a hand press and the spectra were collected between 4000 and 400cm^{-1} at 4cm^{-1} resolution, using a Thermo Nicolet 380 spectrometer. The interpretation of the spectra was conducted by combining the internal library of infrared spectra of archaeological materials (Kimmel Standards) and the appropriate reference (*Weiner 2010; Chukanov 2014; Shoval, Paz 2015; Shoval 2016*).

Ceramics are produced by firing clay raw materials, which during this process undergo a series of reactions and transform into the final product. Using the FITR technique the main components of this final product can be identified (*Weiner 2010; Chukanov 2014*). This allows us to determine what was the original composition of the raw material and estimate the firing temperatures of this process (*Shoval, Paz 2015; Shoval 2016*). The most common components reported in archaeological pottery/ceramics are clay minerals (*e.g.*, kaolinite, smectite), quartz and calcite, and they are recognized on the FTIR spectra by specific bands (Tab. 1).

The raw clay component transforms through firing to fired-clay, also defined as meta-clay (*Shoval* et al. *2011a; 2011b*). The transformation occurs over a process called dehydroxylation during which the raw clay loses the water (H_2O) from its structure. Depending on the type of clay, this process takes place at different temperatures and subsequently forms different meta-clay components (*Shoval* et al. *2011a; 2011b; Shoval, Paz 2015*). A clay material dominated by kaolinite transforms into meta-kaolinite and the dehydroxylation occurs at 450–500°C (*Frost, Vassallo 1996*). A clay material dominated by smectite transforms into meta-smectite and this transformation occurs at *c.* 600°C (*Heller-Kallai, Rozenson 1980*).

Meanwhile, calcite decomposes through a thermal process called decarbonation (*Shoval 2016*). During this process carbon dioxide (CO_2) is released from the mineral's structure and free-lime (CaO) is formed (*Fabbri* et al. *2014*). The decarbonation of calcite in ceramics takes place under prolonged firing at temperatures between 600 and 800°C (*Maggetti* et al. *2011*). After long-lasting high firing temperatures (800°C and above), part of the free-lime is re-carbonated and crystallized as reformed calcite (*Shoval* et al. *2011b; Fabbri* et al. *2014*). The presence of a calcareous (calcite-rich) component in the raw material is very important since it greatly affects the thermal reactions and the firing process (*Fabbri* et al. *2014; Shoval 2016*).

Petro thin-section analysis

Petrographic analysis took place at the Laboratory for Material Analysis Laboratory within the Department of Archaeology at the University of Ljubljana. The preparation of ceramic thin sections adhered to a standard protocol (see *Quinn 2022.23–36*), and the examination was conducted under the polarizing Zeiss Axio Scope A1 microscope. Three distinct groups of ceramic material were chosen. The first is associated with the Renče clay source (Samples 1, 2, 5 and 7). The second group is linked with the Tabor near Vrabče site (Samples 11 and 18), while the third pertains to the Štanjel site (Samples 9 and 13).

Archaeological experiments

The experimental kiln was made of Renče clay that was tempered with straw. After the completion of the experiment, samples were collected from the base (Sample 2), the chimney (Sample 3), and the wall (Sample 4), which was taken 10cm above second thermocouple. During the experiment two thermocouples were placed at the base of the kiln, one under the fired vessels and the other adjacent to the wall (see *Vinazza, Dolenec 2021.Fig. 3*). The temperature measured with the thermocouples in the experimental kiln was 670°C. Several pots were fired in the experimental kiln, including Sample 1, modelled from Renče clay; Sample 10 modelled from Veliki Dul clay; and Sample 11 modelled from Griže clay. All of these pots were tempered with calcite.

In accordance with recent research by Richard Thèr *et al*. (*2018*), which proposed a model for distinguishing firing structures based on soaking time duration, we conducted experiments firing two clay cubes (5x5x 5cm) from Renče clay in a laboratory kiln. The first cube (Samples 5 and 6) was fired at 600°C, while the second cube (Samples 7 and 8) was fired at 800°C.

Tab. 1. Samples 1–21 which are part of our study.

Sam-ple	Lab ID	ITEM	Description	Firing structure	Clay	Tem-per	Firing structure	Maxi-mum	Other
1	2022-2	Vessel	Rim of the bowl	Archaeological experiment	Renče	Calcite	Replica of the kiln	670 °C	XRD (*Vinazza, Dolenec 2022.Sample 2*)
2	2022-3	Kiln	Bottom of the kiln	Archaeological experiment	Renče	Straw	Replica of the kiln	670 °C	XRD (*Vinazza, Dolenec 2022.Sample 3*)
3		Kiln	Chimney of the kiln	Archaeological experiment	Renče	Straw	Replica of the kiln	670 °C	XRD (*Vinazza, Dolenec 2022.Sample 5*)
4	2021-4	Kiln	Wall of the kiln	Archaeological experiment	Renče	Straw	Replica of the kiln	670 °C	XRD (*Vinazza, Dolenec 2022.Sample 4*)
5	2022-23	Cube	Core	Laboratory firing	Renče	0	Electrically operated kiln	600 °C	XRD (*Vinazza, Dolenec 2022.Sample 6*)
6	2022-23	Cube	Outer surface	Laboratory firing	Renče	0	Electrically operated kiln	600 °C	XRD (*Vinazza, Dolenec 2022.Sample 6*)
7	2022-24	Cube	Core	Laboratory firing	Renče	0	Electrically operated kiln	800 °C	XRD (*Vinazza, Dolenec 2022.Sample 7*)
8	2022-24	Cube	Outer surface	Laboratory firing	Renče	0	Electrically operated kiln	800 °C	XRD (*Vinazza, Dolenec 2022.Sample 7*)
9	2022-4	Silo	Štanjel site, US 28	Archaeological pottery					
10	2020-18	Vessel	Part of the vessel	Archaeological experiment	Veliki Dul	Calcite	Replica of the kiln	670 °C	
11	2020-24	Vessel	Part of the vessel	Archaeological experiment	Griže	Calcite	Replica of the kiln	670 °C	
12		Vessel	Part of the vessel	Archaeological experiment	Renče	Calcite	Pit fire	702 °C	
13	2022-1	Situla	Štanjel site, US 28	Archaeological pottery					
14		Clay		No manipulation	Renče				
15		Clay		No manipulation	Veliki Dul				
16		Clay		No manipulation	Griže				
17		Clay		No manipulation	Ostri Vrh				
18	2020-4	Pithos	Tabor near Vrabče site, US 18, outer surface	Archaeological pottery					
19	2020-4	Pithos	Tabor near Vrabče site, US 18, core	Archaeological pottery					
20	M349	Pot	Štanjel site, US 42, core	archaeological pottery					
21	M349	Pot	Štanjel site, US 42, outer surface	Archaeological pottery					

The last experimental sample (Sample 12) was pit fired in 2021, as documented by Vinazza (*2021.61, Fig. 1*). The firing reached temperatures of 702°C in less than one hour, with a subsequent cooling time lasting two hours and 41 minutes.

Archaeological material

Archaeological material comes from two sites. Beginning from the Tabor near Vrabče site, archaeological research (*Vinazza 2021.Pl.1:1*) established that the pithos (Sample 18, 19) belonged to the first occupation phase (Late Bronze Age). Macroscopic technological analysis data indicated the prevalence of a reduction atmosphere (*O.c.432*), yet it remains unclear whether the firing technique involved a bonfire/pit fire or a kiln.

From the Early Iron Age, we sampled material from the Štanjel site. A silo (Sample 9), was chosen first due to its status as the most diverse material within the site's assemblages and its local origin. It is presumed that the firing was not conducted in a kiln type (or related) structure. Based on its diameter of up to 100cm and a wall thickness of 5cm, it was believed to have been fired at low temperatures (*Vinazza 2016.9,11*) in a bonfire.

The next archaeological find from the Štanjel site is a ceramic situla (Sample 13), which, based on macroscopic analysis, is believed to have been fired in a double-chamber kiln, as this type of pottery vessel requires an ORO firing (*cf. Aloupi-Siotis 2020.3,5*).

The last vessel from the Štanjel site is a pot (*Vinazza 2021.Pl.6: 8*) from which samples were taken from the core and outer surface (Samples 20, 21).

Results

FTIR Spectroscopy

The analysed material has been categorized into three main groups. Initially, we examined the raw materials, encompassing analysis of four different clay sources. Subsequently, the experimental material was investigated, comprising materials collected from both the kiln and pottery. Finally, attention was directed towards the archaeological material.

Raw material

Renče clay (App. 5: 14)

The spectrum from the Renče clay source recorded a principal Si-O stretching band at 1028cm^{-1} which is indicative of smectite (Kimmel Standards). The dominance of this mineral is further supported by the shoulder band at 913cm^{-1} and the band at 3620cm^{-1}. The Si-O/Al-O bending mode at 469cm^{-1} can equally relate to smectite and quartz (*Weiner 2010*; Kimmel Standards), although research on clay and pottery has assigned this mode based on the overlap between these two minerals reported in such materials (*Shoval 2016*). The presence of quartz is confirmed by the characteristic band-doublet at 778 and 798cm^{-1}, and the minor peak at 695cm^{-1}. The spectrum also recorded a shoulder band at 1166cm^{-1}, which is related to SiO_2 mineral polymorphs (*e.g.*, tridymite, cristobalite, quartz) (*Chukanov 2014*). Clay materials contain small amounts of water in their mineralogical structure and/or between the layers of these minerals (*Wenk, Bulakh 2016; Kumari, Mohan 2021*). The presence of such water is detected by the very broad H_2O-stretching band at 3422cm^{-1} and the H_2O bending mode at 1637cm^{-1}.

The band at 528cm^{-1} is assigned to kaolinite–montmorillonite based on previous work on this type of clay minerals (*Chukanov 2014*). Montmorillonite, in general, is the most prominent member of the smectitic group of clay minerals (*Kumari, Mohan 2021*), and very often interstratifies with other clay minerals (*e.g.*, kaolinite, illite), which further supports its existence in this sample. The band at 528cm^{-1} could also be related to albite (plagioclase – Na-feldspar) and muscovite (mica mineral), which are minerals commonly found within clay materials (*Chukanov 2014; Kumari, Mohan 2021*). However, the spectrum did not record any of the indicative bands of these minerals, so the likelihood of their presence is low.

Veliki Dul clay (App. 5: 15)

The spectrum from the Veliki Dul clay source recorded a principal Si-O stretching band at 1032cm^{-1}, which is associated with smectite. The dominance of this mineral is supported by the shoulder band at 913cm^{-1}, the bands at 3620cm^{-1} and 534cm^{-1}, and the minor peak at 3692cm^{-1}. The combined Si-O/Al-O bending mode at 469cm^{-1} is again considered the result of the overlap between smectite and quartz (*Shoval 2016*). The presence of quartz is confirmed by the characteristic band-doublet at 777 and 797cm^{-1}, and the minor peak at 694cm^{-1}. Water, related to the clay components, is recorded by the very broad H_2O-stretching band at 3438cm^{-1} and the H_2O bending mode at 1637cm^{-1}. The band at 534cm^{-1} could again relate to muscovite or albite, but for the same reasons as with the Renče sample it is attributed to the kaolinite–montmorillonite.

Griže clay (App. 6: 16)
The spectrum from the Griže clay source is very similar to those collected from the samples of Renče clay and Veliki Dul clay sources. It is dominated by smectite based on the principal Si-O stretching band (1032cm^{-1}) and the bands at 3693cm^{-1}, 3620cm^{-1}, 915cm^{-1}, and 531cm^{-1}. The combined Si-O/Al-O bending mode at 469cm^{-1} is regarded as the result of the overlap between smectite and quartz. Clay-related water is recorded by the very broad H_2O-stretching band at 3422cm^{-1} and the H_2O bending mode at 1637cm^{-1}. Furthermore, quartz is identified by the characteristic band-doublet at 777 and 797cm^{-1} and the minor peak at 695cm^{-1}. The spectrum also included a shoulder band at 1165cm^{-1} that is related to SiO_2 mineral polymorphs.

Ostri vrh clay (App. 6: 17)
The spectrum from the Ostri vrh clay source has many similarities with the ones collected from the other three sources. The principal Si-O stretching band at 1031cm^{-1} the shoulder band at 913cm^{-1}, the bands at 3620cm^{-1} and 531cm^{-1}, and the minor peak at 3691 cm^{-1} indicate the dominance of smectite in this sample. Meanwhile, the combined Si-O/Al-O bending mode at 470cm^{-1} is again considered the result of the overlap between smectite and quartz. Clay-related water is again recorded by the H_2O-stretching band at 3422 cm^{-1} and the H_2O bending mode at 1637cm^{-1}. Lastly, the presence of quartz is confirmed by the characteristic band-doublet at 779 and 798cm^{-1} and the minor peak at 694cm^{-1}.

Experimental material (2020)
Base (App. 1: 2)
The spectrum of the sample collected from the base of the Kiln recorded a principal Si-O stretching band at 1036cm^{-1} which is associated with a meta-clay (*i.e.* fired-clay). Considering that this band falls within the range of 1030–1060cm^{-1}, the main component of this sample is meta-smectite (*Shoval 2016*). Besides the main band, the spectrum includes a shoulder band at 1090cm^{-1}, suggesting that this sample also includes meta-kaolinite. The dominance of meta-clay in this sample is further supported by the combined Si-O/Al-O bending mode at 469cm^{-1}, which is also related to the fired-clay material (*O.c.*).

Clay-related water is also detected by the very broad H_2O-stretching band at 3422cm^{-1} and the H_2O bending mode at 1636cm^{-1} (*Shoval 2016*). The meta-clay ceramics, being dehydrated after firing, strongly absolve water (*i.e.* absorbed water) during a slow rehydration process (*Muller* et al. *2000*; *Shoval, Paz 2013*). Quartz is identified by the characteristic band-doublet at 779 and 798cm^{-1}, the minor peak at 695cm^{-1} and the shoulder band at 520cm^{-1}. Lastly, the shoulder band at 1166cm^{-1} and the weak band at 1870cm^{-1} are associated with SiO_2 mineral polymorphs.

The presence of the meta-smectite suggests that this ceramic material endured temperatures around 600°C (*Heller-Kallai, Rozenson 1980*). However, the spectrum recorded a minor band at 3621cm^{-1}, which is attributed to raw smectite (*i.e.* retains its original structure). This suggests that the firing procedure did not consistently maintain high temperatures (600°C and above) and allowed the preservation of a small raw smectitic component. Meanwhile, the presence of meta-kaolinite does not support temperatures below 450°C, so the base probably experienced temperatures between 450 and 650°C.

Wall (App. 2: 4)
The spectrum of the wall sample recorded a principal Si-O stretching band at 1040cm^{-1} which is indicative of meta-smectite since it falls within the range of 1030–1060cm^{-1}. Moreover, it presented a shoulder peak at 1085cm^{-1} that is assigned to the overlap occurring between quartz and meta-kaolinite. The combined Si-O/Al-O bending mode at 469cm^{-1} further confirms that meta-clay is the principal component of this sample.

Absorbed water, associated with the meta-clay unit, is detected by the H_2O-stretching band at 3421cm^{-1}. Quartz is identified by the characteristic band-doublet at 779 and 798cm^{-1}, and the minor peak at 694cm^{-1}. The spectrum also included a minor band at 1618cm^{-1} that is related to SiO_2 mineral polymorphs. In comparison to the base's sample, this one has a calcareous component. A main CO_3 band at 1437cm^{-1} and a secondary band at 879cm^{-1} have been recorded, which are characteristic of calcite. Moreover, the spectrum recorded a minor band at 729cm^{-1}, which is indicative of dolomite.

The presence of meta-smectite and the absence of raw smectite suggest that this ceramic material endured high firing temperatures (>600°C). The main CO_3 band falls within the range of 1430–1450cm^{-1}, which is associated with reformed calcite (*Shoval 2016*). The presence of this type of calcite suggests firing temperatures consistently above 700°C. Meanwhile, the spectrum did not present bands assigned to 'firing silicates' (*i.e.* around 912cm^{-1}), which would indicate temperatures above 800°C (*Shoval 2016*). These findings indicate that these walls were exposed to temperatures between 700 and 800°C that led to the complete transformation of the main components of the clay material (*i.e.* clay and calcite).

Chimney (App. 1: 3)
The spectrum of the chimney sample recorded a principal Si-O stretching curve that splits into two peaks. The first at 1082cm^{-1} is generally associated with quartz (*Saikia* et al. *2008*) but in pottery samples it is regarded as the result of the overlap between quartz and meta-kaolinite (*Shoval, Paz 2015*). Meanwhile, the second peak at 1038cm^{-1} is indicative of meta-smectite. The combined Si-O/Al-O bending mode found at 465cm^{-1} supports that meta-clay and quartz are the main components of this sample.

The considerable presence of quartz, in addition to the Si-O stretching band, is confirmed by the characteristic band-doublet at 778 and 797cm^{-1}, and the minor peak at 694cm^{-1}. Moreover, the minor band at 1618cm^{-1} and the shoulder band at 1164cm^{-1} are both associated with SiO_2 mineral polymorphs. Absorbed water, associated with the meta-clay unit, is detected with the H_2O-stretching band at 3421cm^{-1} and the H_2O bending mode at 1637cm^{-1}.

Regarding the firing temperature, the presence of meta-smectite and the absence of bands attributed to raw smectite suggest that this sample experienced high firing temperatures (>600°C). Meta-kaolinite retains its structure for temperatures up to 950°C (*Shoval 2016*; *Stevenson, Gurnick 2016*), while the meta-smectite starts to show signs of distortion at temperatures above 900°C (*Stevenson, Gurnick 2016; Tarhan, Işık 2020*). Such signs are not recorded in the spectrum, suggesting that this sample was exposed to temperatures between 600 and 900°C for a sufficient amount of time.

Pot 1 (App. 1: 1) (Renče clay)
A pot was made from Renče clay that was tempered with calcite and fired within the experimental kiln. The FTIR analyses recorded a principal Si-O stretching band at 1082cm^{-1}, which is considered the result of the overlap between the quartz and the meta-kaolinite component (*Shoval, Paz 2015*). The combined Si-O/Al-O bending mode at 462cm^{-1} is also attributed to the overlap between these two components. The important presence of quartz is further identified by the characteristic band-doublet at 778 and 797cm^{-1}, and the minor peak at 694cm^{-1}. The spectrum also recorded a minor band at 1618cm^{-1} and a shoulder band at 1166cm^{-1} that are both associated with SiO_2 mineral polymorphs (*Chukanov 2014*). Absorbed water, associated with the meta-clay is detected with the H_2O bending mode at 1638cm^{-1}. In contrast, the spectrum did not detect a calcite component in the examined sample. Meta-kaolinite is formed at 450 to 500°C (*Frost, Vassallo 1996*) and retains its structure up to 950°C (*Shoval 2016; Stevenson, Gurnick 2016*). Since no other recorded component can provide further information on the firing temperatures, it is considered that this experimental pot was fired at temperatures between 450 and 900°C.

Pot 2 (App. 4: 12), Renče clay
Another pot was made from Renče clay that was also tempered with calcite but fired in a pit fire. The collected spectrum recorded a principal Si-O stretching band at 1036cm^{-1}, which is indicative of a meta-smectite. There is also a shoulder peak at 1085cm^{-1} which is attributed to the overlap between the quartz and the meta-kaolinite component. The dominance of the meta-clay in the sample is supported by the combined Si-O/Al-O bending mode at 473cm^{-1}. Meanwhile, raw smectite is reported by the minor band at 3620cm^{-1} and a band at 521cm^{-1}. Water associated with the clay components (*i.e.* raw and meta) is detected by the broad H_2O-stretching band at 3422cm^{-1} and the H_2O bending mode at 1637cm^{-1}.

Quartz is identified by the characteristic band-doublet at 779 and 797cm^{-1}, and the minor peak at 695cm^{-1}. The spectrum also recorded a minor band at 1872cm^{-1} and a shoulder band at 1164 that are related to SiO_2 mineral polymorphs. Furthermore, the spectrum has a main CO_3 band at 1420cm^{-1}, a secondary band at 875 cm^{-1},and minor bands at 1796 and 712cm^{-1}, which are characteristic of primary calcite (*Shoval 2016*).

The reported meta-clays in this sample support firing temperatures between 600°C and 900°C (*Shoval 2016; Stevenson, Gurnick 2016; Tarhan, Işık 2020*). However, the occurrence of primary calcite does not justify temperatures that go much higher than 700°C. Moreover, the detected raw clay suggests that the firing procedure did not consistently maintain high temperatures (>600°C). Based on these results, the highest temperatures reached in the pit fire was probably around 700°C, while the average firing temperatures should have been around 600°C.

Ceramic cube (App. 2: 5, 6)
A pottery cube was made from Renče clay, without tempering, and fired in the experimental kiln. The core and outer surface of this cube were sampled and analysed by FTIR. The spectra recorded a principal Si-O stretching band at 1032cm^{-1}, which is assigned to meta-smectite. They also present a combined Si-O/Al-O bending mode (at 469cm^{-1} for the core and 472cm^{-1} for the outer surface, respectively) that relates to the meta-clay component and subsequently supports that this cube mostly consisted of meta-smectite. Meanwhile, the neighbouring shoulder peaks (at 1090cm^{-1} and 1085cm^{-1} respectively) are attributed to the overlap between quartz and a meta-kaolinite component. Nevertheless, the pottery cube retains parts of the raw clay that was not affected by the firing. The FTIR analyses recorded a broad band at 3620cm^{-1}, a shoulder band at 913cm^{-1} and a band at 532cm^{-1} (core) and 525cm^{-1} (outer surface) that are characteristic of raw smectite. These bands, in particular, are associated with kaolinite–montmorillonite (*Chukanov 2014*), which is a mineral also detected in the original clay material (*i.e.* Renče clay source). Furthermore, Kaolinite-montmorillonite complies with the recognized meta-clays (*i.e.* meta-smectite and meta-kaolinite) since they are the expected outcome after firing this type of mineral.

Water related to clay components is detected by the very broad H_2O-stretching band at 3421cm^{-1} and the H_2O bending mode at 1637cm^{-1} (outer surface). The presence of quartz is confirmed by the characteristic band-doublet at 779 and 797cm^{-1}, and the minor peak at 694cm^{-1}. Additionally, the spectra included minor bands at 1870 and 1618cm^{-1}, and a shoulder band at 1166cm^{-1} (1164cm^{-1} for the outer surface) that are related to SiO_2 mineral polymorphs.

The presence of the meta-smectite suggests that this ceramic material was exposed to temperatures around 600°C and above (*Heller-Kallai, Rozenson 1980*). The examined sample, though, retains a raw clay component (*i.e.* kaolinite–montmorillonite) suggesting that the firing did not consistently maintain high temperatures (>600°C). Meanwhile, the presence of meta-kaolinite does not support temperatures below 450°C, so this pottery cube was probably fired at temperatures between 450 and 650°C.

Ceramic cube 2 (App. 3: 7, 8)
Another pottery cube was made from Renče clay, without tempering, but fired in an electric kiln. Similar to the previous cube, samples were collected from the core and outer surface, and analysed by FTIR. The core's spectrum recorded a principal Si-O stretching band at 1082cm^{-1} which is the result of the overlap between the quartz and a meta- kaolinite. The Si-O asymmetrical bending vibration at 457cm^{-1} is more compatible with quartz rather than a meta-clay. The increased presence of this mineral is further confirmed by the characteristic band-doublet at 778 and 797cm^{-1}, and the minor peak at 694cm^{-1}. The spectrum also recorded minor bands at 1870 and 1618cm^{-1}, and shoulder bands at 1164 and 557cm^{-1} that are related to SiO_2 mineral polymorphs. These findings suggest that SiO_2 mineral polymorphs (*e.g.*, quartz) are the dominant component of this cube's core. Lastly, absorbed water related to the meta-clay component is detected by the H_2O-stretching band at 3421cm^{-1}.

The outer surface's spectrum recorded a principal Si-O stretching curve that splits into two peaks. The first is at 1036cm^{-1} and it is assigned to meta-smectite, while the second peak at 1086cm^{-1} is the result of the overlap between the quartz and the meta-kaolinite component of the sample. The dominance of the meta-clay in this sample is further supported by the combined Si-O/Al-O bending mode at 470cm^{-1}. Absorbed water is detected by the very broad H_2O-stretching band at 3421cm^{-1} and the minor H_2O bending mode at 1637 cm^{-1}. Regardless, this sample also holds a strong content of SiO_2 mineral polymorphs. Quartz is identified by the characteristic band-doublet at 779 and 797cm^{-1}, and the minor peak at 694cm^{-1}, where other SiO_2 polymorphs are detected by the two shoulder bands at 1164cm^{-1} and 561cm^{-1}.

Regarding the firing temperature, the presence of only meta-kaolinite in the core of this pottery cube suggests that it was broadly exposed to temperatures between 450°C and 900°C (*Frost, Vassallo 1996; Shoval 2016*; *Stevenson, Gurnick 2016*). In contrast, the sample of the outer surface also contains meta-smectite, which along with the absence of raw clay indicates that this part of the cube was exposed at higher firing temperatures (>600°C) and more precisely between 600°C and 900°C (*Shoval 2016; Stevenson, Gurnick 2016; Tarhan, Işık 2020*).

Pot 3 (App. 4: 11), Griže clay
This pottery sample was made of Griže clay that was tempered with calcite and fired within the experimental kiln. The FTIR analyses recorded a principal Si-O stretching curve that splits into two peaks. The first

at 1082cm^{-1} is assigned to the overlap between the quartz and the meta-kaolinite. Meanwhile, the second at 1046cm^{-1} falls within the range of 1030–1060cm^{-1} relating to a meta-smectite composition. The dominance of the meta-clay in the sample is supported by the combined Si-O/Al-O bending mode at 473cm^{-1}.

Absorbed water is detected by the very broad H_2O-stretching band at 3421cm^{-1}. Quartz is identified by the characteristic band-doublet at 777 and 797cm^{-1}, and the minor peak at 694cm^{-1}. The spectrum also included two minor bands at 1872 and 1618cm^{-1} and a shoulder band at 1164cm^{-1} that are related to SiO_2 mineral polymorphs. Lastly, the small CO_3 band at 1420cm^{-1} is associated with primary calcite (*Shoval 2016*).

The reported meta-clays in the sample support firing temperatures between 600°C and 900°C (*Shoval 2016; Stevenson, Gurnick 2016; Tarhan, Işık 2020*). However, the occurrence of primary calcite does not justify temperatures much higher than 700°C. Therefore, this pottery sample was fired at temperatures between 600 and 700°C.

Pot 4 (App. 4: 10), Veliki Dul clay
This pottery sample was made of Veliki Dul clay, which was tempered with calcite and fired within the experimental kiln. The collected spectrum recorded a principal Si-O stretching curve that splits into two peaks. The first peak at 1039cm^{-1} is related to meta-smectite, while the second peak at 1086cm^{-1} is again associated with the overlap between the quartz and the meta-kaolinite. The dominance of the meta-clay component is further supported by the combined Si-O/Al-O bending mode at 473cm^{-1}. Absorbed water related to the meta-clay is detected by the broad H_2O-stretching band at 3420cm^{-1}.

Quartz is identified by the characteristic band-doublet at 777 and 797cm^{-1}, and the minor peak at 694cm^{-1}. The spectrum also recorded minor bands at 1870 and 1617cm^{-1} and a shoulder band at 1166cm^{-1} that are related to SiO_2 mineral polymorphs. Meanwhile, the main CO_3 band at 1421cm^{-1} and the bands at 1793, 878 and 713cm^{-1} are assigned to calcite, and based on the value of the main CO_3 band it is described as primary calcite (*Shoval 2016*). Lastly, the spectrum included a band at 3480cm^{-1} that it has not been possible to relate to any suitable mineral/component.

Regarding the firing conditions, the meta-clay supports fire temperatures between 600°C and 900°C. However, the occurrence of primary calcite does not justify temperatures much higher than 700°C. Therefore, this pottery sample was most probably fired at temperatures between 600 and 700°C.

Pithos (App. 6–7: 18, 19), Tabor near Vrabče
Samples from the core and outer surface of a pithos (from the Tabor near Vrabče site) were collected and analysed by FTIR. The core's spectrum recorded a principal Si-O stretching band at 1032cm^{-1} which is indicative of a meta-smectite. The combined Si-O/Al-O bending mode at 473cm^{-1} is also attributed to the meta-clay. However, the band at 534cm^{-1} is characteristic of kaolinite–montmorillonite and shows that the sample retains a small part of the original raw clay. Water, associated with the clay components (*i.e.* raw and meta), is detected by the H_2O-stretching band at 3448cm^{-1} and the H_2O bending mode at 1637cm^{-1}. Meanwhile, the main CO_3 band at 1429cm^{-1}, the secondary band at 875cm^{-1}, and the minor bands at 2512, 1797 and 712cm^{-1}, are indicative of calcite. Based on the value of the main CO_3 band, this is further described as primary calcite (*Shoval 2016*). Moreover, quartz is identified by the characteristic band-doublet at 779 and 799cm^{-1}.

The outer surface's spectrum recorded a principal Si-O stretching band at 1028cm^{-1} which is associated with raw smectite. Moreover, the band at 534cm^{-1} is attributed to kaolinite–montmorillonite (*Chukanov 2014*) and further supports the dominance of raw clay in this sample. The Si-O/Al-O bending mode at 473cm^{-1}, however, is related to a meta-clay component, which in this case is a meta-smectite. Water, related to the clay components (*i.e.* raw and meta), is detected by the H_2O-stretching band at 3422cm^{-1} and the H_2O bending mode at 1637cm^{-1}. Equally with the core, the outer surface also contains an important quantity of calcite. This is recorded with a main CO_3 band at 1425cm^{-1}, a secondary band at 875cm^{-1}, and minor bands at 2512, 1794 and 712cm^{-1}. Based on the value of the main CO_3 band this is also described as primary calcite (*Shoval 2016*). Moreover, quartz is identified by the characteristic band-doublet at 779 and 797cm^{-1}.

Regarding the firing conditions, the presence of meta-smectite and primary calcite supports temperatures between 600 to 800°C. However, the detected raw clay (*i.e.* kaolinite–montmorillonite) indicates that the firing also included temperatures below 600°C. It seems that the core of the pithos was fired for a longer period and at high temperatures than the outer surface. We discuss about this in the discussion part and it is not neccesary an error.

Silos (App. 3: 9), Štanjel

This sample was taken from a large silo that was made from a large clay band. The spectrum recorded a principal Si-O stretching band at 1032cm^{-1} which is indicative of a meta-smectite. The combined Si-O/Al-O bending mode at 476cm^{-1} is also related to the meta-clay and confirms that this is the main component of this sample. Absorbed water is detected by the very broad H_2O-stretching band at 3431cm^{-1} and the H_2O bending mode at 1636cm^{-1}. Quartz is identified by the characteristic band-doublet at 778 and 797cm^{-1}, and the minor peak at 694cm^{-1}. The spectrum also included a shoulder band at 1165cm^{-1} that is related to SiO_2 mineral polymorphs. Moreover, the spectrum also reported a main CO_3 band at 1420cm^{-1}, a secondary band at 874cm^{-1}, and a minor band at 712cm^{-1}, which are characteristic of calcite.

The main CO_3 band is assigned to primary calcite (*Shoval 2016*), suggesting firing temperatures below 800°C. Meanwhile, the presence of meta-smectite and the absence of raw clay indicate that this pottery was consistently fired at 600°C and above. Hence this silo was exposed to firing temperatures between 600 and 700°C.

Ceramic situla (App. 5: 13)

The spectrum of this sample recorded a principal Si-O stretching band at 1036cm^{-1} which is indicative of a meta-smectite. Moreover, there is a shoulder peak at 1085cm^{-1} that is assigned to the overlap between quartz and meta-kaolinite. The combined Si-O/Al-O bending mode at 474cm^{-1} is also related to the meta-clay and confirms that it is an important component of this sample. The spectrum reported the significant presence of calcite, which was identified by a main CO_3 band at 1420cm^{-1}, a secondary band at 875cm^{-1}, and minor bands at 2513, 1794 and 712cm^{-1}. Furthermore, absorbed water is detected by the H_2O-stretching band at 3421cm^{-1} and the H_2O bending mode at 1637cm^{-1}. Quartz is identified by the characteristic band-doublet at 779 and 798cm^{-1}. The spectrum also included a band at 1618cm^{-1} that is related to SiO_2 mineral polymorphs.

The presence of meta-smectite and the absence of a raw clay component suggest that this ceramic find was fired at high temperatures (>600°C), which resulted in the complete transformation of the original clay. Meanwhile, the main CO_3 band is associated with primary calcite (*Shoval 2016*), suggesting firing temperatures below 800°C. The ceramic situla was thus exposed to firing temperatures between 600 and 700°C.

Pot (App. 7: 20, 21)

Samples from the core and outer surface of a pottery fragment were collected and analysed by FTIR. The spectra recorded a principal Si-O stretching band at 1028cm^{-1} which is associated with raw smectite. Moreover, the band at 534cm^{-1} (at 535cm^{-1} for the outer surface) is attributed to kaolinite–montmorillonite (*Chukanov 2014*) and further supports the dominance of raw clay in this pottery fragment. The Si-O/Al-O bending mode at 474cm^{-1}, however, is related to a meta-clay component which in this case is a meta-smectite. Water, related to the clay components (*i.e.* raw and meta), is detected by the H_2O-stretching band at 3422 cm^{-1} (at 3423cm^{-1} for the outer surface) and the H_2O bending mode at 1637cm^{-1}. Quartz is identified by the characteristic band-doublet at 778 and 798cm^{-1} (at 779 and 798cm^{-1} for the outer surface). Additionally, the spectrum recorded the important presence of calcite with a main CO_3 band at 1425cm^{-1}, a secondary band at 875cm^{-1}, and minor bands at 2512, 1794 and 712cm^{-1}.

Having raw smectite as the principal component generally indicates low firing temperatures (<600°C). However, the presence of a small meta-smectite particle suggests that for a short period the fire reached temperatures of 600°C and above. The main CO_3 band falls within the range of 1420–1430cm^{-1} and is associated with primary calcite (*Shoval 2016*), suggesting firing temperatures below 800°C. Therefore, this pottery fragment was most likely exposed to firing temperatures around 600°C.

Ceramic petro thin-section

The initial focus in the ceramic petro thin-sections involved the analysis of Renče clay, revealing two distinct different fabric types. Sample 2 (Fig. 3.1), derived from a kiln base, exhibits a fabric consistent with firing structures observed in archaeological sources (*e.g.*, *Quinn 2022.Figs.3.53, 7.12*). The presence of numerous irregularly oriented planar voids due to the burning out of organic matter – in this case straw – is a characteristic feature. The preparation of the clay was less precise compared to that seen with the vessels, resulting in poorly sorted and individually closed inclusions. Inclusions, comprising quartz, muscovite mica, clay pellets, calcite, and ferruginous minerals, occur naturally in the clay and constitute 40% of the composition. Organic matter was used as a temper. Sample 1 (pot 1, tempered with calcite; Fig. 3.2) has the same clay matrix as Sample 2 but lacks organic matter and calcite temper. Similarly, there are no differences in the clay matrix among the remaining two samples made from the Renče clay (Samples 5 and 7) (Tab. 1).

The subsequent group pertains to the Tabor near Vrabče site and consists of two samples: one experimentally made from Griže clay (Sample 11; Fig. 3.3), tempered with calcite, and another from a pithos fragment (Sample 18; Fig. 3.4). The inclusions recorded in these samples, encompassing mono- and polycrystalline quartz, iron opaque minerals, muscovite mica, and iron-rich clay pellets, constitute 30% of the sample. The majority of these inclusions appear as equant rounded or elongate rounded particles, with quartz reported as equant subangular. They exhibit a single-spaced and randomly aligned distribution, occasionally forming locally oriented planes, resulting in a coarse fabric. Meanwhile, in the pithos (Samples 18, 19) we identified the presence of calcite and grog temper. The calcite grains exhibit intentional cracking, showing equant angular to equant subangular shapes. Additionally, rare grog was detected, a characteristic feature of this period (see *Vinazza 2021.433*). Other inclusions include mono- and polycrystalline quartz, muscovite mica, iron-rich clay pellets, and iron-opaque minerals. The clay matrix reveals evidence of intentional clay mixing, contributing to its moderate heterogeneity. Approximately 10% of the sample is occupied by macro and micro-sized voids, characterized as planar and channel-shaped. These voids are attributed partly to firing cracks and partly to the remnants of burned organic matter, utilized as temper, albeit in minimal quanti-ties.

The third group pertains to the Štanjel site and constitutes the most diverse group, involving the analysis of local clay from Veliki Dul (Sample 10; Fig. 3.5), a presumably local pottery type known as a silo (Sample 9; Fig. 3.6), a local pot (Sample 20; Fig. 3.7), and a presumably imported ceramic situla (Sample 13; Fig. 3.8). The Veliki Dul clay has 40% inclusions, among which calcite, mono- and polycrystalline quartz, muscovite mica, iron-rich clay pellets and opaque iron minerals were identified. The silo, presumably tempered with calcite, grog, and partially burned organic matter, features macro- and mega-sized channel-shaped voids (Fig. 3). Quartz is the predominant inclusion, but muscovite mica, iron-rich clay lumps, iron-rich opaque minerals, flint, zircon, and feldspar (indicative of igneous rocks) were also present. Arranged individually, these contribute to a coarse fabric which constitutes 40% of the overall composition. Similarly, the fragment of the local pot (Sample 20) encompasses 55% inclusions, with calcite dominating at 90%. Apart from a minimal presence of grog grains (0,1%), calcite prevails as the temper. Other identified inclusions include monocrystalline quartz, muscovite mica, and iron-rich clay pellets. The homogeneous clay matrix represents 40% of the sample, accompanied by 5% of micro-sized vughs voids irregularly orientated within the clay matrix.

The ceramic situla (Sample 13) was tempered with calcite speleothem grains, originating from stalagmite/stalactite formations, along with grog and clay lumps. The clay lumps exhibit visible cracks, potentially linked to the incorporation of fine clay material that underwent drying before being mixed with the clay. Other inclusions encompass mono- and polycrystalline quartz, limestone, flint, iron-rich clay pellets, iron-opaque minerals, and muscovite mica. Notably, muscovite mica is more prevalent in the grog than in the clay matrix. Planar macroscopic voids are evident, associated with the drying process and the forming of the vessel, particularly those that are parallel in orientation.

The petrographic results within the Renče group align with the referencing model for various ceramic forms, including vessels and structures. A comparative analysis between the pottery from Tabor near Vrabče (Sample 18) and the local clay (Sample 11) validates its local provenance. Moreover, the pottery was tempered with calcite, grog, and organic matter, consistent with the prevalent practices during the Late Bronze and the beginning of the Early Iron Age. The Štanjel group yields even more interesting results. While Pot 5 is identified through a comparison with experimental material sourced from local Veliki Dul clay, the same cannot be asserted for the silo, which incorporates components of igneous rock not native to the Karst. Conversely, the ceramic situla exhibits a composition entirely derived from local material.

Discussion

Petrographic analysis has elucidated the utilization of both local and non-local clay sources in archaeological ceramics. Given the geological diversity of Slovenia, which influences the composition of clay sources, we employed a singular clay source, such as Renče clay,

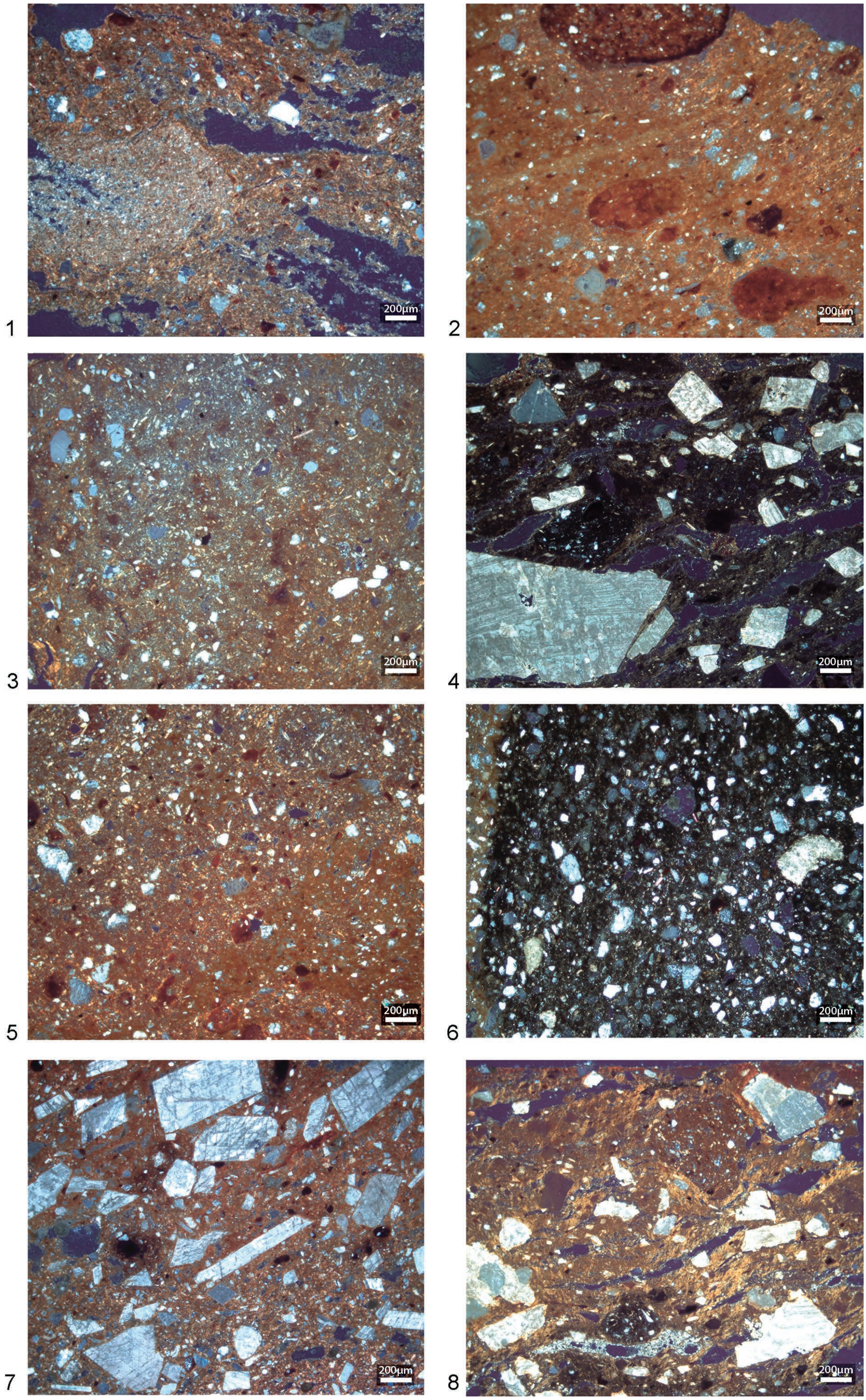

Fig. 3. Ceramic thin-section. Photos taken under plain polarized light.

throughout the entire operational sequence – from pot shaping to pot firing. Additionally, for processes occurring in different firing structures we utilized other clay sources from the vicinity of the aforementioned archaeological sites (Fig 1).

The samples from all four clay sources predominantly exhibit a smectitic clay composition. Moreover, those from the Renče and Veliki Dul clay sources indicated the presence of kaolinite-montmorillonite, a clay mineral polymorph that combines kaolinitic and smectitic compositions. Quartz is consistently recorded as the second most abundant mineral in all the examined sources. However, the FTIR results did not detect bands assigned to calcite in any of the clay sources.

The FTIR analyses of experimental clay revealed that the kiln dominantly consists of meta-clay and exhibits a higher quartz content. Meta-clay is characterized by a combination of kaolinitic and smectitic origins, reflecting the clay minerals present in the original clay source. Unexpectedly, findings from the wall (Sample 4) indicate the presence of a small calcite component. Calcite was not reported in the original clay, and possibly these related to small pebbles that were in the outcrop that was sampled.

The FTIR results additionally indicate that the base of the kiln was exposed to lower firing temperatures compared to the wall and chimney. The presence of raw clay in the base's sample suggests temperatures ranging between 450 and 650°C, while neither the wall nor chimney retain any traces of raw material. The composition of the chimney supports a wide range of high temperatures (*i.e.* 600 and 900°C), while the presence of reformed calcite in the wall's sample is indicative of temperatures between 700 and 800°C.

The suggested temperatures align with those recorded by two thermocouples during the conducted experiment. They indicated that the temperature near the wall exceeded 600°C for at least 30 minutes, while at the base it was maintained for at least two hours. The temperature at the base gradually increased, reaching around 600°C by the end of the firing procedure. Meanwhile, the temperature rise along the wall did not exhibit a similar pattern, possibly due to the incomplete loading of the kiln and the vessels not being in direct contact with the kiln wall. The sample from the wall of the kiln was taken 10cm above second thermocouple, implying that the selected sample area was in direct contact with the fire, resulting in temperatures higher than those at the bottom base. AMS measurements (*Vinazza, Dolenec 2022.Fig. 3*) agree with the FTIR results, and the lower temperatures at the base probably relate to the fact that the sampled area was under the vessels and eventually not in direct contact with the fire. The occurrence of the different temperatures at the different parts of a kiln was confirmed by thermovision camera measurements in another archaeological experiment conducted in 2018 (*Vinazza 2021.Fig. 150*). The temperature measured with thermocouples in the experimental kiln was 670°C, closely corresponding to the samples taken from the base of the kiln *i.e.* between 450 and 650°C. Furthermore, the XRD results help refine and narrow down lower temperature estimates, confirming firing above 550°C (*Vinazza, Dolenec 2022.396*). Combining the FTIR and XRD results yields a final estimated firing temperature ranging from 550 to 650°C. This suggests that the FTIR results reflect the firing process very well and help us better understand its complexity. Additionally, the complexity of these results emphasizes the importance of thoughtful consideration before sampling archaeological material.

The FTIR results for a pot (Sample 1) initially indicated a broad temperature range between 450 and 900°C, but subsequent XRD results, as reported by Vinazza and Dolenec (*2002.396*), refined the temperature estimate to between 550 and 900°C.

The FTIR results of the firing pot in pit firing (Sample 12) displayed temperatures around 700°C, aligning closely with the firing temperatures measured by a thermocouple. Despite the short heating time, the FTIR accurately reflected the process. The FTIR results for the pottery samples modelled from local clay Veliki Dul (Sample 10) and Griže (Sample 11) indicated that both pottery vessels were composed of meta-clay, quartz, and calcite, suggesting firing temperatures between 600 and 700°C. These findings fit well with temperatures measured by thermocouples during the firing procedure (*i.e.* 670°C).

In order to distinguish firing structures based on soaking time, the FTIR analyses are also very helpful. FTIR results for the first cube indicate exposure to temperatures ranging from 450 to 650°C. The core retained some raw clay, suggesting lower temperatures (450 and 600°C), consistent with the understanding that the core requires more time to fire. Conversely, the outer surface showed no presence of the raw clay, indicating prolonged exposure to higher temperatures

(>600°C). For the second cube, the FTIR results clearly demonstrated an overall exposure to higher temperatures (>600°C). The dominance of meta-clay and quartz, coupled with the complete absence of raw clay, suggested temperatures between 600 and 900°C, aligning with the temperatures achieved in the electric kiln (*i.e.* 800°C).

Since these results confirmed the laboratory firing temperatures we can also use this method for the archaeological material.

The final step of our investigation involved the application of FTIR and petrographic analyses to archaeological materials, aiming to interpret the firing process that was employed.

Starting with the Tabor near Vrabče site, both the outer surface (Sample 18) and core (Sample 19) of the pithos were analysed. The FTIR analyses of the outer surface revealed a predominance of raw smectite, signifying low firing temperatures. Nevertheless, a small meta-smectite component was identified, indicating that for a brief period high temperatures were reached (between 600 to 800°C). In contrast, the core exhibited an increased meta-clay component, indicating consistent exposure to higher temperatures (>600°C). These odd temperature findings between the outer surface and the core may be connected to the vessel's position during firing, where heat is radiated from the interior to the vessel's exterior or temperature drop during firing, characteristics more indicative of a bonfire/pit fire rather than of a kiln.

Thin-section analysis revealed that this silo (Sample 9) was tempered with calcite, organic matter, and grog. Moreover, the clay matrix included minerals typical of igneous rocks, which are not naturally occurring in the Karst plateau. Notably, it also contains a higher concentration of muscovite mica compared to the local Veliki Dul clay (Sample 10), suggesting a distinct clay origin not indigenous to the area. The FTIR results reindicated that it primarily consists of meta-smectite, quartz and primary calcite. Furthermore, the absence of raw clay suggests firing temperatures between 600 and 700°C. Given the wall thickness, an extended firing duration is required for proper firing due to the slower heat penetration. Thin-section analysis indicated temperatures not exceeding 670°C, as calcite grains did not exhibit signs of decomposition (*Vinazza, Dolenec 2022.395*).

The next archaeological find from the Štanjel site is a ceramic situla (Sample 13), which was initially presumed to be an imported ware, but petrological characteristics revealed that it was tempered with speleothem calcite, a material commonly found in the Karst caves surrounding the archaeological site. The investigation of the situla also identified the use of grog and clay lumps for tempering. Notably, the grog exhibited a significantly higher muscovite content compared to the clay matrix, indicating a distinct clay composition. The presence of a planar voids suggests a lack of proper clay preparation. This, coupled with the speleotherm calcite grains, strongly supports the local production of this situla.

Since petrographic analysis revealed no visible degradation of the calcite and the FTIR results support these findings and indicate firing temperatures between 600 and 700°C, this suggest that the situla was indeed fired under controlled environment, such as the one within a kiln. Moreover, the macroscopic examination revealed ORO firing. All these results strongly support the idea of the existence of a double-chamber kiln in the area under study during the Early Iron Age.

Pottery findings from Štanjel contribute also to a hypothesis supporting the local production of pottery using at least a one-chamber pottery kiln. To test this hypothesis a pot (Samples 20, 21) from the Štanjel site was examined. The FTIR results indicate temperatures around 600°C, consistent in both the core and outer surface, suggesting that the firing conditions were stable, devoid of temperature fluctuations, a characteristic achievable in a kiln. Furthermore, petrographic analysis revealed that the vessel was tempered with calcite, and no grain decomposition was observed, indicative of temperatures below 650°C. The ability to control the firing temperature in a kiln likely facilitated the use of calcite temper, a practice common in this region and elsewhere.

Conclusion

Archaeological investigations have unveiled the utilization of distinct firing structures by the Late Bronze and Early Iron Age communities in the Karst Plateau. A detailed examination of a variety of firing processes was conducted through the development of an interpretative model based on experimental firings.

By synthesizing results from different analyses, it becomes feasible to understand and accurately interpret the results collected from archaeological materials. This paper presents, for the first time, an investigation that was successful in detecting and confirming the utilization of firing structures during the Late Bronze and Early Iron Ages in western Slovenia. Given the absence of archaeologically excavated firing structures in this region, this type of analysis stands as the most effective means to gain insight into firing practices during that period. The research findings indicate that bonfire/pit-fires were utilized in the Late Bronze Age, while kilns became prevalent in the Early Iron Age. Notably, the presence of locally produced ceramic situlae in the Early Iron Age (6th century BC) serves as evidence for the use of double-chamber kilns during this period, predating their archaeological attestation in the Late Iron Age.

The archaeological research illuminated the complexity of firing processes and emphasized the importance of meticulous sampling to yield meaningful results and definitively answer research questions. FTIR analyses also help to detect irregularities in the firing, but special care must be given to proper sampling. Lastly, outdoor experiments provide more realistic insights into past processes, and proved to be highly suitable for cross-referencing with archaeological material.

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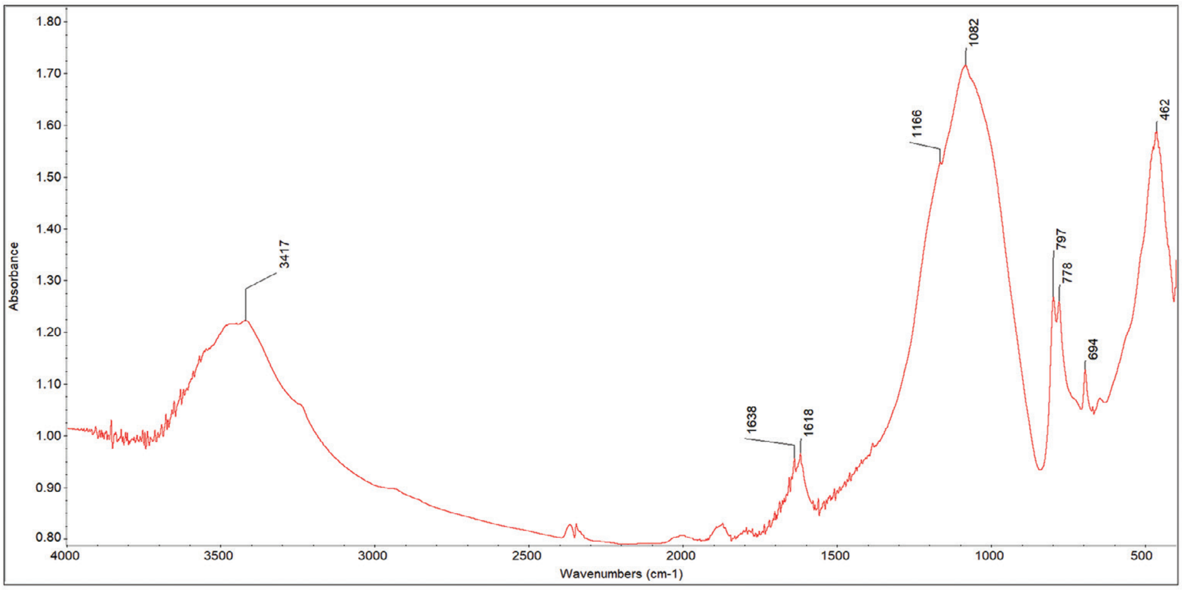

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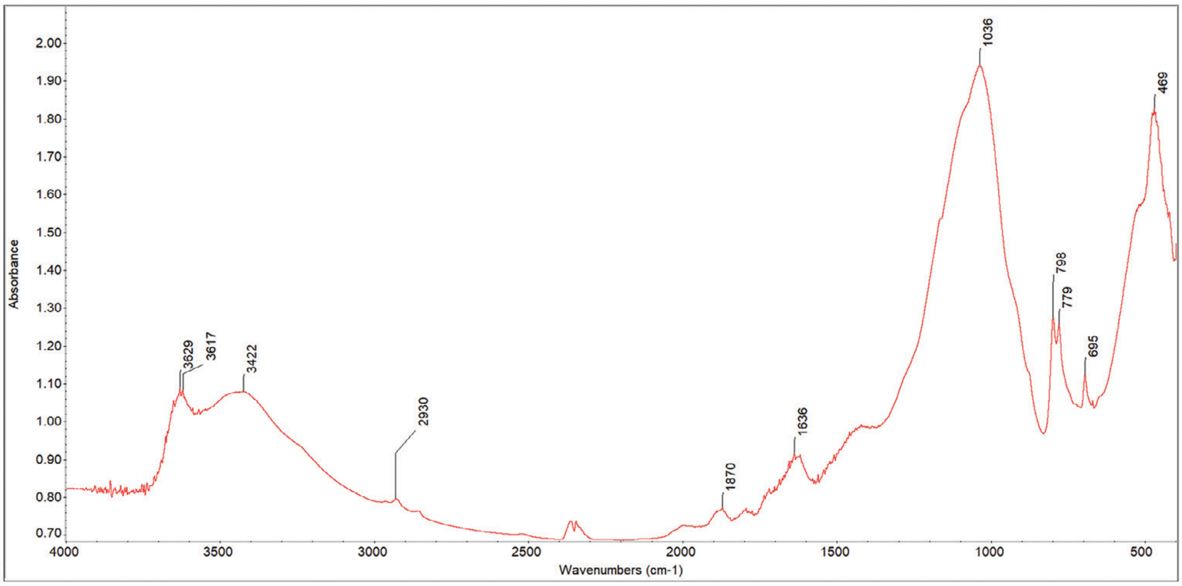

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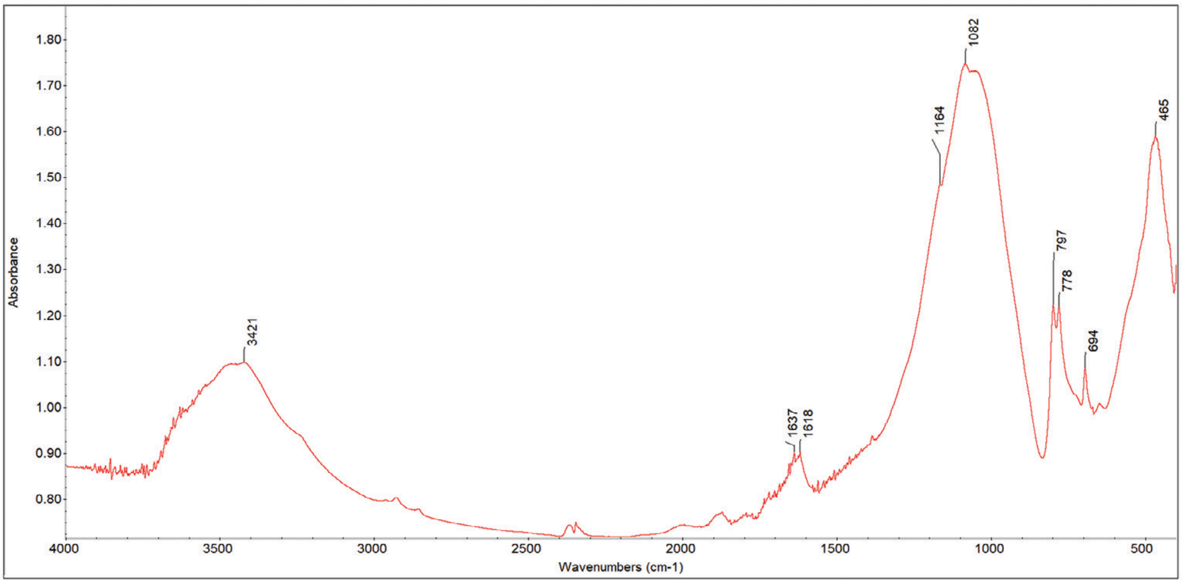

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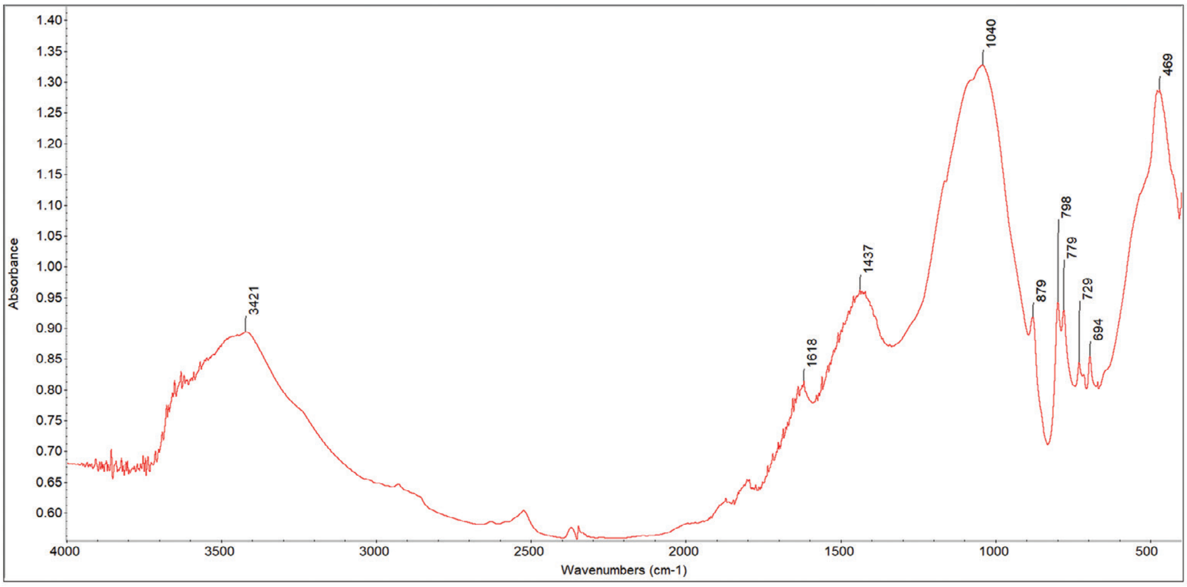

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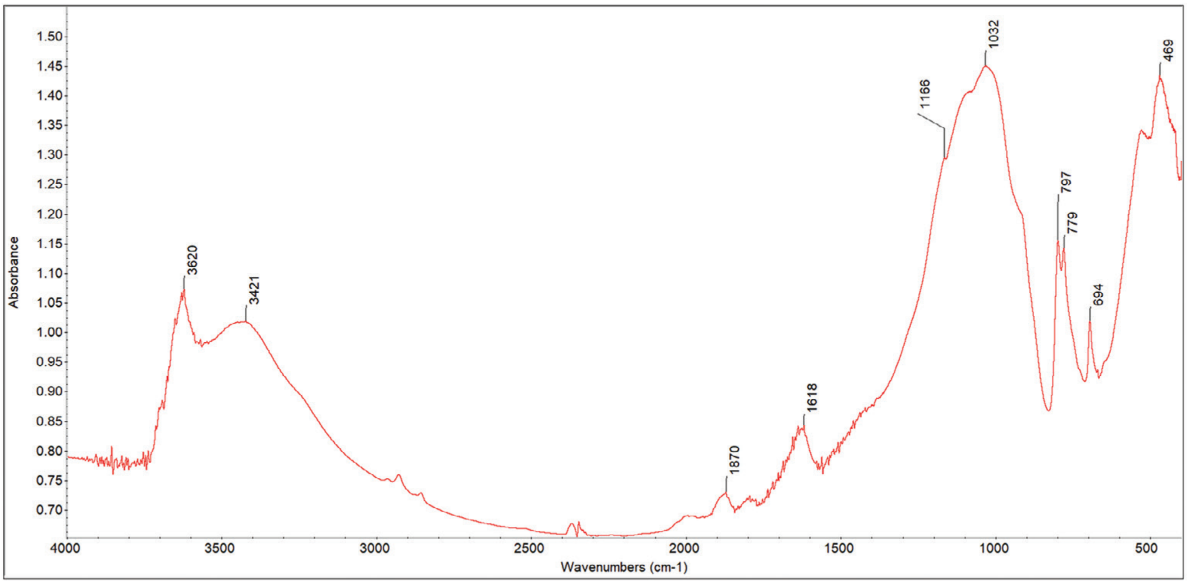

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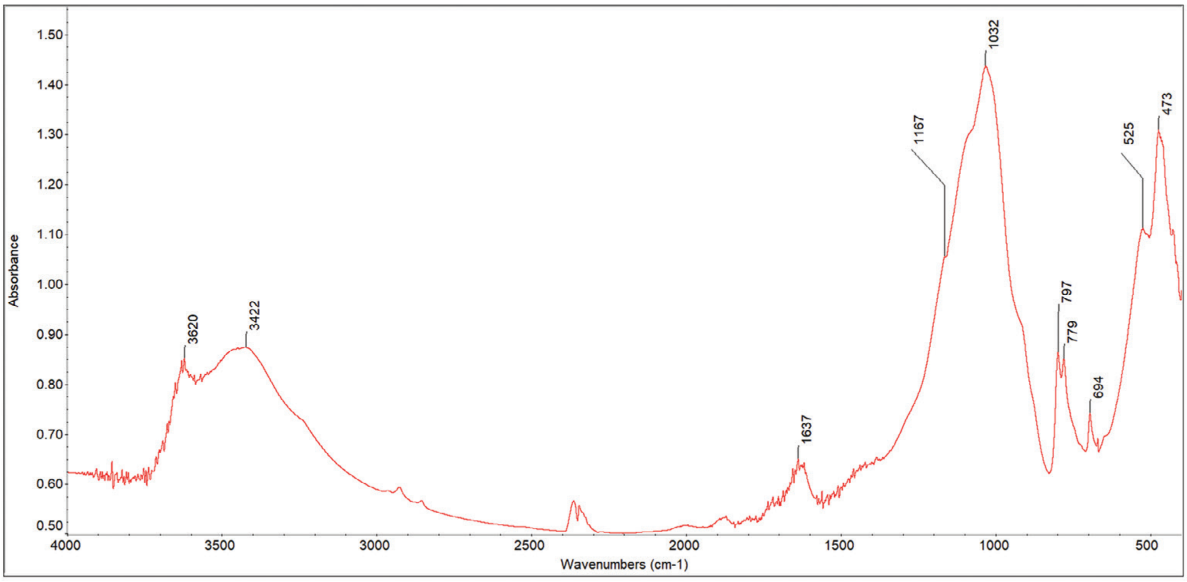

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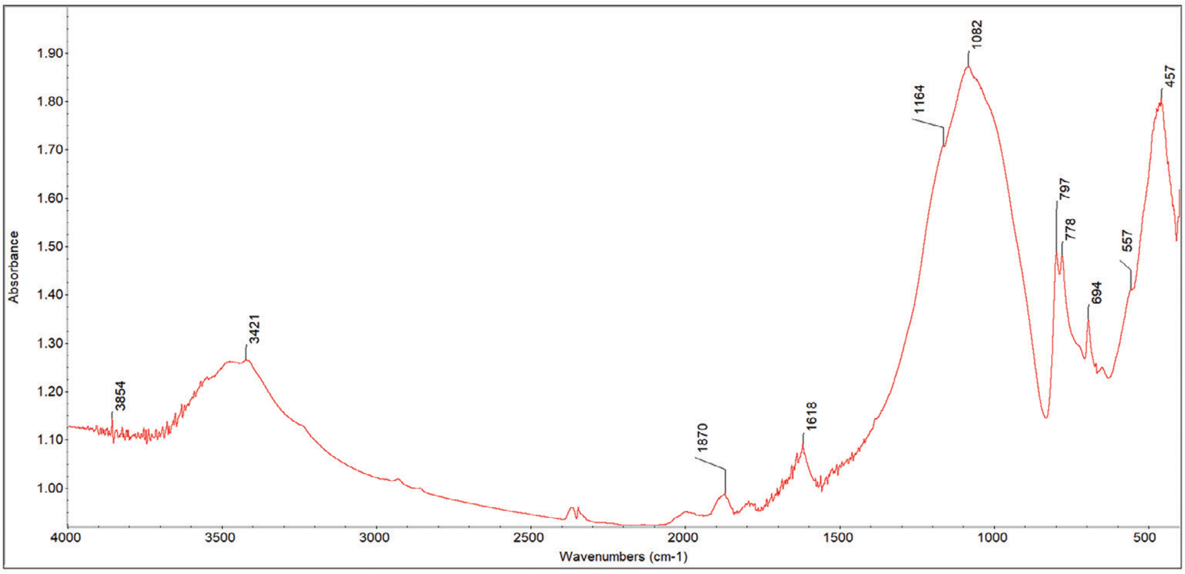

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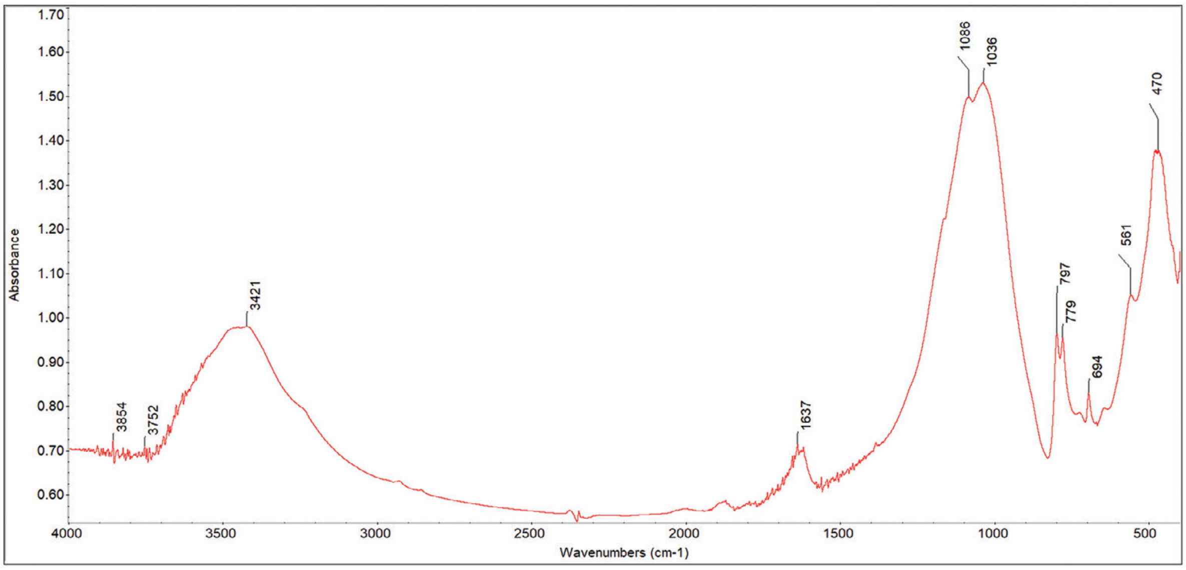

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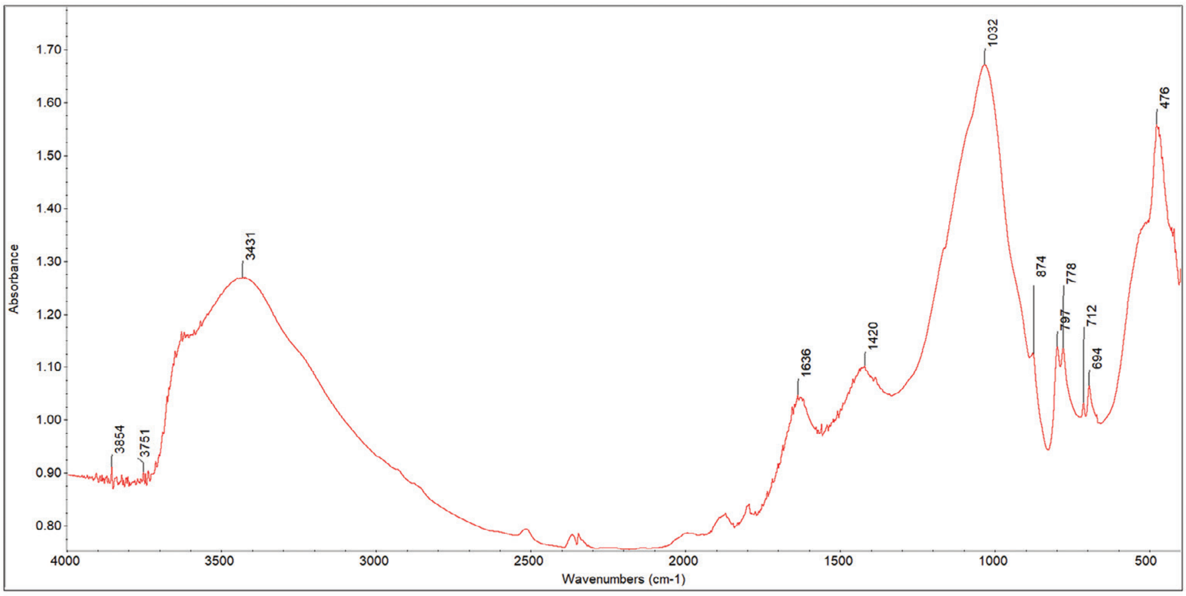

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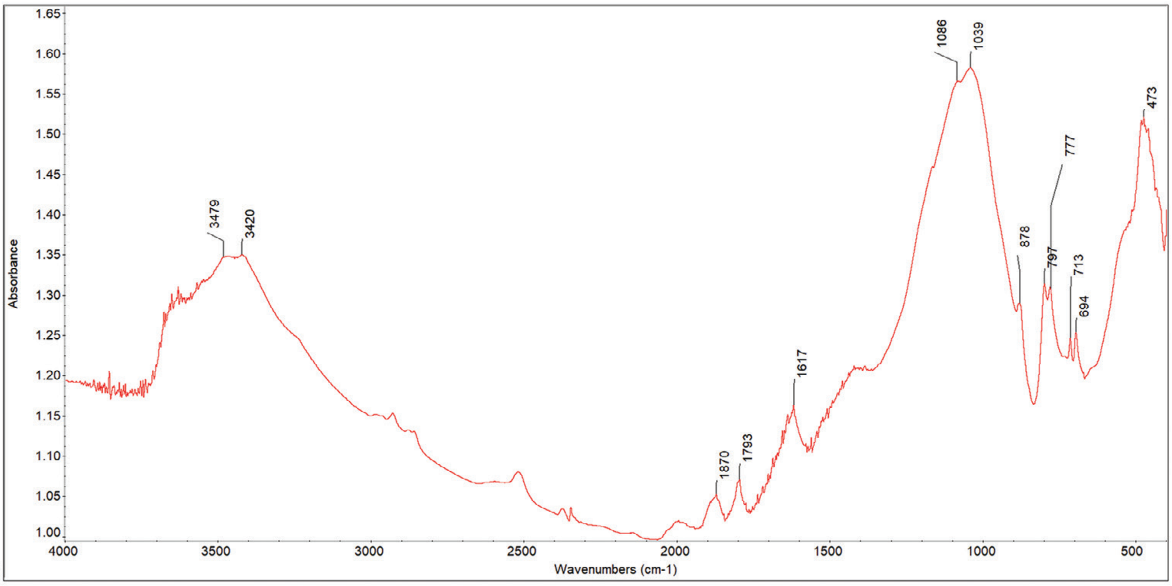

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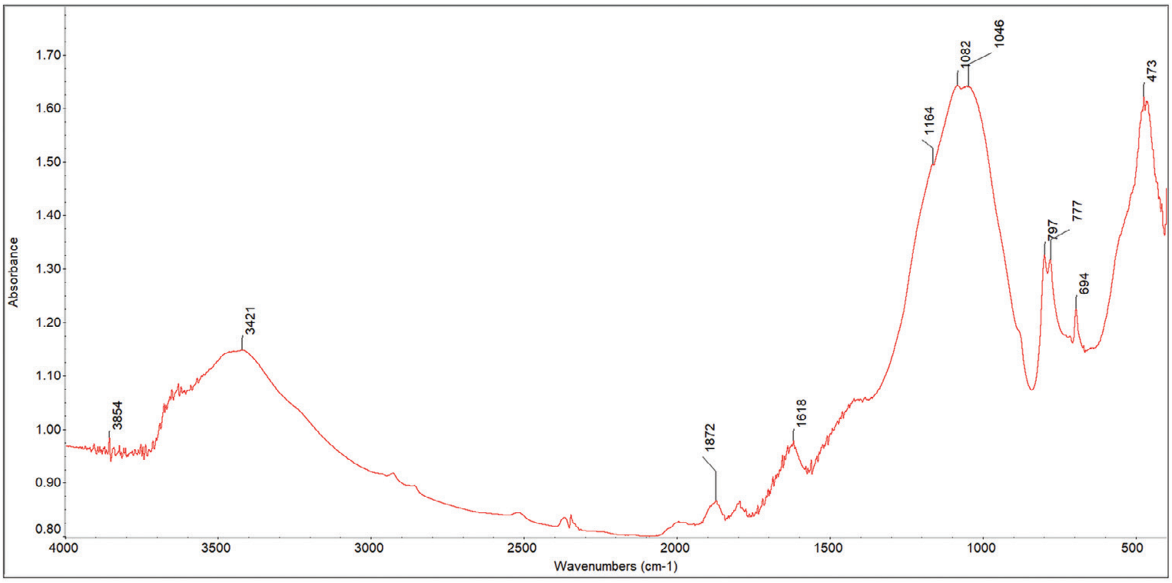

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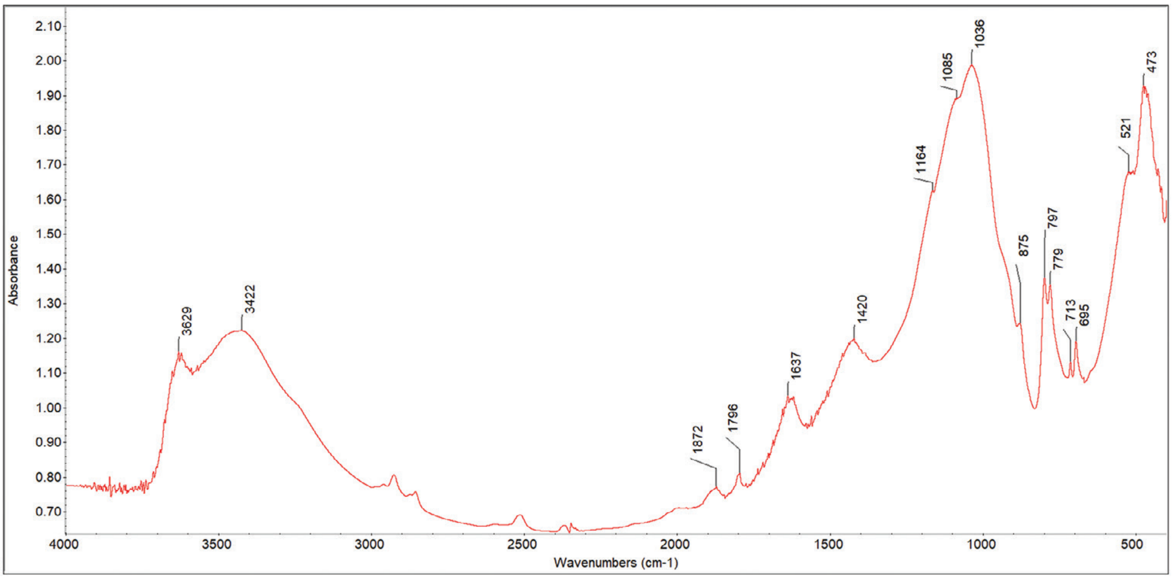

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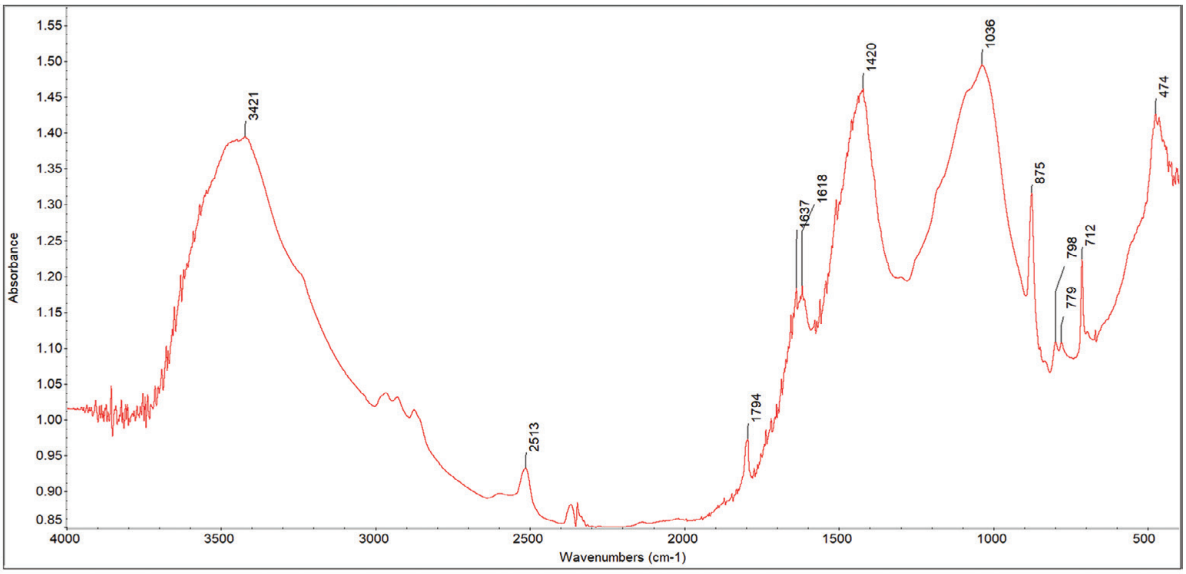

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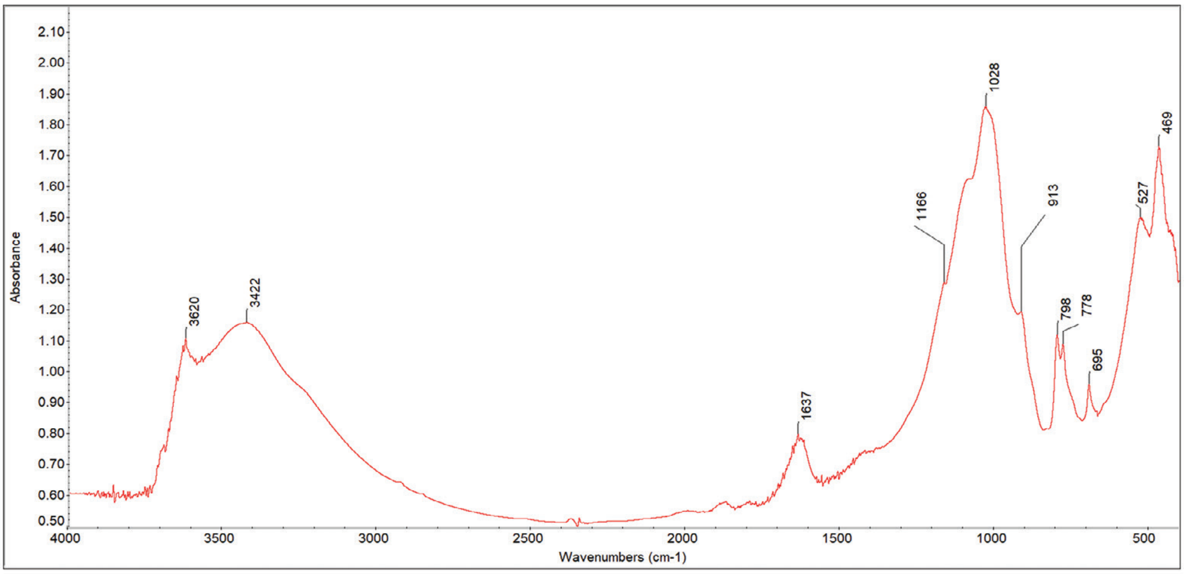

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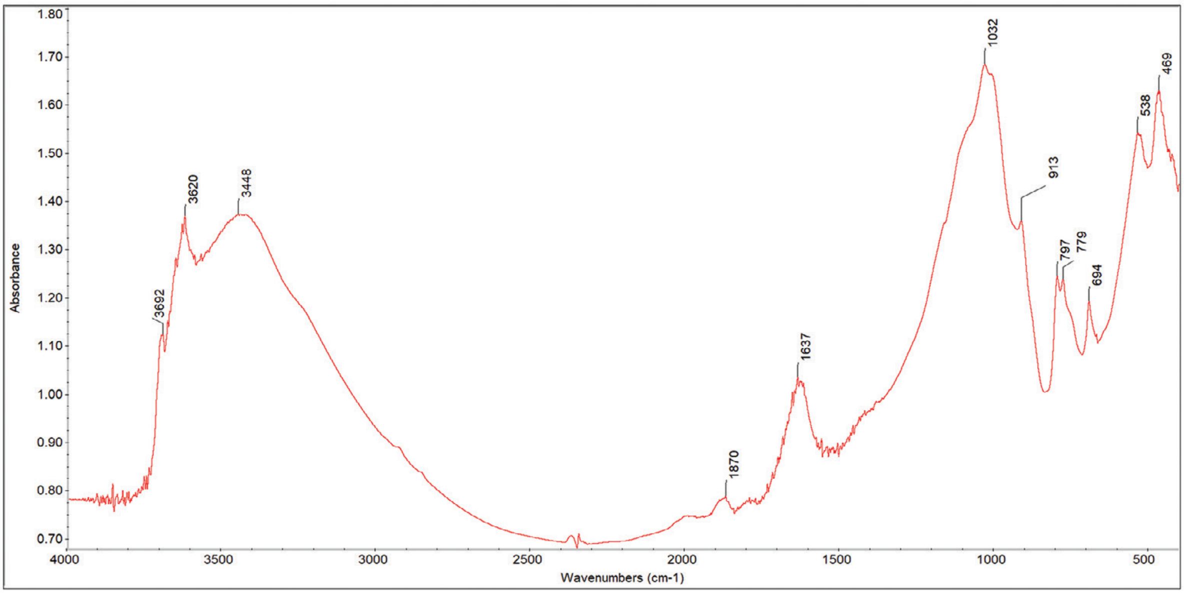

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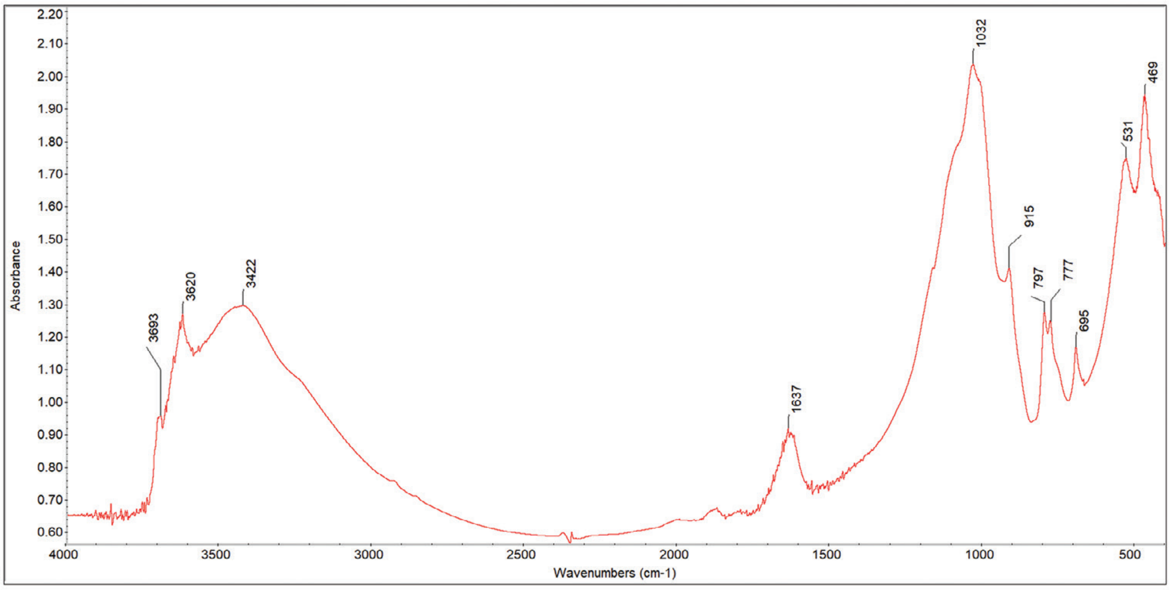

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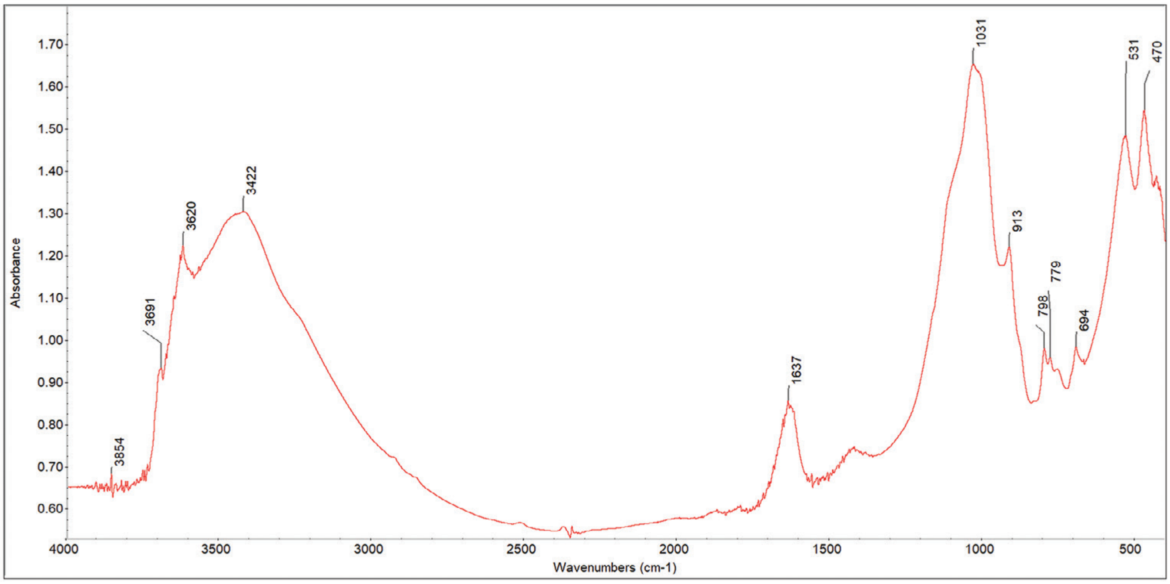

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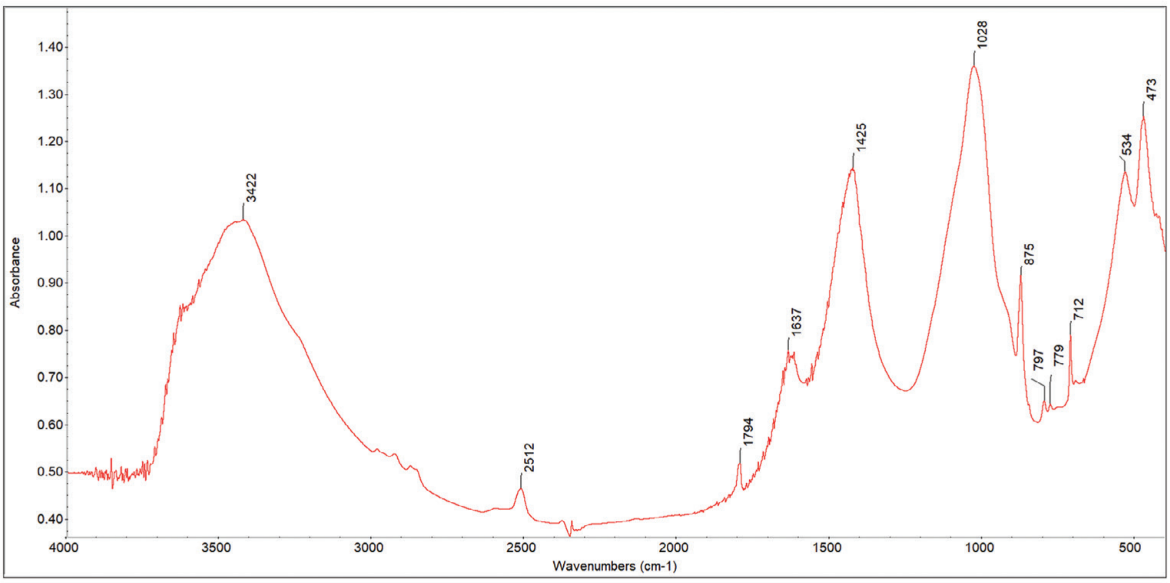

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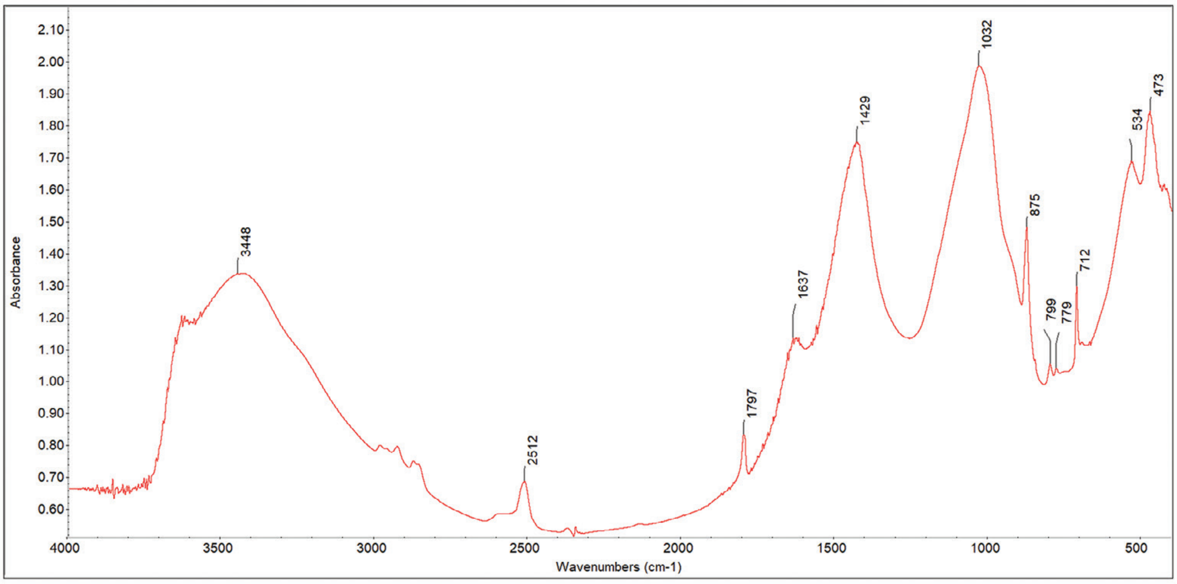

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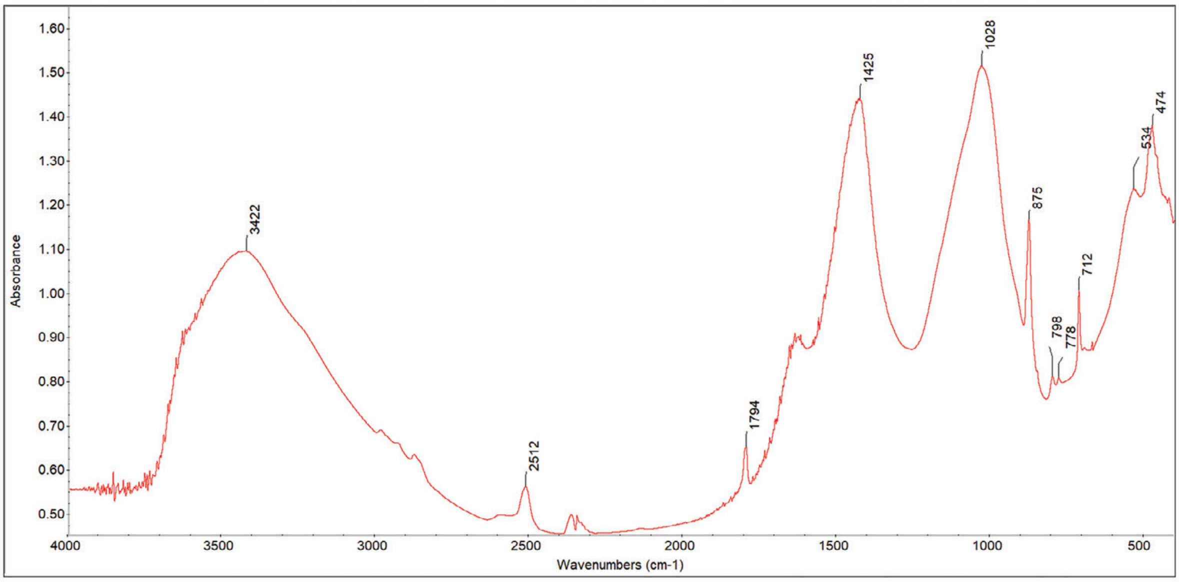

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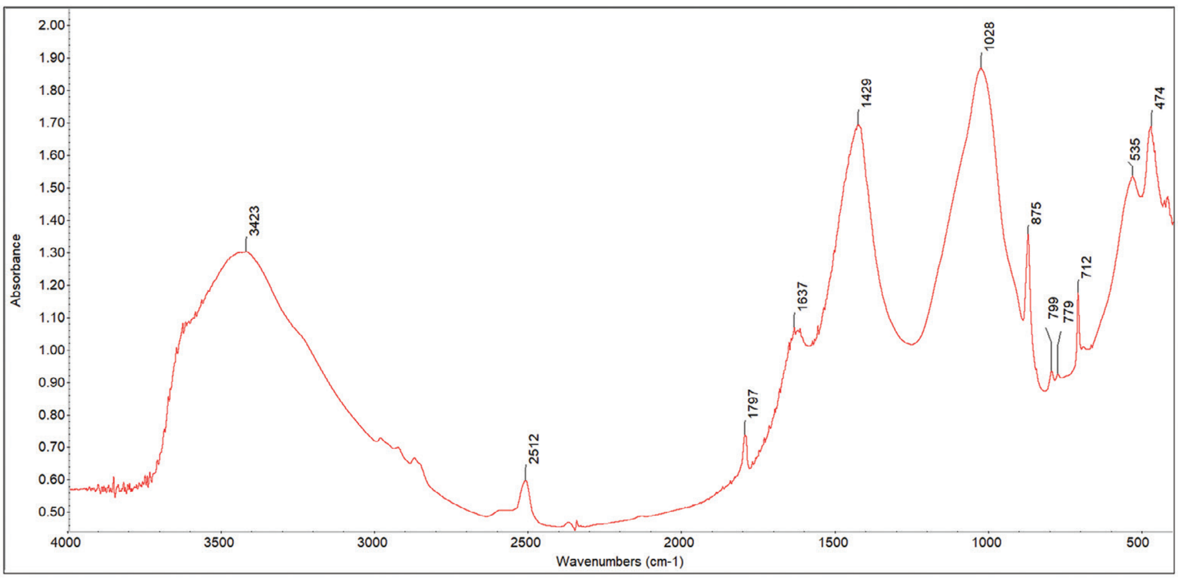

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Backed pieces at Sharbithat SHA-10 (Sultanate of Oman): technological issues and chronological assessment

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ABSTRACT - *Sharbithat 10 (SHA-10) was discovered in 2017 during the first extensive survey of the northern part of the Dhofar region. Located on a vast mesa surrounded by wadi deltaic branches and abundant sources of flint, SHA-10 is characterized by flint scatters, dwellings, and cairns. Initial test trenches revealed a single period stratification sequence, highlighting a rich marine faunal composition and intense flintknapping activity. The fishing equipment, typical of coastal sites from this period, accompanies a distinctive lithic industry comprising blades, backed pieces, and tanged points. Through the study of technological processes leading to the manufacture of these artefacts, analysis of the points' morphological variability, and examination of the prevalence of backed bladelets, new hypotheses regarding coastal subsistence strategies and chronological issues have emerged. However, the potential co-occurrence of different facies complicates a chronological definition which can be partly clarified by radiocarbon data results. In this communication, we present a preliminary study of this unique assemblage, discuss its chrono-typological implications, and explore their significance within the framework of South Arabian prehistory.*

KEY WORDS – *Southeastern Arabia; Late Neolithic; lithic technology; backed pieces; fisherfolks campsite*

Orodja s hrbtom v Sharbithat SHA-10 (Sultanat Oman): tehnološka vprašanja in kronološka ocena

IZVLEČEK – *Sharbithat 10 (SHA-10) je bil odkrit leta 2017 med prvim obsežnim raziskovanjem severnega dela regije Dhofar. Za SHA-10, ki se nahaja na obsežni planoti, obdani z deltastimi vadiji in bogatimi viri kremena, so značilni razpršeni skupki kremenovih odbitkov, bivališča in megaliti. Prve testne sonde so razkrile enofazne stratifikacije, s plastmi z bogato morsko favno in intenzivno industrijo kremenovih odbitkov. Ribiška oprema, značilna za obalna mesta iz tega obdobja, spremlja značilno kameno industrijo, ki jo sestavljajo rezila, orodja s hrbtom in konice s trnom. Proučevanje tehnoloških procesov izdelave teh artefaktov, analiza morfoloških variabilnosti konic in razširjenost klinic s hrbtom so pripeljali do novih hipotez o strategijah preživljanja na obalah in novih kronologijah. Vendar pa mogoče sočasno pojavljanje različnih skupkov otežuje kronološke opredelitve; delno jih lahko pojasnimo z rezultati radiokarbonskih datiranj. V članku predstavljamo predhodno študijo tega edinstvenega zbira, razpravljamo o njegovih krono-tipoloških implikacijah in raziskujemo njegov pomen v južnoarabski prazgodovini.*

KLJUČNE BESEDE – *jugovzhodni Arabski polotok; pozni neolitik; kamena tehnologija; orodja s hrbtom; naselje ribičev*

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Introduction

For more than ten years, the project Archaeology of the Arabian Seashores has aimed at studying the evolution of the Omani coastline, from the hunter-gatherer communities of the end of Pleistocene to the rise of Metal Age societies (*Charpentier 2021*; *Charpentier* et al. *2023*). The extensive survey focused on the land extending from Ra's al-Jinz, at the eastern tip of Arabia, to the villages on the Yemeni border, including Masirah and Hallanyat Islands (Fig. 1). In the framework of this project, between 2017 and 2019, the fieldwork activities focused on the Sharbithat Bay (Figs. 1, 2). Located at the turn between Al Wusta and Dhofar Governorate, this area revealed extraordinary potential for a re-definition and re-evaluation of the Neolithic Period in southern and southeastern Arabia. At Sharbithat, sites dated to the Middle and Late Neolithic (6500-4500 and 4500–3100 BC) were discovered and radiocarbon dated (*Maiorano* et al*. 2018; 2022; Charpentier* et al*. 2023*). Sites dated to these two phases of the Neolithic had never been found in co-occurrence at Sharbithat (except for sparse finds), and identify specific technological and chronological horizons. The most ancient is characterized by the production of trihedral and *Concorde* projectile points, shaped through parallel-covering retouch (*Maiorano* et al*. 2018*). The latter is dominated by blade and bladelet production together with the manufacture of tanged points on thick bladelets, or laminar-flakes (also called Sharbithat points), and an incredibly large number of backed pieces (*Maiorano* et al*. 2018*; *2023*).

In the first phase of the Late Neolithic (4500–3800 BC, *Charpentier 2008*), the temporary campsites spreading along mangroves and lagoons that dotted the coastline began to turn into more structured settlements. The exploitation of marine and lagoon resources became intensive and was often accompanied by the consumption of wild and domestic mammals (*Uerpmann* et al*. 2009*; *Zazzo 2014*). During this phase, the production of trihedral points declined (*Charpentier 2008*), and elongated-fusiform, or tanged, shouldered points with biconvex or plano-convex sections reached their maximum diffusion (*Charpentier 2008*; *Maiorano* et al*. 2020*). However, the discovery of a localized form of tanged points at Sharbithat SHA-10B contrasts the previous theory that sees the disappearing of projectile weaponry after the Late Neolithic Period 1 (*Charpentier 2008*). Indeed, it suggests that, during the Late Neolithic Period 2 (3700–3100 BC),arrowhead production persisted in some regions, with a lower technical investment in manufacturing such tools (*Maiorano* et al*. 2018; 2020*). These points consist of a rough, thick flake-blank characterized by abrupt retouching made via direct percussion on an anvil, and represent a possible shift in the use of weaponry (from projectile to perhaps thrusting). These points were found in association with a large quantity of backed pieces, large scrapers on flake and shell blanks, and a net sinkers engraved with a continuous line along their longest axis (Fig. 6), retrieved in most of the coastal 4th–3rd millennium BC assemblages (*Maiorano* et al. *2023*).

Apart from the peculiar point assemblage, the backed pieces represent the most interesting aspect of this industry. First, because armatures – backed inserts – and backed pieces, in general, were considered to be completely absent from southeastern Arabia until recently (*Clarkson* et al*. 2018*). However, six backed artefacts assemblages have started to be reported from different sites belonging to extremely varied chronological periods (*Maiorano* et al*. 2018*; *Rose* et al. *2019*; *Buchinger* et al. *2020*; *Hilbert, Lischi 2020*; *Moore* et al. *2020*; *Danielisova* et al. *2023*). Second, the backed assemblage from Sharbithat contains an incredibly high rate of these inserts, together with the presence of a specific type of flaking accident related to backing.

The most ancient trace of armatures discovered in Oman come from the site of Matafah, a stratified deposit in Wadi Ghadun, southern Oman (*Rose* et al. *2019*). Here, three archaeological horizons were identified and excavated. They include Holocene assemblages that overlie a previously unknown assemblage characterized by the production of geometric microliths. Through optically stimulated luminescence, the team dated this assemblage to between 33 and 30 thousand years ago, providing the first evidence for the use of projectile armatures in the Peninsula (*Rose* et al. *2019*). Furthermore, recent use-wear analysis (*Hilbert* et al. *2021*) confirms that backed pieces were also used in cutting and piercing activities in addition to their use as projectiles. Additional Late Palaeolithic backed pieces have been reported from TH68 (*Hilbert 2020*) in Dhofar and the UAE at Jebel Buhais 84 (*Bretzke 2018*; *2020*). In the latter, preliminary OSL results dated the assemblage to the last part of MIS 2 (*c.* 30–15 ka). Backed points associated with a typical Late Palaeolithic blade technology (*Rose, Hilbert 2014*) and several rock shelters in the Jebel Qara (*Cremaschi, Negrino 2002*) have also been discovered in southern Oman.

Dated to a much younger site, backed pieces, and particularly lunates, were reported by Roberto Maggi and Hans Gebel (*1990.Fig.16/10-12*) from Ras al-Hamra RH-5 (5th–4th millennium BCE) in Oman. They were interpreted as unused tools or unfinished chisels and their size resembles some of those found in Sharbithat, even if considerably different from the specimens found in the Bronze Age sites in the UAE.

The recent excavations at the Early Bronze Age site Hili 8 in al-'Ain (Abu Dhabi Emirate, UAE) showed persistent pressure reduction for bifacial points performed together with flake- and bladelet-based production of backed microliths (*Buchinger* et al. *2020*). This novel technique for exploiting local raw material could thus represent a different response to new demands. Similar artefacts were previously retrieved on the surface in Marawah MR-1 (*Shepherd-Popescu 2003; Charpentier 2004*), at Abu Dhabi sites ADA1 and ADA7 (*Kallweit 2004*), and Sharjah Tower (*Millet 1988*). Two other early Bronze Age sites where backed pieces have recently been identified are the two towers of Al-Khashbah (KSB), specifically Building I and V (Ochs 2020). However, the comprehensive study of this assemblage has only recently commenced by the author, and further information is not yet available.

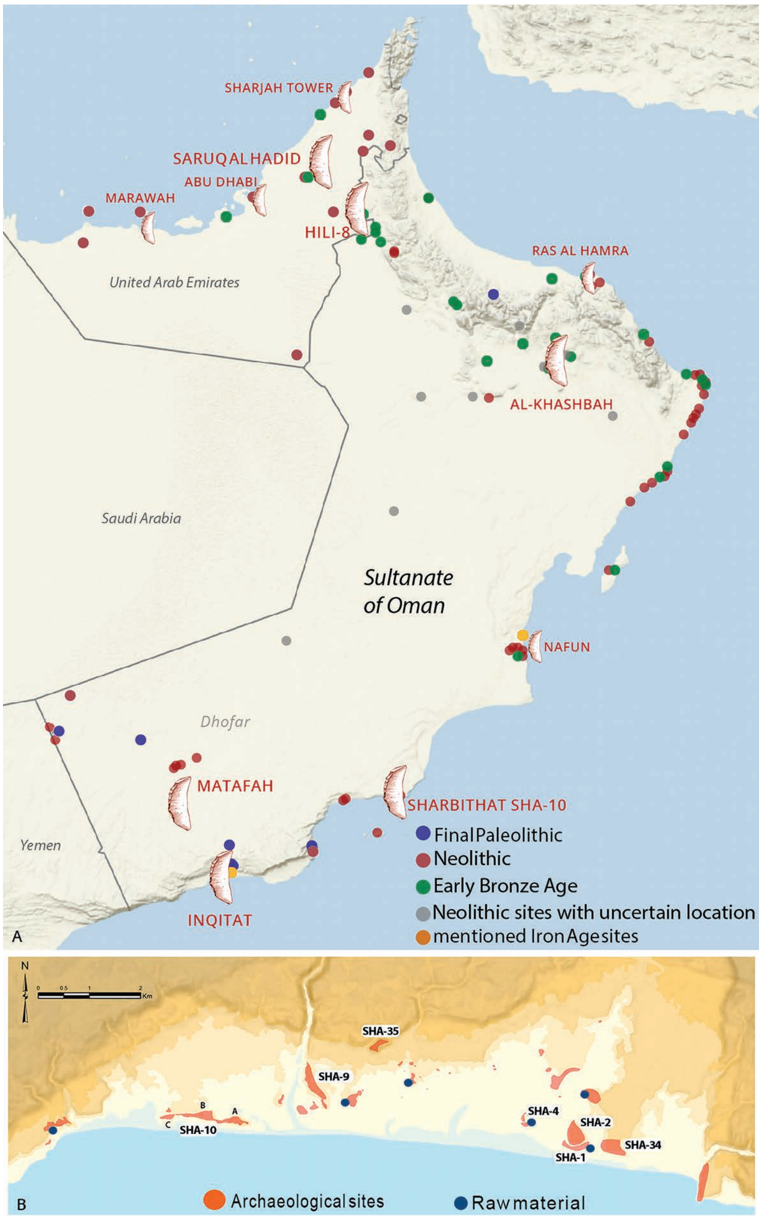


Fig. 1.* A *Map of Oman and the UAE showing the location of the main prehistoric sites, divided by age. The lunates show the assemblages including backed pieces (large lunates), and the sites where their presence is reported but not studied or the specimens are not sufficient for a complete technological study (small lunates).* B *Map of Sharbithat Bay with the location of archaeological sites (red shaded areas), the names of the main sites, and raw material outcrops (dark blue). Maps by M. P. Maiorano and F. Borgi.

Recent work carried out at Saruq al-Hadid (Dubai, UAE) has recovered a large assemblage comprising a large amount of backed microliths (*Moore* et al. *2020*). They were identified in a mound rich in animal bones dated to mid-2nd millennium BC. Here, simple core reduction methods were combined with sophisticated backing techniques. Knappers shaped unstandardized flake blanks into microliths with occasional truncation of the blanks into segments, which were subsequently backed. The final stage of backing was probably achieved using the pressure technique. Most microliths are asymmetrical in shape, but several of them display a triangular morphology. The microliths were interpreted as armature for projectile points, but other possible functions were not excluded (*Moore* et al. *2020*).

Another interesting discovery which yielded evidence of microlith and backed piece production in Oman comes from the area of Salalah, in Dhofar (*Hilbert, Lischi 2020*). From the excavation of the settlement at Inqitat (HAS1), archaeologists reported the discovery of a settlement dating from the Iron Age (8th–7th century BC) to the pre-Islamic period (1st–2nd century AD). They made use of raw materials from local sources (Jebel Qara) and long-distance trade, such as obsidian imported from western Yemen. Core reduction strategies were mainly opportunistic; small flakes make up most of the lithic sample (*Hilbert, Lischi 2020.Fig.5*) together with drills, scrapers, retouched blanks, and geometric microliths in rectangular, triangular, and lunate shapes. The latter represented an unexpected characteristic of this assemblage, unique in Oman (*Hilbert, Lischi 2020*). A similar Iron Age assemblage is reported from Nafun NAF-3, in the area of Duqm (*Danielisová* et al. *2024*), where the technology is defined by simple flake production and a high level of opportunism. However, the discovery of two microliths (*Danielisová* et al. *2024.Fig. 11.3-4*) marks a critical aspect of the assemblage, creating a potential connection between central and southern Oman.

Interestingly, in southern Arabia as well as in other areas of the world (*Clarkson* et al. *2018; Leplongeon* et al. *2020*), microlithic technologies appeared and faded out at a geographical and chronological gradient.

Here we describe and contextualize the manufacture of backed pieces from Sharbithat SHA-10B, analysing its novel technology, the chronological context, and the comparison with late prehistoric backed microlith production in southeastern Arabia. The discovery of a consistent and homogeneous technology based on specific backing techniques raises interesting issues relating to technological evolution, environmental constraints, and cultural connection and isolation.

Site description and sampling methodology

Sharbithat Bay is characterized by an imposing limestone massif which surrounds the shore, marked by numerous wide marine terraces (*Platel* et al. *1992; Maiorano* et al. *2018*). Thirty-six sites were recorded and labelled SHA–1 to SHA–36 (Fig. 2). Post-depositional and erosive phenomena have affected the encountered surface scatters, and only a few sites on the marine terraces featured a legible stratigraphy.

The intense fieldwork activities carried out at Sharbithat were primarily based on the study and examination of regional geological and geomorphological settings. In previous publications (*Maiorano* et al. *2018; 2023*) the authors described the general landscape and its archaeological composition, presenting the main sites (Sharbithat SHA-2, SHA-4, SHA-9, and SHA-10) and related features. The Sharbithat plain is characterized by deltaic fans and conglomerates related to the Late Miocene-Pliocene phase, in contrast with the oldest Tertiary calcareous formations that characterize the system of marine terraces (also referred as mesas[1]) scattered all over the coast. It is in this area that the majority of the Neolithic settlements and temporary encampments were located. Indeed, the high plateau in the hinterland appears to be composed of a tertiary bioclastic carbonated deposit belonging to the known Dhofar group, which developed a tabular morphology due to the exposition to the coastline. This massive plateau was cut by deep canyons shaped by wadi branches. However, a detailed geomorphological study is still in progress (*Maiorano* et al. *2018*).

The excavation of Sharbithat SHA-10B

At Sharbithat SHA-10B, two test trenches (Trench-1 and Trench-2) measuring 1×2 (T1) and 2×2 metres (T2) were excavated. The soil was dry sieved with 5 and 2mm meshes, and all materials collected and sorted.

The first sounding (T1) is located north of the Sharbithat SHA10B cairn, almost at the limit of the preserved archaeological deposit. Here the sediment is only 7cm deep. Beneath the first two centimetres of aeolian sand lies a black level (Stratigraphic Unit SU1), extremely rich in lithics, shells and fish bones (some vertebrae were still in connection). Underneath SU1, there is an archaeologically sterile reef sand superimposing the bedrock (reef limestone).

T2 is located south of the site core, in an area of well-preserved deposit, outside the cairn. The lithic pieces collected in this 4m^2 trench consist of 4658 specimens, *i.e.* over 1100 artefacts per m^2 in a maximum of 20cm of sediment. Beneath the surface crust, an ashy, dark layer (SU1) very rich in artefacts, shells and fish bones was excavated. In this SU, several fire-spots have been recognized and sieved separately, especially SU5, which contained two long mammal bones (*Equus* sp. cfr *E. africanus*, determined by the zooarchaeologist Elena Maini), one net sinker and various lithic artefacts. A detailed report of the excavation was published (*Maiorano* et al. *2023*), and all of the fish remains are currently under study at the Natural History Museum of Paris by the specialist Philippe Bearez. In both T1

1 'Mesa' is a Spanish word that means table. It indicates a flat-topped, wide hill with steep sides.

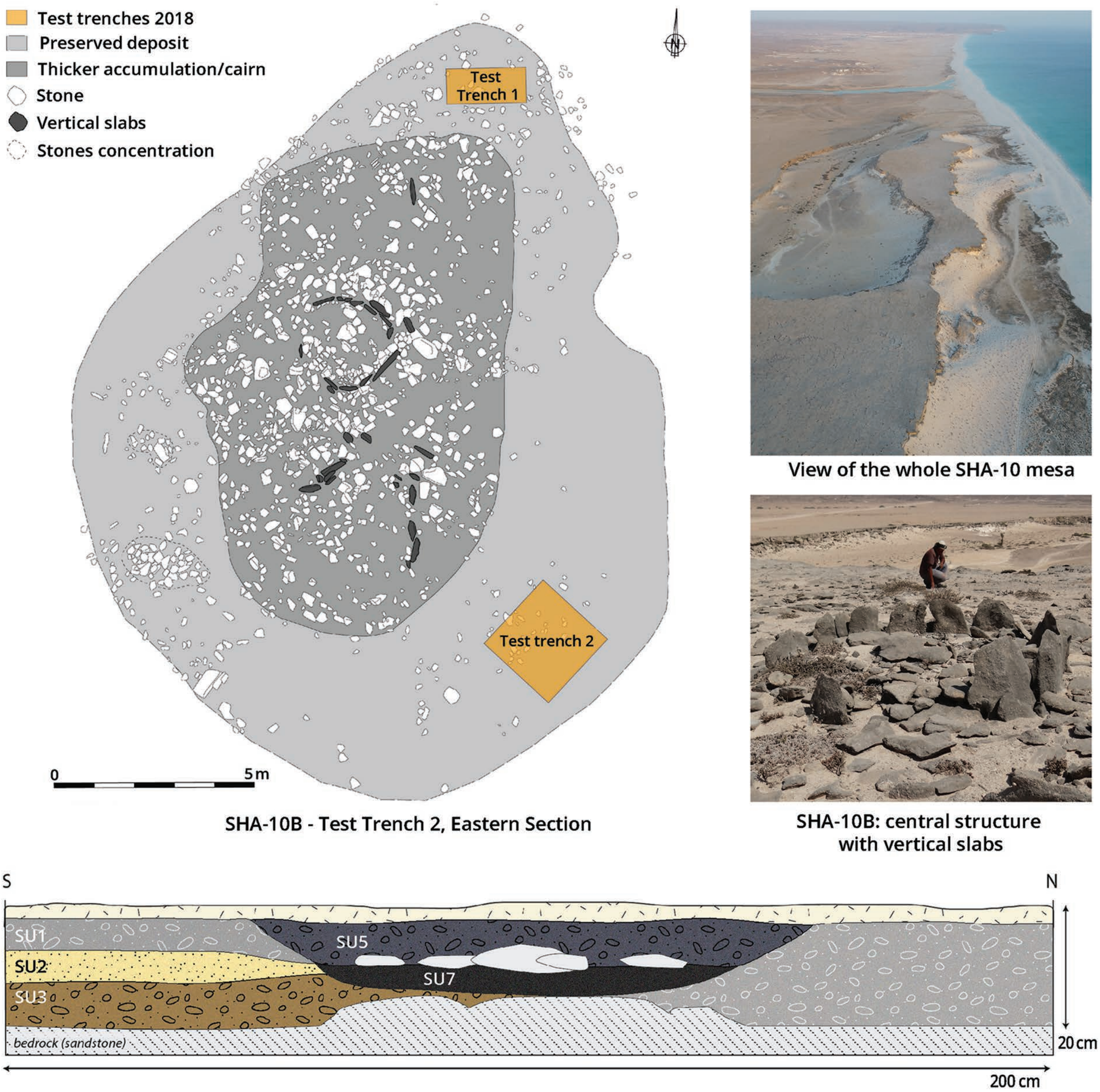


Fig. 2. Map of SHA-10B and test trench excavation (top left) with a general view of the terrace (top right), the main structure (centre right) and the eastern section of T2. (Graphics L. Quesnel, G. Marchand, M. P. Maiorano, A. Al-Mashani).

and T2, the lithic assemblage is characterized by a considerable number of flakes, blades and laminar flakes, and a clear technological and typological continuity is recognisable. The main peculiar classes of remnants were the backed bladelets (found in different sizes and shapes), the retouched and unretouched blades, the scrapers made on large flakes, blades, and big shells (*Tivela ponderosa* sp.), and the micro-drills. Thanks to the surface collection and trench excavations, the two assemblages were studied and defined as being contemporaneous.

The excavation yielded five ^{14}C charcoal dates, ranging between 3949-3712 BC and 3339-3026 BC (Beta Analytic, USA; Fig. 2). All the main levels from SU1 (the upper) to SU7 (the lowest) yielded a radiocarbon date that places the anthropic occupation within the 4th millennium BC. All dates were calibrated using the OxCal v 4.2.3 software and IntCal13 atmospheric calibration curve (*Reimer* et al. *2013*). The older levels, including SU6 and SU7, date to the second half of the 4th millennium BC (SU6: 4500±30 BP, 3347-3097 BC and layer SU7 in the direct vicinity of the fire-spot in SU6: 4525±30 BP, 3358-3103 BC). The other two dates are one slightly older (SU2: 5035±30 BP) and the last much younger (975±30 BP) possibly resulting from later charcoal disturbance.

Techno-typological study

The lithic assemblage: raw material and technology

The chert outcrops are scattered all over the bay. At Sharbithat, at least seven different spots were mapped (SHA-1, SHA-4, SHA-7, SHA-8, SHA-12 and SHA-13A/B, SHA-31, SHA-32, Fig. 1). The flint is embedded into tertiary formations (Fars Formation or Dhofar Group) exposed to the surface by erosive phenomena. The raw material occurs mainly in the shape of thin plaquettes or small blocks, 5 to 20cm long, with the exception of SHA-7 and SHA-10, where the plaquettes are larger (about 40cm). The flint is grey or black with a homogeneous texture presenting rare chalcedony inclusions, with a thick limestone cortex (5 to 10mm).

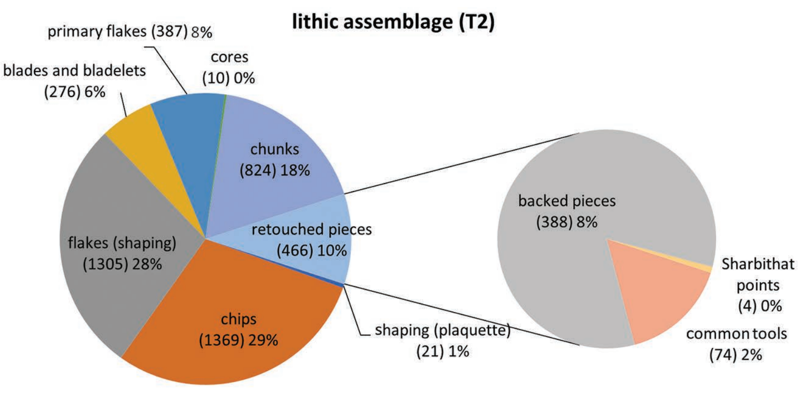
The exclusive use of dark grey Oligocene flint plaquettes, collected directly from alongside the Sharbithat SHA-10 mesa, gives this assemblage a highly homogeneous aspect. Moreover, a white patina covers almost all the artefacts made with this material. The selected blocks and plaquettes measure between 20 and 40mm thick.

The lithic assemblage is extremely rich, especially considering the limited excavation area, covering only 6m^2 at a depth of less than 20cm (Fig. 2; Tab. 1). The massive quantity of flint flakes in T2 (1369, *i.e.* 29.4% of the total; Tab. 1) attests to the very good preservation of the archaeological deposit, even considering the important effect of the aeolian deflation to which the terrace is subjected. As the deposit in T1 is thinner, probably due to the higher position of the bedrock and peripheral location respect to the core of the site, (8.4% of the total), the lithic study focused on the assemblage collected in T2 (Graph 1; Tab. 1).

Blanks production systems

Starting from flint blocks and plaquettes, the debitage is oriented toward the production of laminar blanks, groupable in two clearly distinct artefacts: first, wide and thick blades with a straight longitudinal, sagittal cross-section and a cortical edge, 7-8cm long (except for a unique 13.4cm long blade); second, thin bladelets without cortex. The morphology of these blanks is directly linked to volumetric and technical choices, which can be assessed by analysing the plaquettes abandoned at the first stage of reduction. It is generally the narrow side of a rectangular volume of about 10cm by 8cm that was chosen to set up a knapping surface, which was then exploited following unidirectional sequences. The initial striking platform could be either cortical, created by transverse flaking, or resulting from a naturally broken face. The plaquette's shaping process could have occurred through exploiting a bifacial crest (*e.g.,* in square 2N, US 1[2]) removed prior to the detachment of further blades (primary crest). This bifacial ridge covers at least 3/4 of the plaquette. When this initial shaping of the plaquette is chosen, the main production does not develop from the narrow area of the block, and for this reason it may be not successful.

Blade production is obtained through a unidirectional sequence of removals, either from one single or two opposite striking platforms. In this case, there is only a partial overlap between the two blade sequences. The reduction process is extended laterally to the left and right of the core surface. These *débordantes*[3] blades are thick, with a thick cutting edge and a negative scar that shows the edge of the plaquette (cortical or ancient surface). This simple volumetric principle results in thick-backed knives with an asymmetrical cross-section and a straight profile. It also gives the debitage surface a curved lateral profile which favours a further reduction process. In addition, there is a second type of blade, much



Graph 1. Percentages of the main artefact categories from Test Trench 2.

2 Due to the global pandemic, it was not possible to complete the photographical documentation of the assemblage – planned for the winter 2020 – and graphic documentation of crested flakes is still missing.

3 *Débordantes* is a French term from lithic studies meaning 'overflowing' or 'oveplunge'. Débordant blades are cortical unidirectional thick blades whose lateral and distal edges overcome the limits of the debitage surface. In some cases, the flaking starts from the lateral side of the striking platform.

Trench	SU	Plaquette	Chips	Flakes - decortic	Blades-bladelets	Flakes - first sequence	Cores	Chunks	Tools	Backed pieces	Total
1	0	5	27	53	10	10	1	77	0	10	193
1	1	0	2	52	22	8	0	38	0	8	130
1	2	0	0	15	2	0	0	2	1	0	20
2S	Surface	0	15	73	21	25	0	57	3	25	220
2S	1	4	389	275	65	116	2	206	16	113	1187
2S	2	1	430	191	27	60	4	181	8	61	963
2S	3	0	56	67	13	17	0	29	5	17	204
2N	Surface	3	5	27	6	5	1	15	0	5	67
2N	0	5	50	75	18	14	0	66	6	14	248
2N	1	3	179	252	37	53	1	92	16	56	689
2N	2	0	57	41	12	21	1	34	4	21	192
2N	3	0	28	42	8	13	0	19	2	13	126
2N	4	0	41	26	18	12	0	15	4	12	128
2N	5	2	21	49	21	14	0	16	4	13	140
2N	6	0	0	6	2	0	0	2	1	1	12
2N	7	3	70	127	12	25	1	63	0	25	326
2N	7	0	24	44	12	10	0	19	3	10	122
2N	8	0	2	10	2	1	0	10	2	1	28
2N	Pit B	0	2	0	2	1	0	0	0	1	6
Total Trench 1		*5*	*29*	*120*	*34*	*18*	*1*	*117*	*1*	*18*	*343*
Total Trench 2		*21*	*1369*	*1305*	*276*	*387*	*10*	*824*	*74*	*388*	*4658*
Total		**26**	**1398**	**1425**	**310**	**405**	**11**	**941**	**75**	**406**	**5001**

Tab. 1. Counts of lithic remains from SHA-10B. Test trenches 1 and 2 (north 2N, south 2S).

finer and without cortex, which comes from the inner part of the core, not extending on the flanks, which we will call an 'intermediate blade'.

The use of a hard hammer on smooth platforms, without preliminary abrasion of the edges and detachment angles extremely close to 90° (about 80° to 85°), leads to several knapping accidents as bulges and abrupt orthogonal breaks. As is observable on blanks and final products, there is no effort in adjusting the percussion angles, nor are other precautions taken to prevent breakages. This is probably due to the abundance of raw material and the non-necessity of regular blanks. The diacritical diagrams shown below (Fig. 3) distinguish the sequences in phases (A, B, C, *etc.*) that aim to group together the removal sequences following the same direction, while single removals within each phase are numbered from 1 (the earliest) to *n* (the latest). As shown in Figure 3 and Figure 4, we can observe a certain degree of technical variability as the debitage progresses.

Shaping an elongated plaquette (Fig.3.1 - T2-US0, Fig.4.1)

On this 35mm thick elongated plaquette, a sharp edge was obtained at the base of the core through two unidirectional removals, followed by an additional detachment in the proximal part, either to obtain better control on the distal ends of the blades or to facilitate the opening of an opposite platform. An opposite platform shows negatives of frontal unidirectional debitage, abandoned at this stage for lack of favourable right convexities. Also visible on the plaquette is the beginning of another debitage sequence on the opposite platform, with a unidirectional tendency and frontal setting, abandoned at the first stage.

Cores with two frontal unidirectional platforms (Fig 3.2 - T2-US2; Fig.4.2)

This core was shaped through the detachment of a bifacial crest on at least three sides (phase A), which was removed to create a facetted percussion surface (phase B) and set a unidirectional platform exploited with a succession of frontal detachments (phase C). The aim is to obtain short bladelets with cortical edges. One of the removals from the main surface (removal 1 of phase C) was chosen as a new striking platform to establish another platform parallel to the first one, which was then only slightly exploited (phase D). The debitage was performed with a hard hammer, without any preparation of the edge.

Flake from unidirectional debitage (Fig 3.3 - T2-US2)
This thick flake is a unidirectional core-trimming element, resulting from a violent shot. The debitage is clearly frontal, with two successive series of three removals from left to right and, later on, from right to left. The platform is short (65mm) and narrow (20mm). Such a percussion surface made it possible to obtain semi-cortical and non-cortical blades with pointed or straight distal ends.

Core with two orthogonal, successive unidirectional platforms (Fig. 3.4 - T2 - US1; Fig.4.3)
On a 19mm thick plaquette, a first surface (phase A) was created to be successively exploited as a striking platform for a second surface (phase B). It might therefore be considered a core with two successive orthogonal unidirectional platforms. It allows to produce semi-cortical and non-cortical flakes, 10 to 12mm wide, with a hard hammer. A test phase on the back of the core (phase C) is also detected. Ochre traces were identified on the plaquette's cortex.

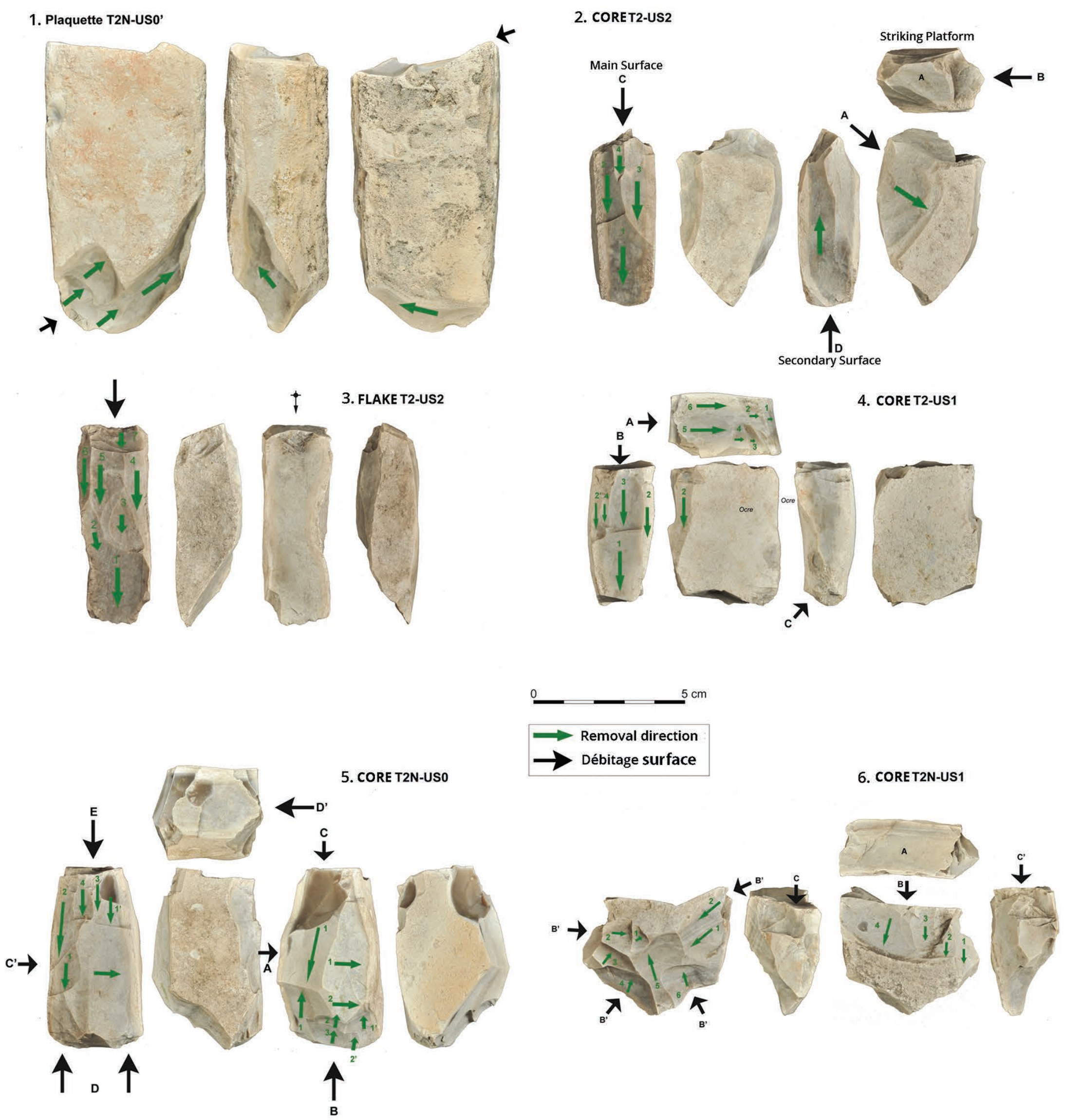


Fig. 3. **1** ***Shaping of elongated plaquette;*** **2** ***core with two unidirectional frontal percussion planes;*** **3** ***flake from unidirectional debitage;*** **4** ***core with two orthogonal and successive unidirectional platforms;*** **5** ***core with two parallel bipolar platforms;*** **6** ***multidirectional core. Photo J. Vosges; diacritic scheme G. Marchand.***

Core with two parallel bidirectional surfaces (Fig 3.5; Fig.4.4)
On a 28mm thick plaquette, a crest, or neo-crest, was created (phase A), probably off-centred towards one of the edges that was then removed to open a knapping surface. This surface is exploited in one direction (phase B) and, later, from the opposite side (phase C). The removals of these two successive sequences partially overlap in the distal parts of the blanks. As far as it can be evaluated with a diachronic scheme, during phase B the knapper chose a frontal detachment sequence. The plaquette was turned around and another bidirectional working platform was opened with a neo-crest (phase C'). Another new striking platform was developed (phase D'), with a first detachment sequence (phase D), followed by a second sequence extracted from the other side (phase E). The obtained blanks are poorly calibrated bladelettes. The platforms are smooth and without prior abrasion of the edges. only hard hammers were used, but the absence of proper longitudinal convexities led to the end of the production.

Multidirectional flake core with frontal setting (Fig. 3.6 – T2 – US1; Fig.4.5)
This core is the only one showing negatives detached on the largest face of the block, without the exploitation of the plaquette's edge. Detachments come from several striking platforms, leading to the production of short and wide flakes, about 20 to 30mm long.

Retouched artefacts
Backed pieces (Tab. 2, Graph 2, Fig. 5)
The production of backed pieces is well developed at the site, and 387 specimens have been collected in the trench, both complete and fragmented. During the first stage of our study, the elements were divided into macro categories based on metric characteristics: small backed pieces or segments with a maximum thickness ranging between 3 and 5mm; medium backed pieces, 5 to 7mm thick; large backed pieces, more than 7mm thick; irregular backed pieces, made on semi-cortical blanks; and micro-drills, less than 3mm thick.

Backed pieces often show a backed side overcoming the central ridge. This gives the artefacts a triangular cross-section, except for the micro-drills, which are produced with a double parallel back on both sides.

On the well preserved fragments of medium and large backed bladelets, a convex delineation of the back can be observed, suggesting a tendency to produce 'segmentiform' objects.[4] However, whatever the shape of the back, apical ends are not pointed but often trihedral-shaped, showing a roughly broken distal ends (more visible in the distal breakages of the drawn specimens in Figure 5, from n. 7 to n. 11). This observation suggests that they might have been used as lateral inserts, both for their vivid sharpness and the absence of pointed ends.

The retouching of the backed pieces is generally direct. It becomes bipolar when needed to make the back overcome the ridge of the blank. In other cases the retouching of the back is abruptly inverted to adapt the blanks to different morphological constraints. They present a slightly denticulated edge,frequently turned and regularized through overshot retouches. The chosen retouching method is direct percussion with a stone hammer (pebbles) and bipolar percussion on a stone anvil, resulting in very abrupt an-

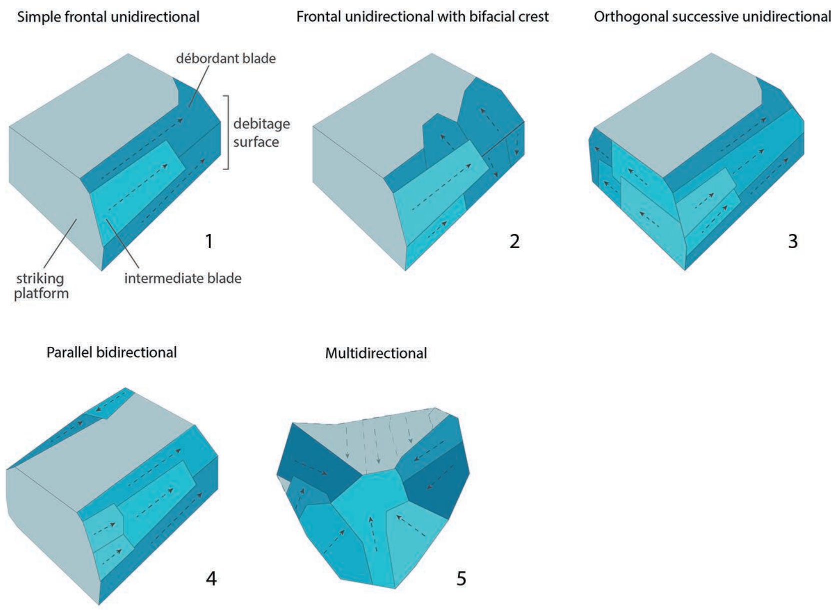


Fig. 4. Schematic representation of core volume management at SHA-10. Darker blue areas show the negatives of older removals, and lighter blue areas the more recent ones. In 5 the grey area (cortex) with reduced opacity and dotted arrows aims at showing the removals on the back side of the object.

4 Double-pointed flake/bladelet resulting from bipolar flaking.

Class	State	SU0	SU1	SU2	SU3	SU4	SU5	SU 6	SU7	SU-8	PitB	Total
SBP (Segment)	E	2	6	1	-	1	1	-	2	-	-	13
	F	8	13	11	4	1	5	-	3	-	-	45
	K	-	15	10	2	1	-	-	1	-	-	29
MBP (Medium)	E	1	2	2	1	-	-	-	3	-	1	9
	F	11	25	15	3	5	3	1	8	-	-	71
	K	10	37	16	9	3	-	-	7	1	-	83
LBP (Large)	E	-	2	-	-	-	-	-	1	-	-	3
	F	2	8	5	-	1	1	-	4	-	-	21
	K	4	12	8	4	-	-	-	4	-	-	32
BP (Irregular)	E	-	3	-	-	-	-	-	-	-	-	3
	F	1	-	1	1	-	-	-	-	-	-	3
	K	-	-	-	-	-	-	-	-	-	-	0
Micro-Drill	E	-	4	4	1	-	-	-	-	-	-	9
	F	2	7	2	1	-	1	-	2	-	-	15
BP First Shaping	K	1	8	-	-	-	-	-	2	-	-	11
Double BP	E	-	-	-	-	-	-	-	-	-	-	0
	F	-	1	-	-	-	-	-	-	-	-	1
BP (Other Fragments)	F	5	6	7	3	-	2	-	-	-	-	23
Total		**47**	**149**	**82**	**29**	**12**	**13**	**1**	**37**	**1**	**1**	**371**

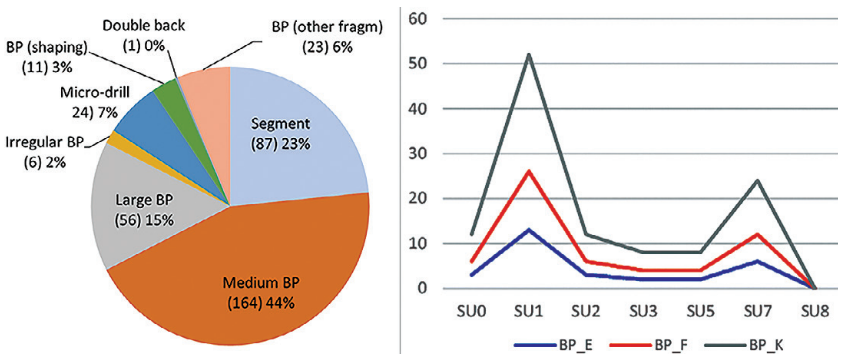
Tab. 2. Counts of backed pieces divided by class and stratigraphic unit (TT2).

gles. It also may explain the high rate of fractures, as demonstrated by several experiments carried out by Jérémie Vosges.

These technical parameters explain one of the most remarkable characteristics of this industry, namely the very large number of fractures known as 'Krukowski-type' micro-burin or pseudo-micro-burin (*Douches* et al. *2018*). This is a frequent fracture generated during the production of backed pieces: an exceeding deep retouch or powerful shot resulting in an oblique triangular-twisted fracture (*De Bie, Caspar 2000*). Different from the traditional micro-burin process, which is intentionally aimed at breaking the blank obliquely, the 'Krukowski' fracture is accidental. The number of this kind of fracture is incredibly high, as 149 Krukowski and 157 orthogonal fractures have been counted in the assemblage. During the experiments carried out in January 2018, the high frequency of this facture was explained by bipolar percussion on an anvil. Interestingly, there was no adaptation of the process to reduce the incidence of this accident, though we cannot completely exclude the non-accidentality of the process. As demonstrated by Jacob Vardi, 'Krukowski' fractures might also occur as intentional elements in association with specific modalities of blade-bladelet breakage (*Vardi, Gilead 2009; 2011*).

Lastly, micro-drills constitute a separate category. They are shaped on thin bladelets or micro-flakes by abrupt, direct, or alternating backed retouching on both sides. Three of them have symmetric shoulders on along the edge (Fig. 5.14,15,16). The tips are heavily blunt.

Sharbithat points (Fig. 6: 1-5)
The tanged points collected at SHA-10 were produced using thick flakes and blade blanks. The tang was shaped by direct hard hammer percussion on an anvil, generating a highly variable points assemblage. Their size ranges between 70 and 43mm in length, but the width is more homogeneous (15 to 25mm). The apical part, in a few cases, is generated by the natural convergence of the blade's distal end (*Maiorano* et al. *2023;* Fig. 8.9). However, the distal part is most commonly shaped by partial removals or continuous retouching along the edge. The tanged points and the backed bladelets were manufactured through the same technical process, exploiting the same local raw material. When first observed at



Graph 2. Backed piece categories in TT 2 (left); frequency of entire (E), fragmented (F) backed pieces and 'Krukowski' chips (K) across the main stratigraphic units in T2 (right).

the site, the points' technological and morphological specificities were difficult to associate, typologically, with a specific chronological framework.

The technical investment is low – when compared to Neolithic points (*Charpentier 2008; Maiorano* et al. *2020*) – and easily attributable to the ancient Fasad points (*Charpentier 2008; Charpentier, Crassard 2013*), but also to other artefacts discovered in Ḥaḍramawt (Type 3A, *Crassard 2008*) and Nedj Plateau (site 14–15, 19, 36 in *Zarins 2001*). However, most of these mentioned points were discovered during sur-

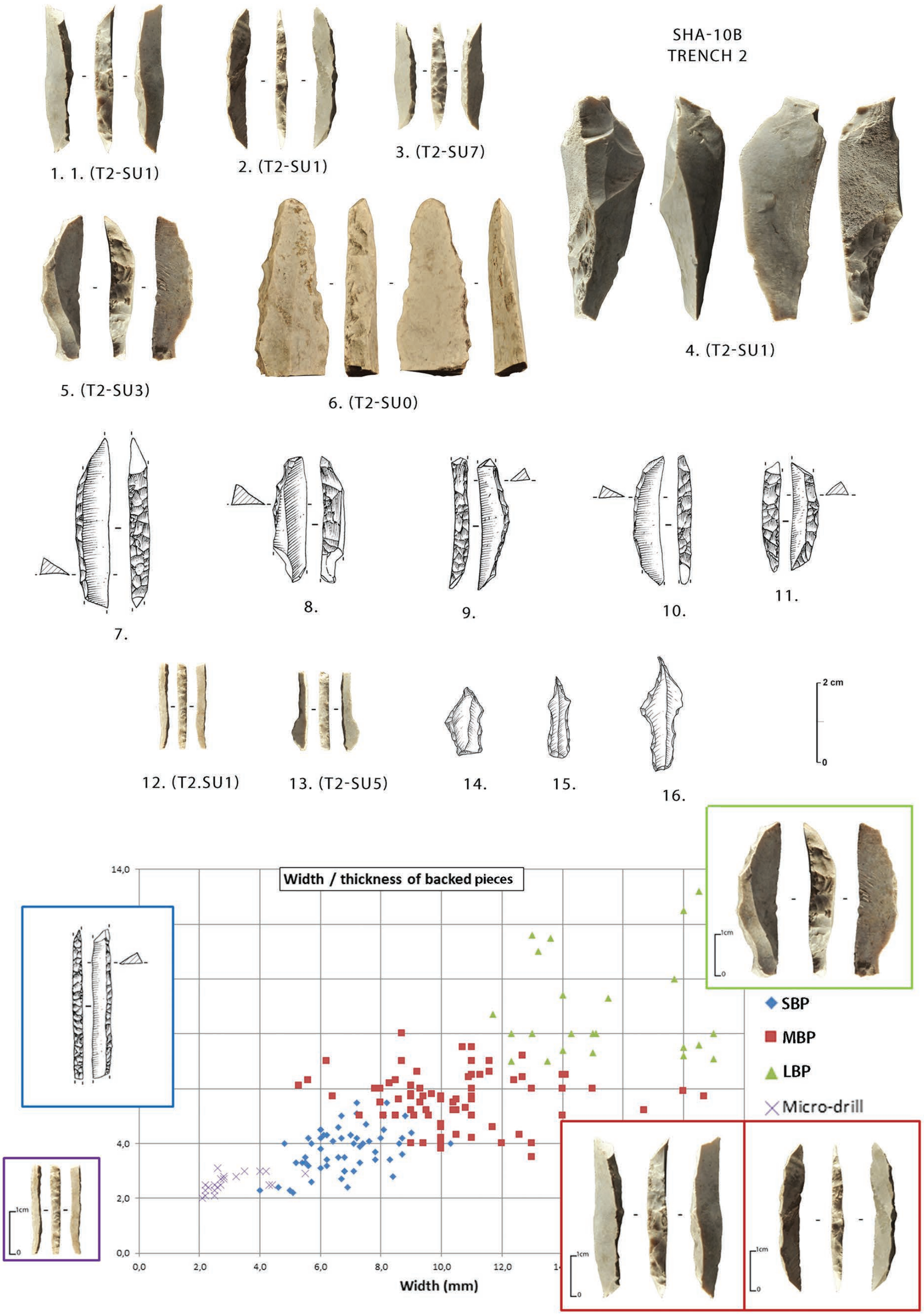


Fig. 5. Samples from the backed piece assemblage and distribution of the backed pieces based on the length-width-thickness ratio from TT2. The main identifiable groups are micro-drills, segments (SBP), Medium Backed Pieces (MBP), and Large Backed Pieces (LBP). A certain degree of standardization within the different groups emerges, likely reflecting functional constraints and diversification.

face surveys, and their chronological definition is not supported by secure radiocarbon dating. In Yemen, Rémy Crassard (*2008*) dated them to earlier periods but, given the recent results of ^{14}C dating at Sharbithat (Tab. 2), the chronological framework for their production and diffusion, at least for Oman, seems slightly later, falling into the 4^{th} millennium BCE. Moreover, previous morphometrical analysis (*Maiorano* et al. *2020; 2023*) that compared all the points made on blade blanks from southeastern Arabia show a clear pattern that separates these points into three main categories, all of which match with the techno-typological groups of the Fasad, al-Haddah, and Sharbithat (*Charpentier, Crassard 2013; Maiorano* et al. *2023*).

The chronological spectrum in which SHA-10B is placed might indicate that several of the previously collected Fasad points, especially in interior Dhofar (*Zarins 2001*), might be attributed to the Late Neolithic (4^{th} millennium BC). However, to safely define a chrono-typologically and technologically separated entity, further investigation at the site is crucial.

Other tools (Fig. 6)

The other part of the assemblage is limited compared to the number of backed pieces (in TT2, 74 retouched pieces, against 388 backed pieces and four Sharbithat points). It is diversified, with a dominant component of thick denticulated flakes and retouched cortical blades, followed by scraping tools on flakes or blades (Fig. 6), notches on flakes, and scaled pieces (*pièces esquillées*). Scrapers on flakes are rare, as well as the so-called *lames mâchurées*[5] (Fig. 6). The latter are marked by prominent invasive scars on their ventral

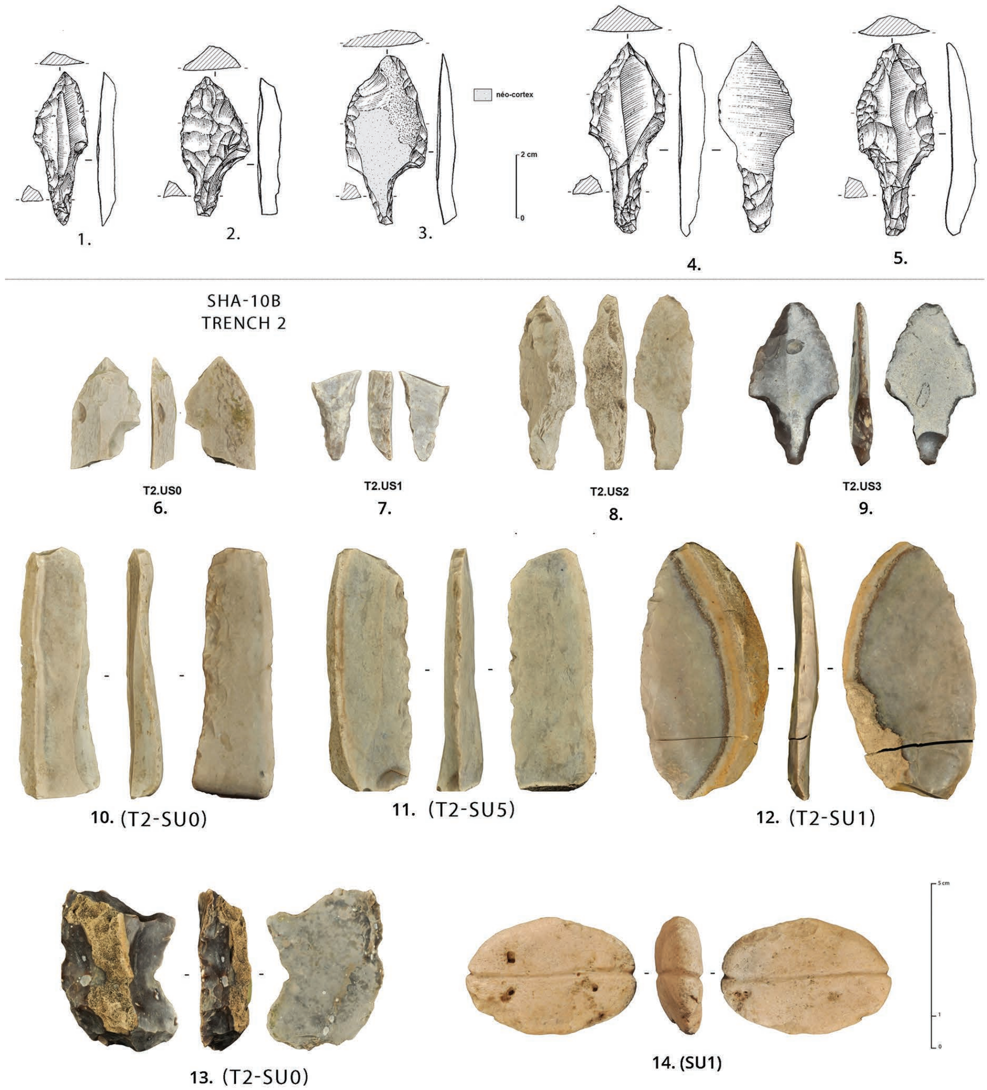


Fig. 6. Sharbithat points from the surface collection (1–5); Sharbithat points from the test excavations (6–9); lames mâchurées (11–12); notch (13); net sinker (14). Photo J. Vosges; drawings G. Devilder.

5 French term used in lithic studies indicating 'bruised' blades.

surface, evidence of utilization, functionally related to the crushing or bruising of spondylus shells, as is also demonstrated by the large amount of worked shell fragments retrieved in TT2.

The presence of ochre traces is reported on the scrapers' edges, marking a possible functional link between this colouring material and the activities carried out with these tools. Ochre stains were observed on the surface of plaquettes and flakes' cortex.

Discussion: homogeneity and specialization

The rich lithic industry collected in T2 looks homogeneous overall. The raw material is always the same, as well as the technical methods involved in the manufacture. The high rate of debitage and production waste (chips, including debris and shatters, chunks, 'Krukowski' debris) clearly indicate the on-site processing of lithic artefacts. The sites appear as multifunctional spaces used for both the production and implementation of such artefacts.

The Oligocene flint plaquettes collected within the Sharbithat area are selected for blade and bladelet debitage using the natural edge, with peripheral bifacial shaping often limited to a single edge, or direct flaking from the unprepared edge. The knappers used direct percussion with a stone hammer to obtain straight blades with asymmetrical cross-sections and natural (often cortical) backs. The debitage is also oriented to the production of straight non-cortical blanks, preferentially selected to shape convex backed pieces. The longitudinal convexities of the blocks and plaquettes were not regularized, and unidirectional sequences successively follow one to another until abandonment. The high rate of accidents and errors that occurred in the production without any attempt at developing alternative solutions that wasted less material could be linked to the abundance of good raw material, and, conversely, to the possible absence of highly specialized knappers.

Moreover, the four Sharbithat points are clearly associated with the backed pieces. We might consider a complementarity usage between the latter, which could be hafted as lateral insets, and the points, hafted on the same spears or used as projectile/thrusting points. This hypothesis will be tested in future studies, through ballistic experiments and impact traces analysis (*Yaroshevich* et al. *2010*).

The proposed interpretation is based on the association of the backed piece production with these morphologically variable points, produced using the same techniques and raw material, together with the presence of other artefacts widely diffused in the assemblages and toolkits spread in the 4th millennium BC (thick laminar products, net sinkers with horizontal continuous incision, specialized bead production, *etc.*, *Maiorano* et al. *2018; 2023; Charpentier* et al. *2023*). Considering the latest results, we can suppose the lithic complex diffused at Sharbithat to be characteristic of the Late Neolithic Period 2 (4th millennium BCE), when the pressure technique was abandoned and point manufacture was not as sophisticated as in previous periods (*Maiorano* et al. *2020; Charpentier* et al. *2023*).

The survey and test excavations in Sharbithat SHA-10B and SHA-4 provided new empirical evidence of different Middle and Late Neolithic facies which have been useful in increasing our knowledge about the lithic technological and typological variability in the region (*Maiorano* et al. *2018; 2023*). The introduction of pressure techniques in the 7th millennium BCE marks the most explicit passage from a simple way of producing points – shaping the tang through direct percussion – to a new process of modelling the entire shape following precise rules of symmetry and balance. Once pressure retouching was ubiquitously adopted (*Charpentier 2008; Maiorano* et al. *2020*), variability was fuelled by the introduction of other sophisticated techniques such as parallel covering retouch and fluting (*Maiorano* et al. *2018; Crassard* et al. *2020*). Their adoption affects the shape of the cross-section (apical, medial, basal), and the symmetry and morphology of retouching. In the last phase of the Neolithic, as suggested by the points discovered at Sharbithat, we can observe a return to the basic shaping with direct retouching and scarce preparation of the thick laminar blanks. However, the processes leading to this technical impoverishment that characterizes the transition from the Middle Neolithic to the Late Period – throughout the entire Oman Peninsula – remain largely unexplained and require further analysis.

The presence of vast flint outcrops and the good quality of the raw material, plus the abundance of marine resources, may have led to the formation of self-sufficient communities during the climatic regression that followed the Holocene Humid Phase. From the end of the 5th through the 4th millennium BC, the Intertropical Convergence Zone (ITCZ) moved southwards, decreasing its effect on southeastern Arabia (*Preston* et al. *2015; Lézine* et al. *2017*), driving human groups to the coast or more suitable areas characterized by permanent water sources (*Crassard, Drechsler 2013*). Consequently, sites dated to the 4th millennium BC, such as SHA-10B, show an increased development of local traditions, generated by the growing isolation and intensive exploitation of confined environments, such as wadi deltas, lagoons, and mangroves, as suggested by the coeval expansion of shell middens (*Cleuziou, Tosi 2018*).

Conclusion

The beginning of the production of backed pieces is usually associated with significant changes in technical behaviours, such as developing different hunting or fishing techniques. However, their function or belonging to the same technological phenomenon at regional and supraregional scale is still under discussion (*e.g., Clarkson* et al. *2018; Groman-Yaroslavski* et al. *2020; Leplongeon* et al. *2020*). The techno-typological analysis of SHA-10B backed pieces suggest that this class of artefacts had a high level of variability across the whole of Late Prehistory in southeastern Arabia. The influence of raw material is limited, as all backed pieces are in good quality chert, and the sites are close to chert sources. Whether the variability observed in our set of backed pieces reflects functional flexibility still needs to be tested by studying a larger sample through extensive excavation and use-wear analyses of the preserved tools. Indeed, these artefacts were used as replaceable armatures and discarded after use without being rejuvenated. However, we do have not enough information to define a possible function, nor whether their variable morphology reflected specific usage constraints (*Iovita 2009; 2010; Leplongeon* et al. *2020*).

Test excavations at SHA-10B have produced an assemblage of 5000 artefacts dated to the 4th millennium BC. The site presents a new facet of the indigenous development of stone tool technology in Late-Neolithic and Bronze Age southeastern Arabia. The technological study has highlighted the *in-situ* production of backed pieces, points, and a composite assemblage, including stone and shell tools. The systematic production of backed pieces has few close parallels in the region. The evidence considerably influences our understanding of the long-term development and evolution of hunting technology, and how the use of bow and arrow technology transformed during the crucial period of the transition from stone to metal projectile technology. Moreover, the development of such technology in different geographical spaces and chronological frames stimulates further investigation into several aspects of Late Neolithic – Bronze Age societies in southern Arabia, comprising population mobility patterns for subsistence, environmental transformation and consequent human adaptation techniques and the emergence of different group identities and inter-site connections, but also the functional differentiation of sites.

A clearer understanding of these issues will need further excavation at SHA-10 as well as comprehensive research, including technological, morphological, and functional comparisons with preceding and subsequent lithic traditions in southeastern Arabia and neighbouring regions. This is a large and diverse geographic unit. The backed lithic tools from this region offer great potential for comparison with those from East Africa (*Tryon 2019*), but our data are still limited.

Recent work in Oman and the UAE (at SHA-10, HAS-1, NAF-3, Hili 8, Saruq al Hadid) further demonstrate that the backing obtained by applying steep retouch along one edge is a highly variable trait that occurred in different places and periods around the world for certain advantages it bestowed in specific contexts. It contradicts an older hypothesis that sees the microlithic technology as a 'package' that emerged in Africa with modern humans, and then diffused to Asia, Europe and Australia (*e.g., Mellars 2006*). As argued by Chris Clarkson *et al.* (*2018*) and Alice Leplongeon *et al.* (*2020*), backing is advantageous, flexible, and highly discoverable, and this might explain its development in several different parts of the world, re-emerging in various time frames, even thousands of years later. However, the forthcoming results of the archaeological, geomorphological and technological investigations at Sharbithat and the other mentioned sites in the region will help clarify these chronological and cultural questions.

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Declaration of interest statement
The authors report there are no competing interests to declare.

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Born again: multiple biographies of ground and abrasive stone tools in the Neolithic of Serbia

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ABSTRACT - *Ground and abrasive stone tools had a long, dynamic and complex life during which they could repeatedly pass through different segments of the operational chain until their final disposal. Those tools would wear out slowly and could be used for a long time with constant renewal. Even after being damaged, they would start a new life cycle through various recycling processes or in a secondary context. The aim of this paper is to consider the transformative processes within the ground and abrasive stone industry in the Neolithic of Serbia and clarify their use in terms of maintenance, secondary use, and recycling, as well as to show the most frequent examples of such technological practices. The focus is primarily on tools for everyday use and the ways in which they were rerouted through various segments of the operational chain.*

KEY WORDS – *ground and abrasive stone tools; maintenance; secondary use; recycling; Balkans*

Ponovno rojena: večkratne biografije kamnitih glajenih orodij in orodij za brušenje v neolitiku Srbije

IZVLEČEK – *Kamnita glajena orodja in orodja za brušenje so imela dolgo, dinamično in kompleksno življenjsko dobo, v kateri so lahko večkrat prešla različne korake operacijske sekvence od obnavljanja do opustitve uporabe. Ta orodja se obrabljajo počasi, zato jih lahko s stalnim obnavljanjem uporabljamo dolgo časa. Čeprav poškodovana, so zaradi različnih postopkov recikliranja, tudi v sekundarnih kontekstih, začela nov življenjski cikel. V prispevku predstavljamo transformativne procese pri zbirih kamnitih glajenih orodij in orodij za brušenje v neolitiku Srbije in pojasnjujemo njihovo uporabo v povezavi z vzdrževanjem, ponovno uporabo in recikliranjem ter predstavljamo najbolj pogoste primere tovrstnih tehnoloških praks. Izpostavljamo predvsem orodja za vsakodnevno uporabo in načine njihovega vračanja v različne stopnje operativne sekvence.*

KLJUČNE BESEDE – *glajena orodja in orodja za brušenje; vzdrževanje; ponovna uporaba; recikliranje; Balkan*

Introduction

Stone has always been a highly valued raw material due to its natural properties. Because of its low solubility and incombustibility, it is essentially indestructible. The only imperfection could be its fragility, although it does not disappear even after breaking, and the remaining pieces can be used for a long time – as a tool, decoration or building material. As such, the human commitment to stone as a raw material has a very deep history, and remained unchanged even after the appearance of metal. Due to the hardness, longevity, and durability of this raw material, stone tools had a long, dynamic, and complex life

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cycle, during which they could repeatedly circulate through various segments of the operational chain, until their final disposal.

Techno-functional analyses of Neolithic ground and abrasive stone tools from several sites in Serbia (Fig. 1) contributed to the identification of all stages of the process through which one ground or abrasive stone tool could pass until it would end up as a discarded product in an archaeological context. Such an approach allowed the reconstruction of the life histories for most types of those tools.

This paper aims to consider the transformative processes within the ground and abrasive stone industry in the Neolithic of Serbia and clarify their use in terms of maintenance, secondary use, and recycling, as well as to show the most frequent examples of such technological practices. The focus is primarily on tools for everyday use and the ways in which they were rerouted through various segments of the operational chain.

Neolithic in Serbia: geographical and chronological framework

The Neolithic in the territory of today's Serbia was determined by two very significant cultures – the Starčevo and Vinča cultures (Fig. 1)(*Garašanin 1979.145–149; Borić 2009.192; Tasić* et al. *2015a; Whittle* et al. *2016.2*).

The Starčevo culture (*c.* 6200–5000 BC, *Whittle et al. 2002; Minichreiter, Krajcar Bronić 2006*) belonged to the Early Neolithic Starčevo–Körös–Criş cultural complex, spread across the large territory of South-Eastern Europe and the Pannonian Plain (Fig. 1). The Starčevo culture itself was present in the territory of today's North-Eastern Croatia and all of Serbia. This was the first Neolithic culture of the middle Danubian Basin. During that time, an economic and technological basis was formed within it, which enabled the appearance of the advanced and highly developed Late Neolithic Vinča and Sopot cultures in this area. The latest palaeodemographic research activities suggest that the end of the Starčevo culture was marked by a significant decrease of the population, which suddenly increased again at the beginning of the Vinča culture, when changes began to occur in the material culture (*Porčić* et al. *2016.7–8*).

The Vinča culture (5400–4500/4450 cal BC, *Borić 2009; Orton 2012; Tasić* et al. *2015a*) was a Late Neolithic culture which continued on into the Starčevo culture, partially overlapping with it in the initial phase. Important changes occurred during the Vinča culture period: the organization of settlements was different, with intense construction of above-the-ground buildings (*Tripković 2009; 2013*), the technology of making and the style of decorating pottery were new (*Vuković 2020*), and the production of stone and bone tools increased, giving a special distinction to this culture (*Antonović 2003; Vitezović 2013*). In this period, the exchange network also began to spread, which probably also caused changes in the system of social organization (*Dimitrijević, Tripković 2006; Tripković 2004*).

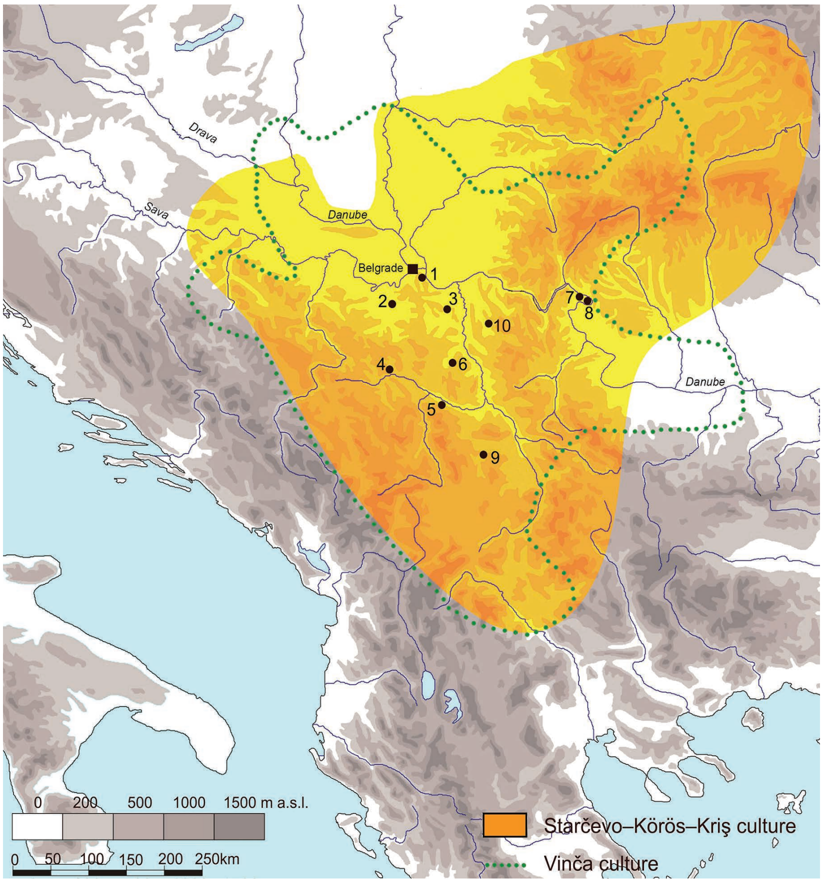

Fig. 1. Map of the Neolithic sites mentioned in the paper:* 1 *Vinča;* 2 *Mali Borak;* 3 *Selevac;* 4 *Trsine;* 5 *Lađarište;* 6 *Divostin;* 7 *Ajmana;* 8 *Zbradila;* 9 *Pločnik;* 10 *Belovode.

The economy of the Starčevo and Vinča cultures was based on agriculture. Several types of cereals (emmer wheat, einkorn wheat, barley, *etc.*) were cultivated, domestic animals (goats, sheep, bovine and pigs) were bred, and hunting and fishing also had an important role as additional food sources. In such a stable economy, the production of specialized stone tools rose to a very high technological level, most visible at the end of the Vinča culture (*Vitezović, Antonović 2019*).

The sudden development of stone tools began at the end of the Starčevo and the beginning of the Vinča culture. Ground and abrasive stone tools became more numerous, more typologically diverse and more uniform in terms of the choice of raw materials. Use-wear traces indicate a prominent specialization of tools, and technological traces – a standardization in their production (*Antonović 2003; Vitezović, Antonović 2019; Dimić 2020; Dimić, Antonović 2021a; 2021b; 2021c*).

Methods and materials

The manner in which a stone artefact was made, from the choice of raw materials to its final form, as well as the ways in which it was used, repaired, damaged, discarded or reused, represent technological sequences that, as part of a wider technological system, directly reflect traditions and cultural practices of a community (*Lemonnier 1986.154; 1992.5–9; 2012. 298-299; Dobres 2000.96–97; Miller 2007.4*). Hence, the research of all these sequences within the ground and abrasive stone tools technology provides a lot of information linked to the structure of a given community, that is to say, the organization, choices and skills of the people who made these tools and the ways in which they would use them. The transformative processes through which the tools would pass, starting from the selection and processing of raw materials, through use, damage, repairs and other types of reuse, until the final discarding, depict the life history of an artefact (*Skibo, Schiffer 2008; Schiffer 2010*), and isolated activities within it represent sequences of the behavioural, *i.e.* operational chain (*Lemonnier 1986; Dobres 2000; Skibo, Schiffer 2008*). By studying and defining the life histories of ground and abrasive stone artefacts within a settlement, it is possible to interpret the cultural practices and technological patterns of the people who lived in it.

The assemblages from several Neolithic sites in Serbia were analysed from the typological and technological perspectives. Collections from certain sites could not be included in the statistical analysis in this discussion due to the selective approach in the gathering of stone tools, which was a common practice in the archaeological research activities in Serbia up to the end of the 20th century. Pločnik thus remained outside of the statistical analysis even though it yielded a unique example of the secondary use of abrasive tools, as mentioned in the discussion (*Dimić, Antonović 2021b; Dimić, in preparation*). The sites selected have collections which comprise all the stone finds discovered during research conducted in the entire or the largest part of a given Neolithic settlement.

Vinča

The Neolithic settlement in Vinča is located on the right bank of the Danube, about 15km downstream from Belgrade. The site has been researched, with interruptions, for more than a century: 1908, 1911–1913, 1924, 1929–1934, 1978–1986 and from 1998 to the present. The most extensive research activities were carried out from 1929 to 1934, when an area of about 2000m² and a layer with a thickness of up to 11m were investigated. The most recent research, which has been ongoing since 1998, has been carried out on an area of 300m² and provided the most representative sample for the study of abrasive stone objects (*Tasić* et al. *2015a.95*). All the phases of the Vinča culture are represented at the site (5770/5565–4570/4460 cal BC; *Tasić* et al. *2015a.128*). Remains of the Starčevo group have also been found in the deepest layers of the settlement, linked to the layer with pit-houses (*Tasić* et al. *2015a.125*). The analysis of the material from precisely this site laid the foundations for the study of the ground stone industry (*Antonović 1992*). A sample of a total of 3000 examples of ground and abrasive stone tools from all research campaigns was analysed, but only those collected during research after 1998 were statistically analysed.

Pločnik

This site is located in the south-west of Serbia, 21km west of Prokuplje. It was discovered in 1927, during the construction of the Prokuplje–Kuršumlija railway section. The first archaeological excavations of the site began in 1928 (*Grbić 1929*), and an area of about 500m² was explored at that time. The site was then researched on several occasions from 1960 to 1978, on an area of 765.5m² (*Stalio 1960; 1962; 1964; 1967; 1973a; 1973b*). The most extensive research activities in Pločnik were carried out from 1996 to 2013 (*Kuzmanović Cvetković 2017; Radivojević* et al. *2021a*), when it was confirmed that it was a large Vinča metallurgical centre. The settlement spread across *c.* 70ha (*Rassmann* et al. *2021*). Five cultural horizons were singled out, in which all phases of the Vinča culture are represented (5389/5003 cal BC to 4446/4231 cal BC, *Marić* et al*. 2021b.451–453*). Ground and abrasive stone tools form a sample of 305 whole and fragmented tools. The tools were analysed in two stages, 2012–2013 (72 examples found in *Dimić, Antonović 2021b*) and 1996–2011 (233 examples found in *Dimić in preparation*).

Divostin

Divostin is located in Central Serbia, 7km west of Kragujevac. The site has been known since 1952, and systematic research was carried out in the period from 1968 to 1970, within an American-Yugoslav project (*McPherron, Srejović 1988*). An area of about 2400m^2 was researched in a 0.4–1.8m thick layer. The settlement itself covered the area of *c.* 15ha, while the surface finds were discovered on an area of about 50ha (*Bogdanović 1988.35*). Research activities confirmed the existence of two basic settlement phases – Divostin I from the Starčevo period (started at *c.* 6300, *McPherron* et al. *1988*; *Porčić* et al. *2020*) and Divostin II from the Late Vinča period (4740/4635–4675/4535 cal BC, *Whittle et al. 2016.21*). After the Vinča period, the site was no longer inhabited in prehistoric times. Ground and abrasive stone tools make up a sample of 658 whole and fragmented objects of this type (*Prinz 1988; Galdikas 1988*).

Mali Borak

During protective archaeological excavations at the Kolubara coal mine in 2006–2010, three large prehistoric sites – Crkvine, Masinske Njive and Jaričište – were located in a row, at a distance of only a few hundred metres from each other – Masinske Njive at a distance of 900 metres from Crkvine, and at half that distance from Jaričište (*Blagojević, Arsić 2008a; 2008b; 2008c; 2009*). The settlement at Crkvine was inhabited during the later phase of the Vinča culture (*Živanović, Spasić 2008.205*). The neighbouring site of Masinske Njive lasted from the Late Neolithic / Early Eneolithic to the Early Bronze Age and it was inhabited by members of the Vinča culture (Vinča B1/B2; 5355/5215–5275/5070 cal BC, *Whittle et al. 2016.18*), as well as some cultures that did not originate from the Central Balkans, such as the Tiszapolgár, Lasinja, Baden, Lengyel and Cernavodă III cultures (*Blagojević, Arsić 2009. 73*).The next site towards the west, Jaričište (6200–5500 BC, *Radivojević* et al. *2021b.14*), was inhabited during the Starčevo and Vinča cultures, and then during the Middle and Late Eneolithic (Baden culture, Boleráz–Cernavodă III and Balaton–Lasinja; *Blagojević, Arsić 2009.74*). It is interesting to note that the stone industry from the site of Crkvine shows no similarities with those from Masinske Njive and Jaričište, even though late Vinča ceramics have been recorded at all three sites. Judging by the stone industry, most prominently the ground stone tools production, the site of Crkvine seems like a completely separate world with no close ties with the inhabitants of the other two settlements. More than 20 000 stone objects, mostly tools (only 0.1% of this number are decorative and cult objects; *Antonović 2013*) originate from the three sites mentioned.

At Crkvine, 5175 stone finds were collected from the researched area of about 3000m^2, out of which 1320 examples (25.5%) were from chipped stone. Only 680 examples can be fully identified typologically as groundstone tools. The most numerous are tools with a cutting edge, followed by abrasive tools. The largest number of stone finds (61.35%) are flakes made during the production of ground stone tools with a cutting edge made from tuff. A large number of semi-finished products and flakes that occurred during their production indicate production within the settlement (*Antonović 2013*).

A total of 6619 stone objects were collected at the site of Masinske Njive, with 4957 examples belonging to the chipped stone industry. Out of the 1662 finds of the ground and abrasive stone industry, 1045 examples were typologically defined, and several types and variants of tools were recorded among them. It was not possible to determine the shape of 617 examples, and the most numerous among them were pieces of raw material or atypical fragments, flakes from ground tools, as well as products of the making of axes, adzes and chisels shaped by knapping. This large sample, however, did not provide solid evidence of an organized production of ground stone tools at Masinske Njive, which was otherwise preliminarily observed in chipped stone tools. Production within the settlement certainly existed, but on a small scale, as evidenced by a small number of pieces of raw material, a slightly larger number of flakes from the production of ground stone objects, as well as numerous ground stones (*Antonović 2013*).

Jaričište is the largest settlement in Mali Borak, with an explored area of 8ha (*Blagojević, Arsić 2008; Marić 2013.18*). At first glance, the stone industry from this site shows great similarities with that from Masinske Njive. These are macroscopically very similar raw materials, as well as a large number of chipped stone tools. In the stone material examined so far, 60.96% of the finds belong to the chipped stone industry, and 39.04% of them have been identified as ground and abrasive stone tools, dominated by grindstones. A high percentage of pieces of raw material, semi-finished products and flakes from the process of making stone tools, as well as numerous grindstones, indicate production within the settlement. More than half of the ground stone finds have been typologically defined, which sets Jaričište apart from the previous two sites, where a significantly lower percentage of defined tools was recorded (*Antonović 2013*).

Neolithic ground and abrasive stone tools

The ground and abrasive stone tools industry had already been fully developed when it appeared in the Neolithic of Serbia, with already clearly defined and formed types of tools. From the oldest to the youngest Neolithic settlement in Serbia, there is no essential difference in the ground and abrasive stone industry, the types of tools remained the same, just like most of the raw materials, but there are noticeable changes in the numerical representation of certain types of tools and raw materials (*Antonović 2003.131*). The only more prominent novelty was the appearance of white rocks among the raw material for the making of tools with a cutting edge, although this brought only a visual change, but not a typological or a technological one. On the other hand, abrasive tools remained constant throughout the entire Neolithic. At the end of this period, new types began to multiply, which had to respond to new demands of the society which was being developed technologically.

The division into ground and abrasive stone tools was made on the basis of the raw material from which they were produced, the manner in which they were made and their function.

The term ground stone tools refers to those tools whosefinal shape was obtained by grinding and polishing of their surfaces (Fig. 2). Their semi-finished products were made by knapping, and traces of this would often not be completely removed by the final processing. In the Neolithic of Serbia, ground stone tools were made from fine-grained rocks of various origins (hornfels, epidote schist, metamorphic sandstone, magnesite, *etc*., *Antonović 2003.16–23; Antonović, Resimić-Šarić, Cvetković 2005; Dimić 2013.36; 2020; in preparation*). These rocks are characterized by a conchoidal fracture, and hence semi-finished axes, adzes and chisels were mostly made from macroflakes, which gave them their recognizable and unique appearance (*Antonović 2014*). The primary function of these tools was for use in woodworking.

Axes are tools with a symmetrical profile (Fig. 2.a), whose cutting edge is in the plane of symmetry (*Semenov 1976.125*). Several types of axes with minimal differences in their shapes have been recorded at Neolithic sites in Serbia.

Adzes are asymmetrical tools (Fig. 2.b), whose cutting edge is not in the plane of symmetry (*Semenov 1976.125*). At Starčevo and Vinča sites, especially in Central Serbia, adzes were the dominant type among tools with a cutting edge, and sometimes even in the complete ground stone material (*Antonović 2003.55*).

Chisels are tools with a cutting edge that were sorted into a special group due to their small dimensions (Fig. 2.c). By their shape, they equally resemble axes and

Fig. 2. Ground stone tools: **a** *axe (Pločnik);* **b** *adze (Pločnik);* **c** *chisel (Pločnik).*

adzes. These tools have been discovered on a large number of sites of the classic Starčevo and Vinča cultures, in a considerable variety of shapes, but they are, therefore, mostly found in small numbers.

Abrasive tools were made from rocks with abrasive properties (Figs. 3–4), such as sandstones and various types of magmatic rocks with a high contents of quartz (*Antonović 2003.23–29; Antonović, Dimić 2022*). Toolsmade of such rocks were produced by pecking, and polished surfaces were obtained during use, and thus such tools are separated into a special group different from ground stone tools. Abrasive tools include grindstones, whetstones, handstones, querns and mortars.

Grindstones, being tools for processing objects made of hard materials, were made exclusively from rocks with abrasive properties, such as sandstones, and morerarely from magmatic rocks containing quartz (Fig. 3.a–c). Several types of grindstones have been found at Neolithic sites in Serbia, differing by the shape and size, which depended on the types of objects that were being processed on them. The basic types were large stationary grindstones and small hand ones.

Whetstones (Fig. 3.d) differ from grindstones mostly by the raw material used for making them, namely fine-grained, softer rocks such as sandstones with no quartz or phyllites.

Handstones (Fig. 4.c) did not gain their form by intentional processing, but through use instead. They were pebbles of a suitable shape, of hard and solid rocks, most commonly magmatic, used to crush grainy fruits, grains, pigments, *etc.* Another type of handstones, namely, loaf-shaped handstones (Fig. 4.b) represented the mobile (upper) parts of saddle-formed querns, which were, due to their morphological properties, held with both hands and rolled over a quern slab while mincing or grinding wheat (*Florin et al. 1958; Lindström Holmberg 1993; 1998.129; Dimić 2015.391–394; Antonović, Dimić 2022*). The only typological difference between querns and loaf-shaped handstones which may (but need not) be indicative are the smaller dimensions of handstones compared to querns. On the other hand, the traceological differences are clear in terms of the orientation of linear traces along the length, or otherwise along the width, of the working surface of the tool.

Querns are massive stone objects with a flat or slightly concave working surface, used to crush grains or other grainy fruits (Fig. 4.a,e). They were most commonly made from fine- to medium-fine-grained magmatic rocks or from fine-grained compact sandstones. When made from sandstones, it is difficult to distinguish querns from static grindstones, especially when they are in the form of smaller fragments.

Mortars are massive stone objects, similar to querns, differing from them by a larger recess on the working surface (Fig. 4.d). They were most probably used for crushing hard materials rather than crushing grains, as querns were used for the latter task.

Long life of ground and abrasive tools

Ground and abrasive stone tools represented the peak in the production of prehistoric stone tools. They had the most complex and very dynamic life cycle. Due to the hardness and durability of stone, as well as its ability to be reused even after breaking, these tools could repeatedly circulate through different segments of the operational chain until they were finally discarded.

The life cycle of a ground or abrasive stone tool would begin with the procurement of the raw material, con-

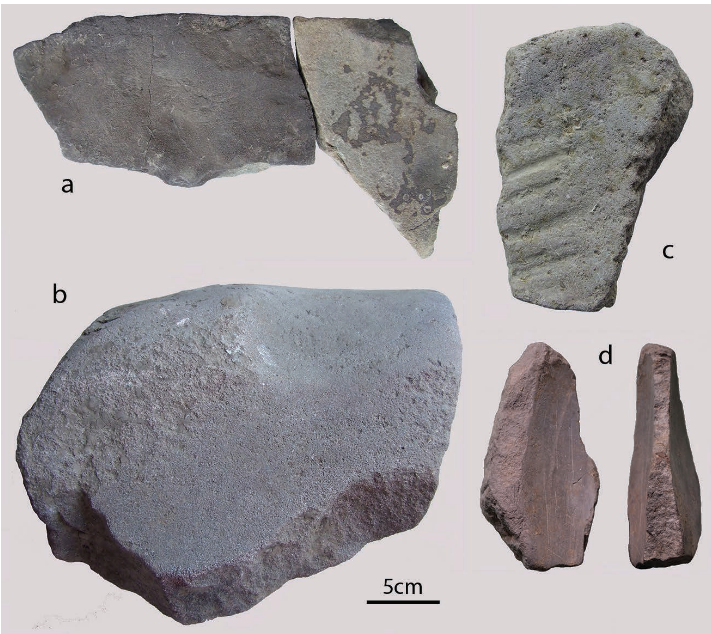

Fig. 3. Abrasive stone tools: **a–c** ***grindstones (Vinča);*** **d** ***whetstone (Belovode).***

tinue with the production of a semi-finished artefact by knapping, followed by the grinding of the final product. After that the tool would be primarily used, often repaired after any smaller damage, and sometimes recycled or secondarily used before being discarded. Before reaching its final destination – an archaeological context – a stone tool couldchange its form and purpose several times during its life cycle (Fig. 5).

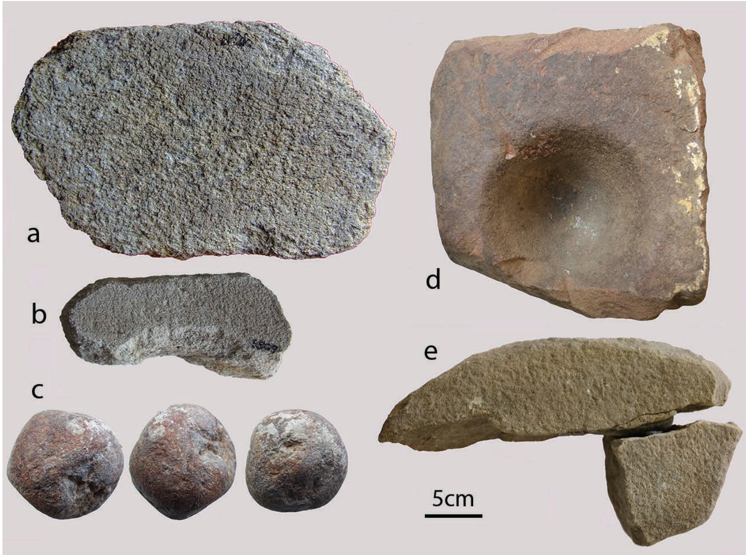

Fig. 4. Abrasive stone tools: **a** ***quern (Jaričište);*** **b** ***loaf-shaped handstone;*** **c** ***handstone (Vinča);*** **d** ***mortar (Pločnik);*** **e** ***quern (Mali Borak, Jaričište).***

The first step of the operational chain – procurement of the raw material – would take place outside of a settlement. For the time being, it is not known whether the raw material was extracted in an organized quarry or collected on the surface of the terrain. No quarry with clear traces of Neolithic exploitation has been discovered in Serbia so far, but there are places where surface stone collection and even primary processing of amorphous blocks separated from the parent rock could have been carried out (*e.g.,* the site of Trsine nearČačak, *Bogosavljević-Petrović 1998.3–5*). These are secondary deposits of stone raw materials where the rock material was deposited by successive erosion and fluvial processes (torrents and denudation). Sometimes, pieces of raw material would be brought to the settlement, where the rock would be turned into a finished product in workshops, as was recorded in Vinča, Crkvine in Mali Borak, Selevac, Ajmana, and Zbradila (*Voytek 1990.451; Antonović 2003.51; 2011. 209–211; 2013.35–36, Fig. 4*). Completed semi-finished products would then be taken into the settlement, for further processing by grinding.

Semi-finished tools with a cutting edge were made by knapping. After separating a stone block for making tools, rough knapping would be performed in order to make a rough pre-form of the artefact that was to be made (Fig. 6.a–d). Knapping was performed on both sides, the ventral and dorsal, as indicated by semi-finished products found. Finer flaking would usually be performed on the dorsal side, so that the platform would be on the ventral side (Fig. 6e).

Pecking is a technique similar to knapping, and it was used in the processing of rocks which do not have a conchoidal fracture. It was usually used for raw materials derived from secondary deposits, which had gained the suitable shape and smooth, round surface, similar to that of ground stone tools, through actions of natural processes, most commonly water (Fig. 4.c).

Grinding represented the final technique used in the processing of stone, with which the ground stone tools would be given their final form (Fig. 2). It was used to remove surfaces that were still not smooth after the previous processing, to correct the shape and form the cutting edge, which would thus become more resistant to damage.

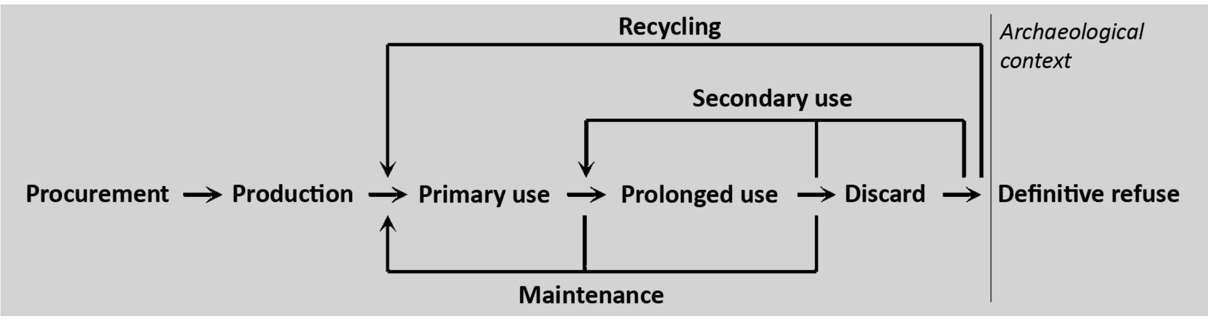

Fig. 5. Life cycle of ground and abrasive stone tools (scheme modified after **Schiffer 1972*).***

The final processing of tools could have been performed within a settlement, but also at the actual sources where the raw material had been obtained, thus leaving this point in the field of speculations. Organized workshops in settlements or places at raw material deposits where tools could have been ground have not been clearly defined as yet in Serbia.

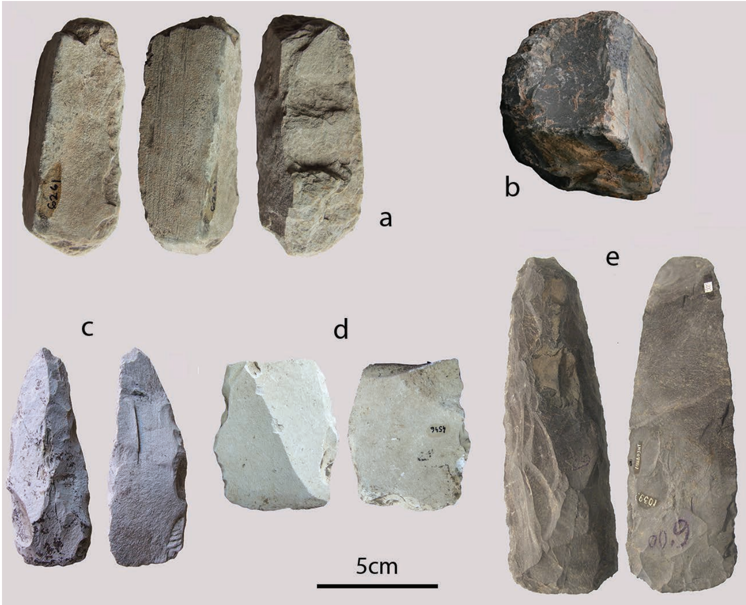

Fig. 6. Production of ground stone tools:* a–b *blocks of pre-formed raw material (Vinča and Mali Borak, Jaričište);* c–d *macroflakes – the first phase in production of roughouts (Mali Borak, Jaričište and Crkvine;* e *semi-finished adze prepared for final grinding (Vinča).

Some tools could have been broken immediately after flaking and before final grinding, without any traces of use (Fig. 7). Such tools could have been used, in an unchanged form, in their basic function, but they could also have been used secondarily or be rerouted to the recycling process.

Primary use

Primary use is the action for which the tool was originally designed. Ground stone tools with a cutting edge (axes, adzes, chisels) were commonly used in woodworking. In the Neolithic, these tools consisted of two elements, a stone head and a wooden shaft to which those stone parts would be attached.

Axes are tools whose primary purpose was to cut down trees and split wood. Since the cutting edge was in the plane of symmetry, the use-wear marks were created evenly on both sides of the cutting edge. Those are short parallel furrows, slanting in relation to the cutting edge, accompanied by a polishing of the surface (Fig. 8.a). The orientation of the furrows can also be followed by longer, arched, isolated scratches. The cutting edge itself would get damaged during work (bluntness, flake negatives) and this damage usually looks like untidy knapping (*Semenov 1976.125–129; Antonović 2003.53; Dimić 2015.54–57; 2020.364–394*).

Fig. 7. Semi-finished adze from Mali Borak, Crkvine.

Stone adzes are tools that are very similar to axes according to their morphology, however, the adzes have an asymmetric shape, and were wedged in the handle so that the cutting edge would extend perpendicularly in relation to the longitudinal axis of symmetry of the handle (*Semenov 1976.126; Antonović 2003.54; Dimić 2015.56–58; 2020.364–394*). The asymmetric shape of adzes corresponded to their function, namely, hollowing and hewing wood, and they were used in the production of various types of wooden objects. Use-wear traces are dominant on the dorsal side, although they can also be found on the ventral side in longer-used examples. Depending on the length and intensity of use, the traces are in the form of fine parallel furrows, perpendicular to the cutting edge, followed by surface polishing, dullness of the cutting edge, as well as micro- and macro-flake negatives (Fig. 8.b).

Chisels were, almost as a rule, less common than axes at the Neolithic sites found in Serbia, and much rarer than adzes. Chisels were used almost exclusively in woodworking, and only exceptionally for splitting bones, too. Their abundance at a given site certainly indicates the more developed specialized production of wooden objects. They differ from axes and adzes by the manner in which they were used. Chisels were not used for direct percussion, and instead force was applied by indirect hits of a stick against the ends of the tool or shaft, while the cutting edge was placed at a certain angle on the wood so as to penetrate it under pressure (*Dimić 2020.364–394*). Use-wear traces are very similar to those on the adzes blade, with the chisels showing a slightly more intense gloss on both sides of the blade (Fig. 8.c).

Abrasive stone tools (grindstones, whetstones, querns, handstones, mortars) were used both for food processing and also in the manufacturing of bone and stone tools. As such, their original use was for crushing, grinding, and abrasion.

Grindstones refer to tools used for grinding objects made of hard materials (stone, bone, antlers, ceramic, wood). This is why the working surface of such tools was smooth and recessed, while traces of previous processing by pecking would often remain visible in the outer parts of a given item. In whetstones, the working surface is also slightly concave, and always very smooth, almost polished (Fig. 3.d). This characteristic of the working surface is the result of using whetstones for working on objects made of medium to hard materials (antlers, bone, certain types of rocks and minerals, such as marble and calcite). The experimental use of whetstones for sharpening the cutting edges of axes, adzes and chisels showed that even such a use would leave no traces in the form of grooves, only concave surfaces (*Dimić 2020.338*). Other use-wear traces, first and foremost grooves, cannot usually be identified on grindstones and whetstones, probably because of the use of water in grinding and polishing, which would erase all grooves (*Miller 2007.59*). Also, depending on the type of tools which were processed by these tools, wide (stone and antler tools) or shallow channels (small bone tools) with a regular or flared U cross-section can be seen on the working surface of grindstones (Figs. 3.c, 12).

The use of handstones is usually linked to wheat grinding, since they were often found alongside querns.However, judging by the use-wear traces on them they were multifunctional tools, also used as retouching tools, hammers and anvils. Out of all abrasive tools, it is difficult the most to fit spherical handstones into the category of ground stone tools, because they had not gained their shape through intentional processing; their ground, levelled and slightly flatten surfaces were created during use.

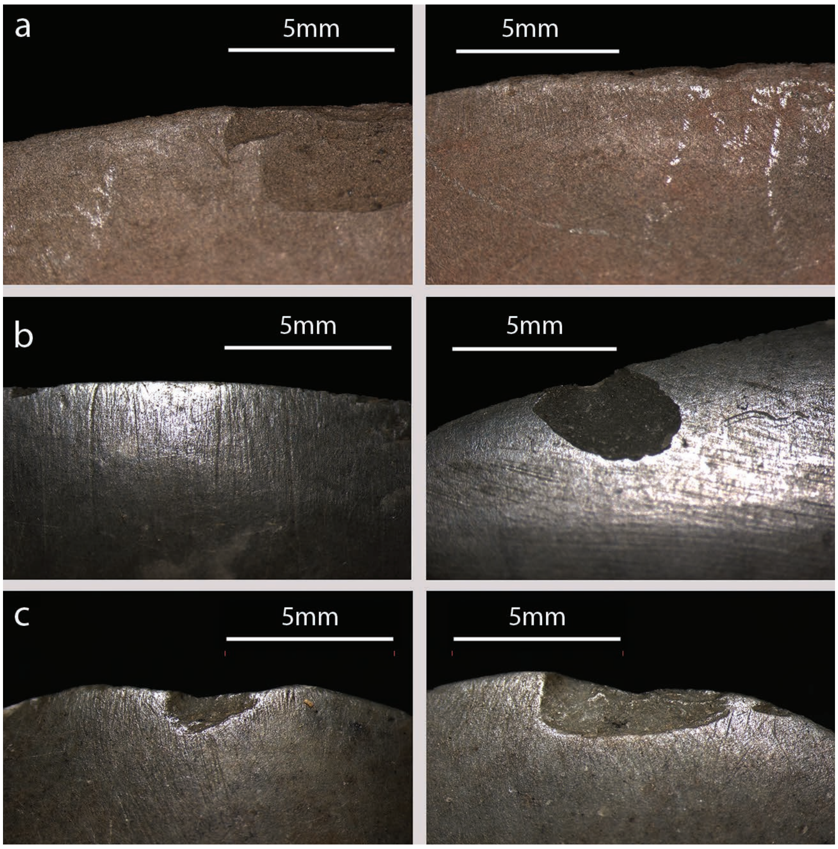

Fig. 8. Traces of primary use:* a *axe (Pločnik);* b *adze (Vinča);* c *chisel (Vinča).

Use-wear traces on querns are rough surfaces which, almost as a rule, follow fine grooves parallel with the longitudinal axis of the tool (Fig. 4.a). The same use-wear traces can be spotted on elongated two-handed handstones ('loaf-shaped'), however, in this case, theuse-wear traces always spread transversally (Fig. 4.b). They wereused for grinding cereals andgrainy fruits, water chestnuts,and so on.

Massive stone mortars with a working surface in the form of a recipient were most probably used for crushing hard materials such as pigments, pottery, mollusc shells, *etc.* Findings from late Vinča layers at Selevac were linked to early metallurgy and thecrushing of malachite, which was further used in copper smelting (*Spears 1990.503*). It is believed that mortars from Potporanj were used for crushing mollusc shells, which would then be added, in this ground form, as admixtures in making pottery (*Joanovič 1982.9*). Several typical examples of mortars from Pločnik should also be added to this group (*Antonović, Dimić 2022.275*), and it represents a transitional form between a grindstone and a mortar. The object was made from a thick slab of sandstone, which had become so concave from use in the central part that it gained the form of a mortar (Fig. 4.d).

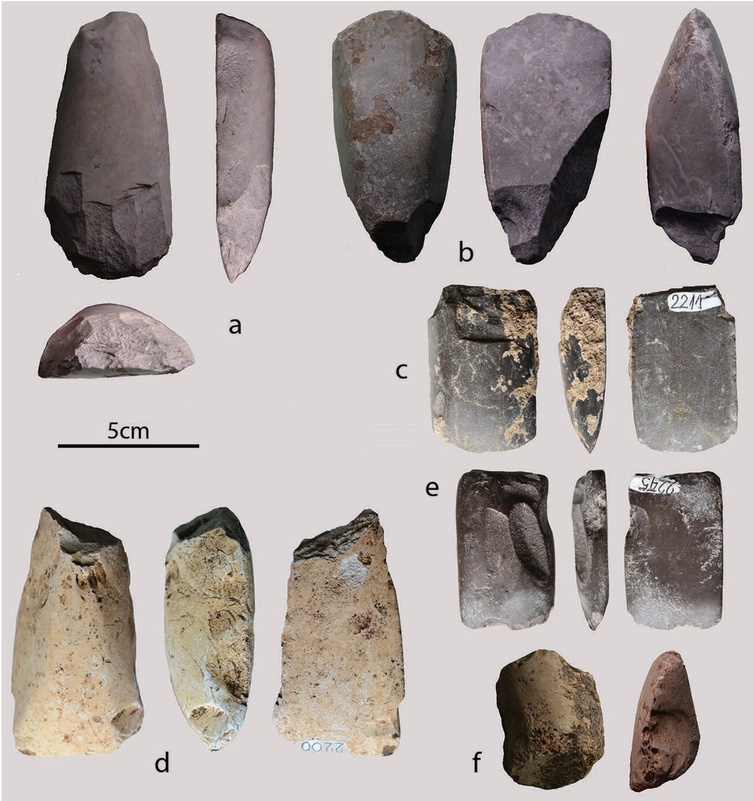

Fig. 9. Traces of maintenance: **a** ***adze with renewed cutting edge (Belovode);*** **b** ***adze with renewed proximal end (Belovode);*** **c–e** ***long used adzes (Pločnik);*** **f** ***adze at the end of life cycle (Belovode).***

Maintenance and prolonged life of artefacts

Maintenance represents the rerouting of an artefact back to the manufacturing process in order to keep its primary function. The properties and efficiency of an object in terms of the task it was originally designed for would thus be maintained (*Schiffer 2010.32–34*). Maintenance is the common set of technological procedures applied to a partially damaged tool, applied so as to restore the characteristics needed for fulfilling the intended task (Fig. 9). Through this practice, a tool would not be discarded, recycled, or secondarily used yet (*i.e.* it would not start a new life cycle), but rather its primary life was preserved and thus extended.

When it comes to ground stone tools, maintenance through sharpening and repair was usually performed on the cutting edge, or on the proximal end, used to affix the tool to the shaft. The repairing of the proximal end is considerably rarer than the sharpening of the cutting edge. If the cutting edge was dull, it was repaired by resharpening, and if it was partially damaged, by retouching and then sharpening. The sharpening of stone tools involved grinding and possibly a final polishing of the cutting edge. This type of repair is recognizable by pronounced processing traces, and often by a complete absence of use-wear traces on the cutting edge. The difference between new, unused tools and repaired tools with a cutting edge is that there are visible use-wear traces on the proximal end of the repaired ones, and the shape of the entire tool would often be changed depending on the length of use.

Ground stone tools with a cutting edge could have remained in use in their primary function for a very long time by means of constant maintenance and careful use. Typical examples of tools that had been used for a very long time are those with a stubby appearance, in which the ratio of length to width is significantly reduced, and the angle of the cutting edge significantly increased (Fig. 9.c–e), making it questionable if they could still be used for their primary use (*Dimić 2020.315–318*). The shape of these tools could reach the lower limit of functionality or lose it completely by going through the process of maintenance and use multiple times (Fig. 9.f). Such tools could then be redirected to the recycling process (Fig. 14) or used without any changes in form in a secondary function (Fig. 11) or transferred to a secondary context, thus starting a second life cycle.

Maintenance of abrasive tools is much less common, primarily due to their massiveness and the size of the working surface, which, even after minor damage or partial fragmentation, still had the potential to perform the same function for which the tool was intended. Traces of maintenance are most noticeable in querns and loaf-shaped handstones, on which the working surface was roughened by pecking. Traces typical of this practice are represented by a concave polished work surface with regularly spaced small recesses. The use of that percussive technique in repairs was a frequent reason for the fragmentation of massive abrasive tools (Fig. 4.e). On fragmented tools that have been discarded, and not rerouted to recycling or secondary use, it is sometimes possible to see the place of the last stroke that caused the fracture. For tools with multiple simultaneous functions, such as those that simultaneously served as grindstones, work plates, and anvils, fragmentation would occur most often after striking at the thinnest, most worn-out part.

The same as in the case of ground stone tools, abrasive stone tools show traces of very long exploitation. Long use, with or without regular maintenance, is characteristic of abrasive tools that were used until the working surface would become so recessed and concave that it would no longer be usable for the basic function of the tool. In those cases, it would often happen that the opposite side of the tool was used until it would become worn out in the same way, eventually leading to the breaking of the tool at its thinnest part (Fig. 10). The extensive usage lasted as long as the form of the tool reached the lower limit of the functionality or lost it. Such an item was either discarded, or, if there was enough usable raw material left, it was redirected to a secondary use or recycling, depending on the tradition and cultural practice of the community (Fig. 3.b).

Secondary use

When it comes to secondary use, no modifications of tool forms would occur before performing the new task (*Jacquier, Naudinot 2015.270–271; Schiffer 2010.33*). If a worn-out tool or the remaining fragment of a tool had a satisfactory shape and technical properties, it could be secondarily used for a function other than the primary one, without any modification. In addition, whole or fragmented ground and abrasive stone tools could be used in different secondary contexts as well.

Therefore, after damage which prevented rerouting a tool to the repairing process, ground stone axes and adzes were secondarily used as hammers, pounders, or retouchers (Fig. 11).

Secondary use is most commonly recorded on abrasive tools. Fragments of bigger grindstones, querns, and mortars would become smaller grindstones, handstones or grindstones for awls and needles, bone and wood handles, and so on (Fig. 12).

Finally, abrasive tools were used as building stones in house and furnace substructures. Usually, they were mixed with pottery sherds, like in Vinča. At Pločnik, there is a unique situation in the Neolithic of Serbia, where numerous abrasive tools with minor damage, practically still functional, were used as building stones (Fig. 13, *Marić* et al. *2021a.291*). It can be assumed that this settlement was the centre for the manufacture of abrasive tools and their inhabitants thus had the privilege of rejecting tools with minor damage and repurposing them as building stones. This is a reflection of a specific technological choice, derived most likely from the fact that the site was surrounded by easily accessible deposits of quality sandstone.

Recycling

Recycling refers to changes in the form of an artefact in order to adapt it to a new function (*Jacquier, Naudinot 2015.270–271; Schiffer 2010.33*), or to use it as a raw material. A prerequisite for recycling is an optimal amount of raw material that would remain after a tool was damaged.

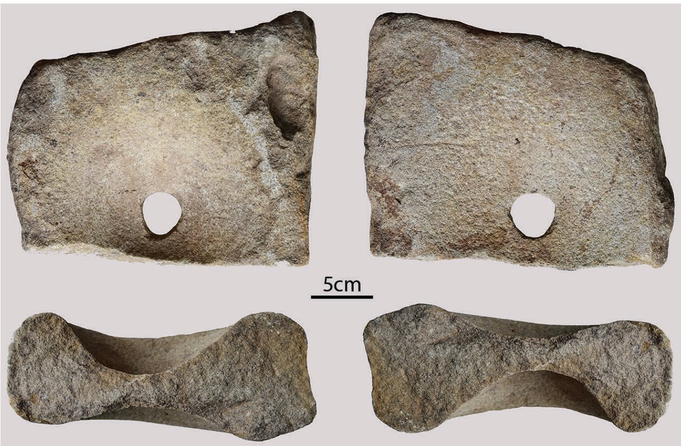

Fig. 10. Worn out mortar from Pločnik.

Ground stone axes, adzes and chisels were usually recycled by knapping into hammers, pounders, or even cores for chipped stone tools (Fig. 14). After knapping, the polishing process would sometimes completely erase the initial traces of manufacture, so it is not always easy to recognize a recycled tool and distinguish it fromone that was in secondary use. Proximal andmedial parts of ground stone axes, adzes and chisels were mostly usedfor recycling.

Abrasive tools have rarely gone through the recycling process and were more often used in

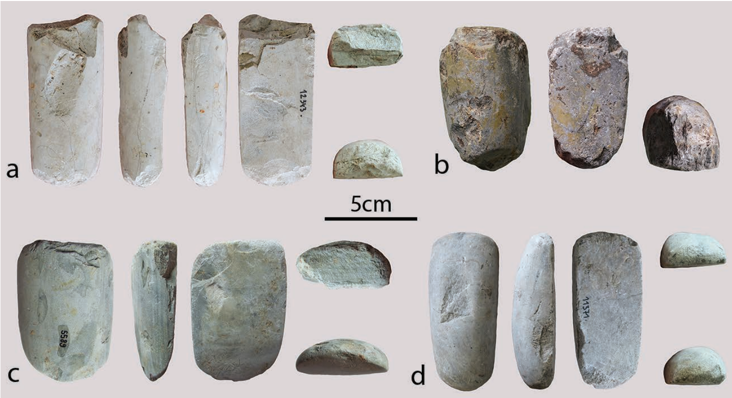

Fig. 11. Secondary use: a,d *medium part of a tool with a cutting edge, secondarily used as hammer (Jaričište);* b *proximal part of a tool with a cutting edge, secondarily used as hammer (Belovode);* c *distal part of a tool with a cutting edge, secondarily used as hammer (Jaričište).*

secondary functions, or in a secondary context, without any change of the final shape which they acquired through primary usage. Some of the frequent examples of recycled abrasive tools are fragments of querns whose shape was adjusted through knapping or pecking so they could be used as handstones (Fig. 4.b).

Discussion

Techniques for processing stone raw materials were largely standardized, and hence the manner in which secondary use, maintenance, repairing and recycling of stone tools would be performed was also largely uniform.

The availability of raw materials, the degree of the development of the related crafts, as well as technological traditions and practices, greatly influenced the general appearance of the ground stone industry in every settlement. The degree and variety of artefact reuse modes could indicate how different Neolithic communities solved certain problems, as well as the technological choices made in solving them. The degree of recycling shows how close a settlement was to the raw material source, how accessible a given raw material was and whether craftsmen who were making stone tools were present in the settlement. It has to be kept in mind that maintenance could be performed as a regular domestic activity in every household, which differs from the professional production of stone tools in workshops specially organized for the production of tools.

The scenario set out above is reflected in some Neolithic settlements. Pločnik, Vinča, and Divostin were large production centres for ground and abrasive stone tools in the Vinča culture. They imply the use of available sources of raw material and the existence of skilful craftsmen, but also of a social organization, in which some settlements were specialized for raw material procurement, some for the production of semi-finished tools, and others for the manufacturing of final products (*Vitezović, Antonović 2019*).

In Divostin, 72% of all ground stone tools with a cutting edge made of porcelanite [1] were semi-finished items (*Prinz 1988.264*). Some tools were made from large thick flakes with clearly visible bulbs for percussion and striking platforms. More than half of the porcelanite tools were only partially polished or have no traces of polishing whatsoever (*Prinz 1988.258*). Numerous porcelanite tools, although without a clearly defined platform and bulbs for percussion, or else traces of cleavage, had shapes suggesting that they were made of flakes. The concentration of debris in some parts of the excavated area indicate the zone, or several zones, where ground

Fig. 12. Pločnik: grindstone for bone awls and needles.

1 Beth Prinz (*1988*) identifies the raw material as porcelanite, while Alan McPherron (*1988*) believed it to be magnesite. The raw material belongs to the group of so-called light white rock, which were typical for the Late Vinča ground stone industry in Central Serbia.

stone tools were manufactured. A large pit (Feature 40) was completely filled with *c.* 1m³ of debris derived from the production of ground stone tools, and 120 ground stone tools were found in Sector D, which is almost twice the expected distribution. Macroflakes of adequate size for the production of axes and adzes were not discovered in the entire excavated area at Divostin (*Prinz 1988.258; McPherron 1988.225*). On the basis of all this, it can be assumed that the final processing of semi-finished products and ground tools, mostprominently those made of porcelanite, was conducted in the actual settlement, on already prepared large flakes, which have not been discovered within the settlement. It can be assumed that they were brought to the settlement for final processing, thus implying that several settlements or at least working camps participated in the production chain.

In Vinča, during the research which has been ongoing since 1998, examining layers of the final phase of the Vinča culture on an area of 450m² (*Tasić* et al. *2015b.1069*), all stone finds were collected with special care taken in registering their horizontal stratigraphy. In that area, where 10 houses were discovered, 1800 mostly fragmented artefacts made of ground and abrasive stone were collected. Only a small number originated from houses, mainly those linked to food preparation (*Borojević* et al. *2020*). Most of the finds were deposited in areas around the houses. Out of the total number of finds collected, 72.85% are abrasive tools (61.95% for processing objects made of hard materials, 11.2% for food preparation), and only 7.05% are defined as tools with a cutting edge, with only a third of them finally processed. No workshop for the production of ground and abrasive stone tools was recorded in this entire area. A possible answer for such a situation was provided by dug-out U 830 north of house 01/02, which abuts its northern wall. Aside from a huge amount of fragmented pottery, animal bones that were not exposed to atmospheric influences for a long time, indicating their rapid deposition, were also found along with waste stone material. In addition to used cores from the production of chipped stone tools and a small number of flakes from the production of ground stone tools, 186 examples of abrasive tools werefound, with 71.5% of them being fragmented grindstones. It could be assumed that the final processing of stone tools by polishing was carried out in the area around the houses, which was regularly cleaned and the waste material was deposited in a pit that only served as a landfill. The few flakes found in U 830 may indicate occasional repairs made to damaged ground stone tools before final processing by grinding.

Fig. 13. Pločnik: foundation of Feature 11 comprising damaged abrasive stone tools (*Marić *et al.* 2021a.291*).

Pločnik, with its remarkable collection of large abrasive stone tools discarded after short-term use, suggests a closeness of raw material deposits and probably numerous very skilful craftsmen who made the stone tools. Out of 305 tools, there are only 2% semi-finished products, and the rest are finished products or tools used without any processing traces (*e.g.,* hammers, some abrasive tools, *etc*.). The technology for making ground stone tools indicates standardization, both in terms of forms and raw material choice throughout the entire life of the settlement (*Dimić, Antonović 2021b*). Adzes made of 'light white stone' are especially prominent among ground stone tools with a cutting edge, and they also represent the only non-metal objects found together with massive metal items in several hoards (*Šljivar 1996; Šljivar* et al. *2006.261–265*). The most recent hoard of adzes was found during the last examination of the site in 2013. It was located in front of the wattle and daub building (feature 1), right next to its outer wall, and it is associated with massive grinding stones. For now, this is the only place that can be interpreted as a workshop at this settlement (*Marić* et al. *2021a.286–288*). Use-wear traces can be noted on 86% of the final processed tools, and the rest are unused tools or fragments. Traces of repairs were identified on 11% of the tools. About 11.5% of the tools have traces of recycling processes, while a smaller number, only 2.6%, were successfully recycled. Secondary use was recorded on 4%

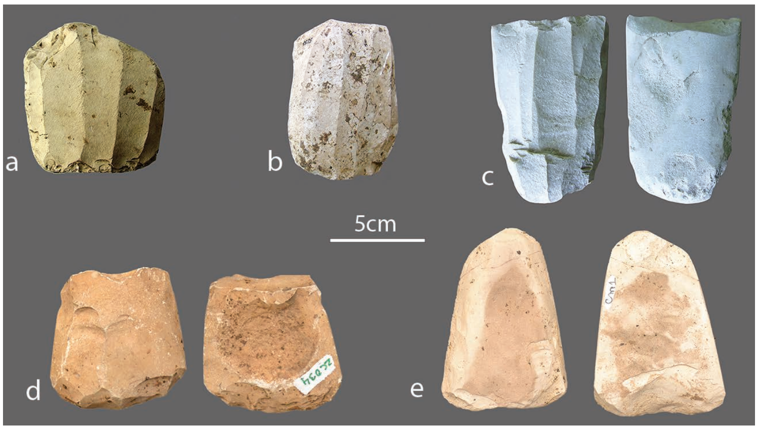

Fig. 14. Recycled tools: a–c ***proximal ends of tools used as cores for chipped stone tools (Crkvine Vinča);*** d–e ***distal end of tools with a cutting edge, retouched and used as scrapers (Lađarište).***

of the tools received for analysis, although this number is significantly higher in reality. We would like to point out that there is a large number of abrasive tools with an uncertain context, and that a large amount of these tools were discarded during excavations before any specialized processing, which unfortunately was a decades-long practice that is slowly changing in Serbian archaeology. In photographs from the field, abrasive tools can be clearly seen in the substructures of buildings (Fig. 13), although they have not been subsequently found in the material. Abrasive tools that arrived for analysis make up 40% of the collection, including a significant amount of static grindstones and whetstones used for processing stone items. A small number of tools from the collection (16%) had been exploited for a very long time, both in a primary and secondary use.

Three settlements in Mali Borak were probably production and recycling centres for the whole area. Judging by the stone finds, especially those made of ground and abrasive stone, one gets the impression that all three sites were collection centres of a kind. A considerable amount of large pieces of raw material, flakes from the production process and semi-finished products confirm the manufacturing character of these settlements. However, a significant number of damaged and broken tools, as well as unsuccessful semi-finished products that were discarded because they could not be shaped into a final tool, show that these places were also used for waste deposits. The material was deposited in pits, which were numerous in all three sites (*Blagojević, Arsić 2008a; 2008b; 2008c; 2009; Živanović, Spasić 2008*). At Jaričište, out of a total of 5000 pieces of ground and abrasive stone tools, almost 30% were final products and only 1.32% have traces of use. The rest of the assemblage consists of damaged artefacts with some traces of unsuccessful repairing and recycling, and pieces of raw material. At Masinske Njive, out of almost 1700 ground and abrasive stone items, 46% are final products, but only 2.1% have traces of use, 55% are also damaged items with traces of unsuccessful repairing and recycling, and pieces of raw material. At Crkvine, out of 635 artefacts of ground and abrasive stone tools, 65% are final products with traces of maintenance and traces of recycling are visible on 12.3%. The only place which can be definedas a workshop was found at Crkvine, which was probably the centre for the production of chipped and ground tools made of white tuff.

Conclusion

On the basis of a large number of secondarily used and recycled artefacts, as well as tools that were in use over a long period of time, it can be concluded that the utilization of raw materials was maximized on the entire territory of Serbia during the Neolithic. Studying multiple biographies of ground and abrasive stone tools can show the place in the technological chain of every Neolithic settlement individually. The maximal usage of raw materials through processes of reuse is not a modern attainment, but instead is a practice which existed from the earliest times, which survived up to today, with a smaller or larger amount of technological changes. Techniques for processing stone raw materials in Serbia during the Neolithic were mostly standardized, and hence this was also the case with the manner of their secondary use, recycling, maintenance and repairs. Consequently, the knowledge of the operational chain of ground and abrasive stone tools enables an analytical focus on defining the ways in which these artefacts may have been primarily used or reused, and ultimately discarded. It is obvious that not all of the settlements were engaged in every step of managing the raw materials, tool production and recycling, suggesting some sort of craft specialization among them (*Vitezović, Antonović 2019*). Technological and functional studies of assemblages of stone artefacts are thus extremely important for a more comprehensive understanding of the social practices and ways of life in the Neolithic, both in this region and elsewhere.

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Lithic production and the use of siliceous raw material in the Neolithic of Istria, Croatia – a case study from Kargadur and Vižula

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ABSTRACT - *This article contains the results of the lithic analysis of assemblages from the Neolithic sites of Kargadur and Vižula in southern Istria, Croatia. The assemblages have been analysed in terms of reduction strategies and typology, with a special focus on raw material analysis and petrographic analysis. During the Early Neolithic, and especially the Middle Neolithic, raw materials circulated the Istrian peninsula, as evidenced by the presence of obsidian and other non-local (exogenous) chert at several sites. Obsidian is certainly an exotic material in this region, and items found at Kargadur come from the Aeolian islands. With these results we have tried to gain a better understanding of lithic production of the period, the approach of the Neolithic people to raw materials and the scope of the distribution network of high-quality chert.*

KEY WORDS – *Early Neolithic; Middle Neolithic; lithic analysis; Istria; Croatia*

Litična produkcija in uporaba silikatne surovine v neolitiku Istre na Hrvaškem – študija primera iz Kargadurja in Vižule

IZVLEČEK – *V članku predstavljamo rezultate analize litičnih zbirov z neolitskih najdišč Kargadur in Vižula v južni Istri na Hrvaškem. Analize zbirov so bile usmerjene v strategije redukcij in tipologije, s posebnim poudarkom na analizi surovin in petrografski analizi. Prisotnost obsidiana in drugih nelokalnih (eksogenih) rožencev na več najdiščih dokazuje kroženje surovin po istrskem polotoku v zgodnjem in zlasti srednjem neolitiku. Obsidian je v tej regiji zagotovo eksotičen material in predmeti, najdeni v Kargadurju, prihajajo z Eolskih otokov. S pomočjo teh rezultatov skušamo bolje razumeti neolitsko proizvodnjo, dostop do surovin in obseg distribucijske mreže visokokakovostnega rožanca.*

KLJUČNE BESEDE – *zgodnji neolitik, srednji neolitik; litična analiza; Istra; Hrvaška*

Introduction

The part lithic industries played in the everyday life of the Neolithic people has only recently come into the focus of archaeologists. The Early Neolithic in the Eastern Adriatic is associated with the Impressed Ware culture that dates to *c.* 6000–5400 cal BC, and it seems there is ample evidence of cultural uniformity of Dalmatian and Apulian Impressed Ware. The almost exclusive reliance of Dalmatian Neolithic sites on the exogenous chert from the Gargano promontory during the Early Neolithic also testifies to the socio-economic relationship of the two Adriatic coasts (*Kačar 2019b*), and to the seafaring abilities of the Early Neolithic peo-

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ple which contributed greatly to the spread of impressed pottery (*Forenbaher, Miracle 2006.514*). The authors Forenbaher and Miracle proposed a model of Neolithisation of the Eastern Adriatic coast that took place in two phases. The first phase constituted a rapid 'pioneer exploration' associated with the typical impressed ware and limited to the southern Adriatic. The second phase was a slower one and it was composed of 'slow agropastoral expansion'. This is when the whole 'Neolithic package', including farming, herding and impressed pottery, was assembled and introduced to the Istrian peninsula *c.* 5750 BC. Later, there was a continuation of the 'agropastoral expansion' into the Northern Adriatic associated with Danilo-Vlaška pottery of the Middle Neolithic, *c.* 5600 BC (*O.c.516*). John Chapman *et al.* (*1996*) and Paolo Biagi and Elisabetta Starnini (*1999*) also support the migrationist view and emphasize the rarity of Late Mesolithic occupation in the region, and an abrupt shift from wild to domestic animals at the Mesolithic-Neolithic transition (*Forenbaher, Miracle 2006*).

Another theory suggests different Neolithization scenarios for Dalmatia and Istria on account of differences in lithic production, settlement patterns and subsistence strategies (*Kačar 2021.807*). The transition to farming in Dalmatia and Apulia was relatively rapid as a result of the colonization of the open landscape linked to the 8.2 ka event. The settlers based their subsistence almost exclusively on agriculture and livestock and their lithic blade production was based on exogenous Gargano chert. On the other hand, in the north of the Adriatic basin (Istria, Karst, Po Plain and Marches) the Neolithic emerged later, possibly as a result of acculturation. Mesolithic groups of hunter-fisher-gatherers may have played an active role in the Neolithisation process in these areas, which can be seen in some Castelnovian traditions identified in the lithic production of Neolithic sites dated to the Impressed Ware period: the use of local cherts, lamellar production by indirect percussion, and simpler forms of pressure flaking. Fishing as a subsistence strategy also remained an important food source (*O.c. 810*). A theory of Neolithisation by Ruth Tringham (*1971*) also suggested a continuity of economic practices and lithic use from the Mesolithic to Early Neolithic. Mihael Budja (*1993; 1996; 1999*) presented a theory that rejected migration as a driving force of Neolithisation and suggested the acceptance of a limited number of innovations by the autochthonous population.

In this paper, we will present the results of the lithic analysis of assemblages from two Neolithic sites in southern Istria, Croatia – Kargadur and Vižula (Fig. 1) – which was done as a part of the author's doctoral thesis (*Šprem 2022*). Kargadur is an Early and Middle Neolithic site situated around two kilometres southeast from the town of Ližnjan in Kuje Bay. The first excavations started in 2002 (*Komšo 2005; 2006a; 2006b*). The remains of terrestrial and marine animals, pottery and stone tools have been recorded at the site in the Early Neolithic horizon, while analyses of palaeobotanic remains have shown that the inhabitants of the settlement grew barley, wheat, legumes and spelt (*Komšo 2006a.235*). Four bone hooks and several

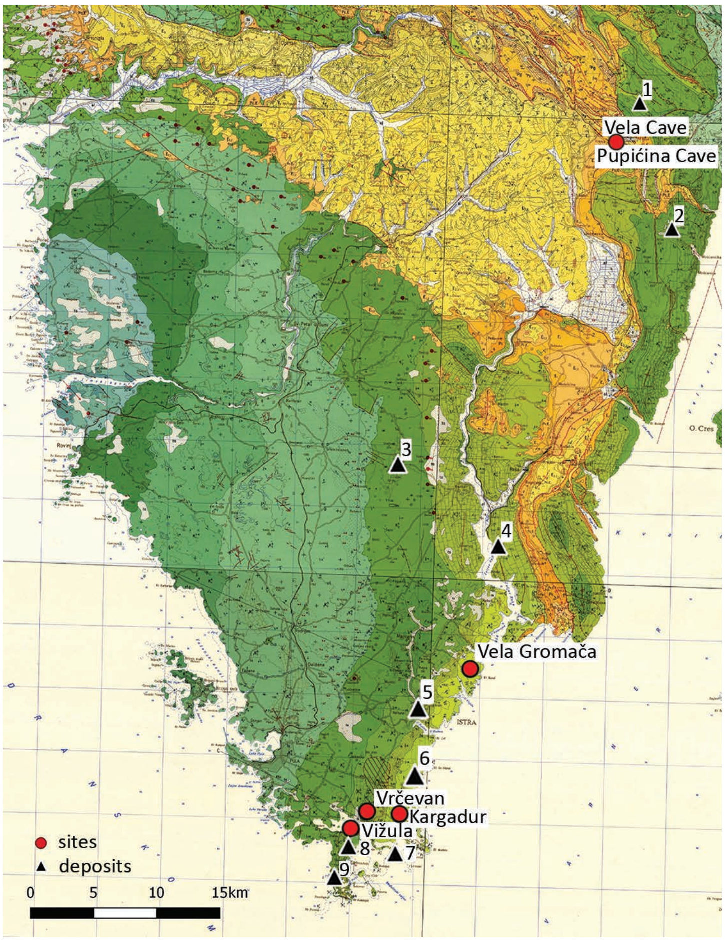

Fig. 1. Map of the Croatian part of the Istrian peninsula and the sites mentioned in the text. **1** ***chert deposits on Ćićarija Mt,*** **2** ***chert deposits on Učka Mt,*** **3** ***Poljaki,*** **4** ***Trget,*** **5** ***Budava Bay,*** **6** ***Kala Bay,*** **7** ***Marlera,*** **8** ***Vižula,*** **9** ***Polje Bay (after*** **Šprem 2023*****). Geological map after*** **Pleničar *et al.* 1969; Šikić *et al.* 1969; 1972; Polšak, Šikić 1973; Polšak 1967; Magaš 1968.**

bone semi-finished products testify to the fishing tradition of the settlement, and represent a unique find from the Early Neolithic period in the eastern Adriatic coast. The first phase of the settlement is radiocarbon dated to 6760±60 BP; 5710–5630 cal BC (Beta – 188924, *Komšo 2006b.113*). After the Early Neolithic phase and a hiatus, a settlement was re-formed on Kargadur in the Middle Neolithic period. One of the main differences in settlements is the presence of cattle. Twenty-five (25) obsidian fragments testify to a branched economic network during the Middle Neolithic. The prismatic blades made of high-quality chert of exogenous origin also stand out (*Komšo 2006a. 235*).

The Early Neolithic site of Vižula is located about 3.5 kilometres west of Kargadur (Fig. 1). It is a small circular peninsula near today's settlement of Medulin. The Neolithic site was discovered in 1969, when the first test trench was opened (*Baćić 1969*). The site was later excavated between 1972 and 1974 (*Codacci 2002.151*). The Early Neolithic layer 20cm thick lay on the bedrock at a depth of 40cm from the present surface (*Baćić 1969.23*). Several hearths and pits were found, along with pottery fragments with impresso decoration, daub fragments and several thousand chipped stone artefacts. Boris Baćić (*1969.24*) pointed out that the Early Neolithic layer was found undisturbed, *i.e. in situ*. A radiocarbon date for the Neolithic layer is available: 6850±180; 6100–5450 cal BC (HD-12093) (*Chapman, Müller 1990.130; Andreasen 2009. 56*). The daub fragments indicate the existence of houses, while a large amount of chipped stone artefacts with cortex show that the activities related to the extraction and initial processing of chert may have happened on site (*Spataro 2002.43–44*), since the small peninsula contains layers of coarse-grained chert in primary deposition, as well as beach pebbles, on its southeastern side. Animal bones and a large number of shells were also found at the site, most often *Cardium edule*, *Lamarcki* and oysters. Little is known about the species of animals represented, except that most of them are ovicaprids. It seems that the survival strategy of the inhabitants of Vižula consisted of hunting, fishing, and agriculture (*O.c.44*).

Materials and methods

This study is based on the lithic analysis of assemblages from the Neolithic sites of Kargadur and Vižula. The lithic artefacts were analysed according to technological and typological aspects, with a special focus on the raw material analysis, as a part of which micropetrographic analysis on finds from Kargadur was done.

The Kargadur assemblage consists of 1482 artefacts found in trench 3 investigated in 2005 and 2006. Lithic material from the site is divided into horizons of the Early and Middle Neolithic, and into mixed horizon (horizon A) (*Komšo 2005.213*). Horizon A is formed by recent layers with a smaller number of cultural finds in secondary deposition, in which 691 lithic artefacts were found. The Early Neolithic assemblage we analysed consists of 216 artefacts, while 1266 analysed artefacts come from the Middle Neolithic horizons. Unattributed artefacts, a total of 199 of them, were exempt from this analysis. We will also not be discussing the results of the analysis of the mixed (A) horizon, which makes the total number of analysed artefacts 1482.

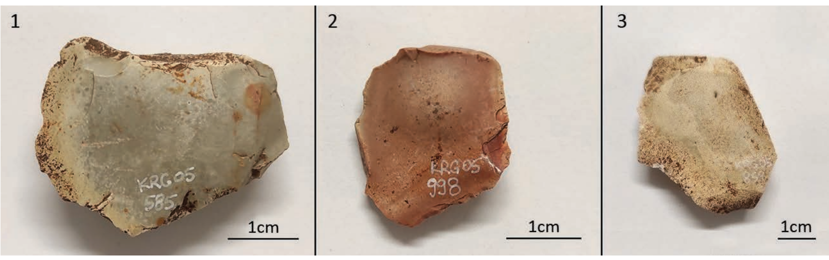

Fig. 2. Lithic finds from Kargadur attributed to Vižula chert.

Fig. 3. Lithic finds from Kargadur attributed to Marlera chert.

The Early Neolithic assemblage from Vižula consists of 2834 lithic artefacts. Part of the material comes from the excavations of the site, while several pieces were collected *"from the soil layer on the southern coast of Vižula"*. Several pieces were extracted *"from the layer of red soilfrom the southeast coast"*, and several pieces were collected *"from the shore on the isthmus where Ro-*

man tombs are".[1] Several pieces were found in an uncertain context along with Roman pottery or black and white tesserae. Some of the material did not have information on the context of the findings. Moreover, due to the unfavourable situation with the COVID-19 pandemic and the relocation of the Archaeological Museum of Istria in Pula, we were not able to complete the analysis of the entire material. Moreover, we cannot say what proportion of the lithic material found at Vižula our sample represents. Given all the above, as well as the lack of detailed documentation kept during the excavation, this lithic material represents a randomly selected sample of artefacts from the site.

The lithic analysis of 416 pieces from Vižula, with an emphasis on typological analysis, was conducted by Giulia Codacci (*2002*). She also conducted a raw material analysis which showed that 91.75% of the products were made from local raw materials from Vižula marked as 'st 1', while 4.37% of the products were made from the subtype of local raw materials marked as 'st 2'. The third type of raw material, marked as 'st 3', is a dark grey-brown chert of better quality represented in 2.91% of the products. About 0.73% of the analysed products were made of white chert, probably of exogenous origin and marked as 'st 4'. Products made of limestone pebbles are represented by 0.96% of the sample (*O.c.159–161*). We conducted our analysis independently of Codacci's results.

Technological analysis

Technological analysis is a discipline that enables the reconstruction of the methods and techniques of making artefacts. The originator of technological analysis was André Leroi-Gourhan, who devised the concept of a *chaîne opératoire* (*Inizan* et al. *1999.14–16*). Therefore, the chain of operations represents a kind of chronological scale of production of artefacts composed of different phases and categories (*Blaser* et al. *1999–2000.367*). For our analysis, we adapted the list of the technological categories used by Rajna Šošić Klindžić (*2010.67–73*) in her work on the Early Neolithic communities in Northern Croatia. These are: pebble or nodule, preform, cortical flake, cortical blade, bladelike flake, flake, blade, flake from retouching, core, crested blade, platform renewal flake, core tablet, overshot blade, debris, miscellaneous.

Typological analysis

For the purposes of typological analysis, another adapted list based on the work of Klindžić (*O.c.74–76*) was used. Thes documented tools are: the retouched piece, end-scraper, side-scraper, burin, perforator, truncated piece, double truncated piece, geometric piece, notched piece, denticulate, point.

Raw material analysis

For the purposes of raw material analysis, the lithic assemblages from Kargadur and Vižula were examined according to visual characteristics using a hand lens (10x magnification). The following variables of the artefacts were taken into account: colour, particles in the texture, structure, gloss, translucency. Based on these characteristics and based on the samples collected from our reference collection of chert deposits in Istria, the artefacts were divided into several categories of raw materials depending on their deposit of origin.

Fig. 4. Lithic finds from Kargadur attributed to Marlera chert, fourth and fifth sample.

Fig. 5. Lithic finds from Kargadur attributed to local raw material of unknown deposit.

1 Information from the field documentation of the Archaeological Museum in Pula, Croatia.

Since this analysis deals with provenance and distribution networks of raw material, we mostly focused on whether the raw material is local (a day's walk from the site, or 30 kilometres) or exogenous (from deposits located outside the peninsula, located more than a day's walk away, or more than 30 kilometres). Artefacts showing 'craters' and fissures as a result of being exposed to heat were also recorded and placed in the 'burned' category. The category 'indeterminate' was used in situations where, for example, the patina covered the entire surface of the piece so the raw material could not be determined. Each site has its own list of raw materials, which was formed on the spot as the analysis of materials took place. The lists were then compared for the final result.

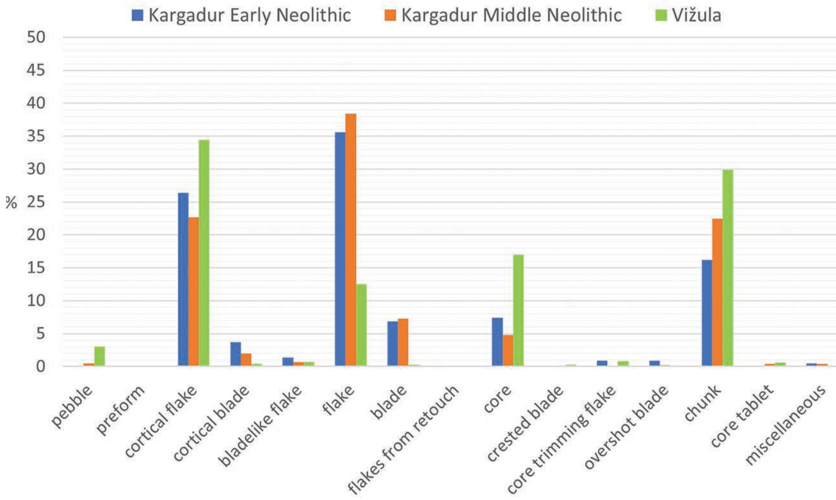

Fig. 6. Chart showing the percentage of technological categories in the analysed assemblages from Kargadur and Vižula.

Petrographic analysis

A micropetrographic analysis was done on lithic finds from Kargadur made from local raw materials since the focus of our doctoral research was the usage of local chert during prehistory and this paper relies mostly on said research (*Šprem 2022)*. We decided on three samples of raw material macroscopically identified as Vižula chert (Fig. 2), five samples of raw material identified as Marlera chert (Figs. 3 and 4) and two samples of local raw material whose deposit of origin is unknown (Fig. 5). The micropetrographic samples are made by grinding them to a thickness of 30 µm. The analysis was performed on a binocular polarising microscope Radical, model RPL-3B.

Results

Technological analysis

Among the flint artefacts from the Early and Middle Neolithic horizon at Kargadur, flakes predominate (Figs. 6 and 7). Blades and cortical blades are less common. Cores are more frequent in the Early Neolithic assemblage. There is a high proportion of cortical flakes in both horizons. We recorded one crested blade and five overshot blades, which suggests some blade cores were reduced at the site. Since flakes are the most dominant category, this suggests they were the main goal of the reduction process. The presence of cores with cortex, along with cortical flakes, indicates that the raw material was brought to the site and the production process started there.

Technological category	Kargadur Early Neolithic		Kargadur Middle Neolithic		Vižula Early Neolithic	
	n	%	n	%	n	%
pebble	0	0	6	0,5	84	3,0
preform	0	0	0	0	0	0
cortical flake	57	26,4	287	22,7	975	34,4
cortical blade	8	3,7	25	2,0	10	0,4
bladelike flake	3	1,4	9	0,7	21	0,7
flake	77	35,6	486	38,4	354	12,5
blade	15	6,9	92	7,3	9	0,3
flakes from retouch	0	0	0	0	0	0
core	16	7,4	61	4,8	481	17,0
crested blade	0	0	1	0,1	9	0,3
core trimming flake	2	0,9	1	0,1	23	0,8
overshot blade	2	0,9	3	0,2	2	0,1
chunk	35	16,2	285	22,5	848	29,9
core tablet	0	0	5	0,4	16	0,6
miscellaneous	1	0,5	5	0,4	2	0,1
Total	**216**	**100,0**	**1266**	**100,0**	**2834**	**100,0**

Fig. 7. Table showing frequencies and percentages of technological categories in the analysed lithic assemblages from Kargadur and Vižula.

Cortical flakes are dominant on Vižula (Figs. 6 and 7). They are followed by debris, which is represented by almost one third of all analysed pieces. This should not be surprising considering the cracking of Vižula chert, the material which was used to the greatest extent at the site. Next in terms of representation are cores and core fragments, followed by flakes, which appear to have been the main goal of reduction strategies at the site. On the other hand, blades are represented by only nine pieces, all from local chert. The presence of nine crested and two overshot blades, also from local chert, suggests that some of the blades were made on site. Pebbles or chunks of unused raw material are also present. We recorded cortex on 81.4% of finds. This can be explained by the fact that the source of raw material used to the greatest extent is located on the nearby southeast coast of the peninsula, about 500 meters away.

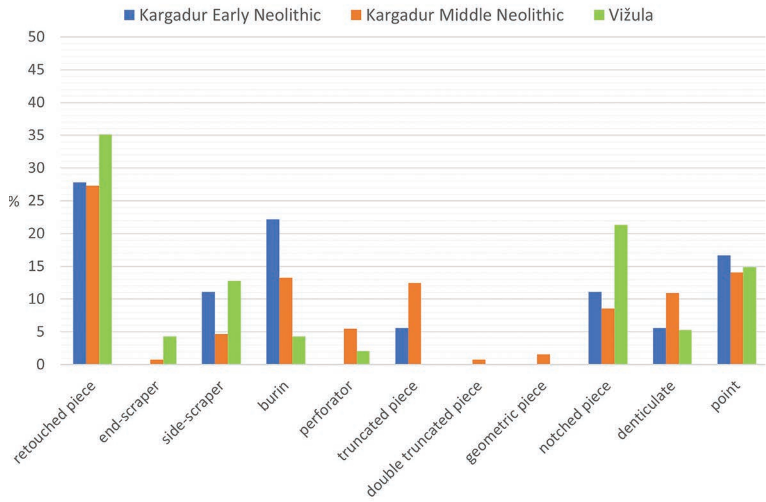

Fig. 8. Chart showing percentage of tool types.

Typological analysis

In the Early Neolithic horizon of Kargadur tools are represented by 8.3% of the artefacts, the most common being retouched pieces (Figs. 8 and 9). Most of the tools from the Early Neolithic horizon at Kargadur were made on flakes (66.7%), with an equal number made cortical flakes and blades (Fig. 10). In the Middle Neolithic horizon tools represent 10.2% of the assemblage, with retouched pieces being the most frequent. Points were also recorded, as well as burins and perforators. Most of them were made on flakes, but also cortical flakes and blades (Fig. 10). When it comes to raw material preference, Vižula chert was more popular for the production of tools during the Early Neolithic, while Marlera chert prevailed during the Middle Neolithic. There is a clear increase in the presence of exogenous chert during the Middle Neolithic, and therefore there are more tools made from it, too (Fig. 11).

Of the 2834 artefacts analysed from Vižula, only 94 pieces (3.3%) were retouched. The most common type of tool is a retouched piece followed by a notched piece (fig. 8 and 9). Scrapers and points are also present. Other tools are represented by less than 10% of the artefacts. Most of the tools from Vižula were made on cortical flakes, which makes a clear difference to the tools from Kargadur (Fig. 10). When it comes to raw materials, all of the tools from Vižula, except two retouched pieces from Marlera chert and one from chert of indeterminate origin, were made from Vižula chert (Fig. 11). We assume that the reason for this lies in the closeness of the Vižula deposit and the users' affinity for *ad hoc* tools in general. The three artefacts made from exogenous chert were not retouched.

Raw material analysis

The material from the Kargadur site was divided into 11 categories of raw materials, described in more detail in Katarina Šprem (*2022*). For the purposes of the provenance analysis, we further grouped the raw materials into seven groups which we use here: Vižula deposit; Marlera deposit; exogenous raw material; local raw material, but the exact location is currently undetermined; burned; undetermined; and miscellaneous. We assume that some exogenous raw materials from Kargadur came from various formations in the area of the Monti Lessini mountains in northern Italy, such as the Maiolica formation, Scaglia Rossa formation,

Tool type	Kargadur Early Neolithic	Kargadur Middle Neolithic	Vižula Early Neolithic
retouched piece	5	35	33
end-scraper	0	1	4
side-scraper	2	6	12
burin	4	17	4
perforator	0	7	2
truncated piece	1	16	0
double truncated piece	0	1	0
geometric piece	0	2	0
notched piece	2	11	20
denticulate	1	14	5
point	3	18	14
Total	**18**	**128**	**94**

Fig. 9. Table showing frequency of tool types.

Scaglia Variegata formation and formation with Tertiary calcarenites (Fig. 26; see *Peresani* et al. *2016.41*).

The analysis of the assemblage from Kargadur showed that during the Early Neolithic Vižula chert was dominant (Fig. 12), while during the Middle Neolithic raw materials from Marlera predominated (Fig. 14). During the Early Neolithic, local raw material from Vižula was mostly used to make blades, with a fifth of all blades being made from Marlera chert (Fig. 13). This situation changes during the Middle Neolithic when the percentage of exogenous raw material increases and Vižula chert decreases (by almost a half), with most of the blades now made from Marlera and exogenous chert (Fig. 15). Most of the local raw material was used to make flakes, however. This data takes into account only flakes and blades without cortex; cortical flakes and blades were not included since it is considered they do not represent the ultimate goal of reduction strategies (*Inizan* et al. *1999*). Despite this, as many as 43 tools out of a total of 147 such items were made on cortical flakes (Fig. 10), which makes up almost a third of all tools. This was done to ensure the most economical use of raw materials (*Karavanić* et al. *2008.38*). The difference lies in their approach to cortical blades. While cortical flakes were regularly retouched, only three cortical blades were retouched into tools. Our data also shows that the local raw material, like that from Vižula and Marlera, was brought to the site and decortified there during the Early and Middle Neolithic. There is a small number of cortical, crested and overshot blades present in both horizons which leads us to conclude that some of the blades were made at the site. Cortical flakes, cortical and overshot blades, as well as cores from exogenous chert,

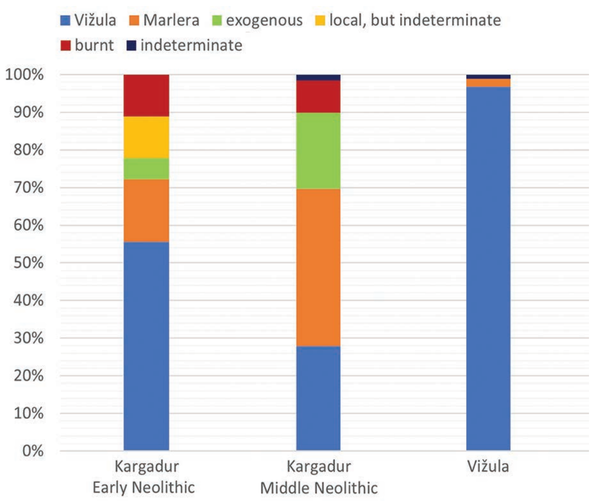

Fig. 11. Percentage of tools according to raw materials.

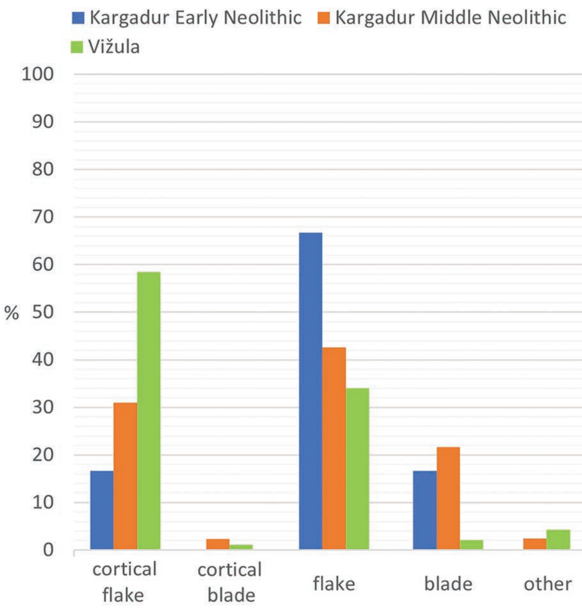

Fig. 10. Percentage of tools according to the blank types.

were recorded in the Middle Neolithic horizon, which suggests that the exogenous raw material was brought to site where the core preparations started and the production of blades was done.

It is also important to mention the obsidian fragments found in the Middle Neolithic layers, which come from the Aeolian Islands, by far the most popular source of obsidian for Neolithic settlements on the eastern Adriatic coast (*Tykot 2014.176–179*). Only two obsidian fragments found in Istria come from Carpathian sources (*O.c.178*). The presence of obsidian also testifies to a branched network of trade and exchange with one advantage: the source of obsidian can be determined geochemically very precisely, even between several deposits in one area (*O.c.174*), which makes research on the provenance and contacts between populations in prehistoric times easier. It is believed that Aeolian obsidian came to the Adriatic region by sea, bypassing southern Italy, but there is also a possibility of a land route from the Tyrrhenian Sea to the eastern coast of the Adriatic Sea (*O.c.178*). Aeolian obsidian is also present at the Neolithic sites of Danilo, Pokrovnik and Sušac, while several fragments of Carpathian obsidian were found at Danilo and Pokrovnik, and two obsidian fragments from Palmarola were found at Sušac (*O.c. 178–179*).

The raw materials represented in the analysed set of artefacts from Vižula are mostly local, meaning the material comes from the peninsula itself (Fig. 16). There are 40 artefacts made from Marlera chert, three

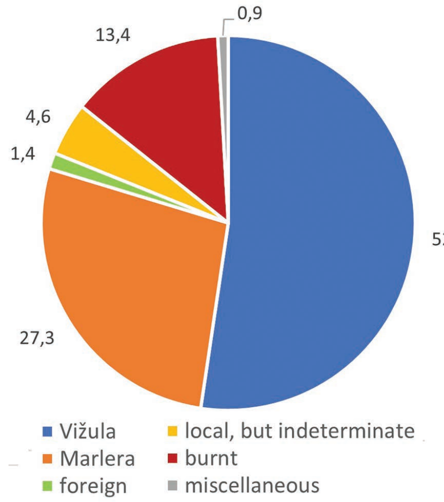

Fig. 12. Raw material present in the analysed assemblage from the Early Neolithic horizons of Kargadur.

artefacts from exogenous chert and 80 artefacts could not be assigned a raw material category. Ten artefacts were made from limestone. The limestone can be explained by the nature of the Vižula raw material. This chert is silicified limestone, or diagenetic chert, with nodules silicified to a greater or lesser extent, and therefore the limestone must have come from the same deposit. The three artefacts made from exogenous raw materials are a core (radiolarite), a chunk and a flake (Fig. 17).

Micropetrographic analysis

Vižula chert

Raw material from Vižula is usually described as greyish, sometimes yellowish chert (N8 to N5, very light grey to medium grey, sometimes 10R 8/2 moderate reddish brown or 10YR 2/2 dusky yellowish brown after Munsell, *Šprem 2022.59*). Our chosen samples were determined as Vižula raw material by macroscopic analysis and comparison with the samples collected at the deposit. Micropetrographic analysis of the first sample showed cryptocrystalline chert with rare microfossil relics, interspersed with cryptocrystalline calcite (Fig. 18).

Sample 2 had a very characteristic colour also seen in some of the samples collected at the deposit. Similarity was also shown by micropetrographic analysis, as both samples contain round 'ghosts' of microfossils and a cryptocrystalline base (Fig. 19).

The third sample was a coarse white chert, and a comparison with the collected samples confirmed it too originated from Vižula. It is a diagenetic chert whose primary structure has been preserved, and we can observe probable calcispheres which are very common in sedimentary rocks of this formation (Fig. 20; *Miko* et al. *2013.36*).

Marlera chert

Marlera chert is mostly very light grey to medium dark grey (N8 to N4) with impurities of light blue, 5B 7/6 after Munsell (*Šprem 2022.59*). The five samples attributed to the Marlera deposit are laminated early diagenetic chert of greyish-blue colour. The first sample consists of cryptocrystalline to microcrystalline quartz and chalcedony, while the second sample is a laminated cryptocrystalline to macrocrystalline chert (Figs. 21 and 22).

The third sample is a dark blue chert with characteristic white inclusions. It is also characterized by the zonation of microcrystalline calcite (Fig. 23).

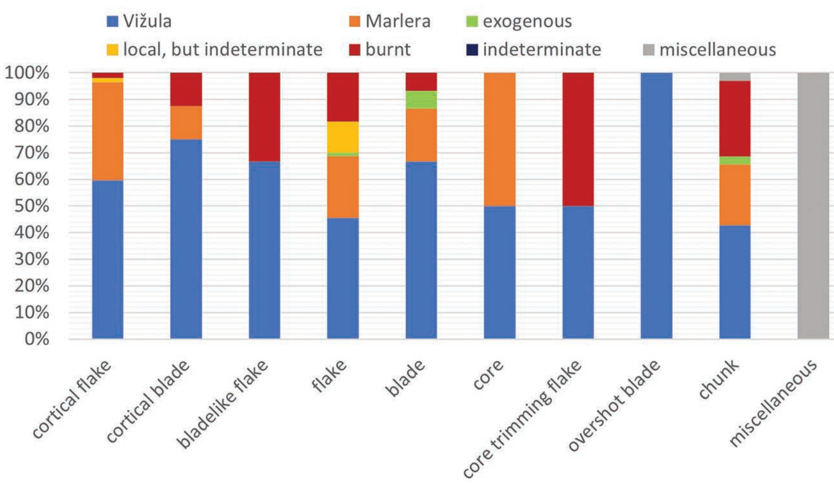

Fig. 13. Chart showing the percentage of technological categories in the Early Neolithic horizon of Kargadur according to raw material.

The fourth and fifth samples first stand out from the others by their macroscopic appearance. Nevertheless, we can link them to the Marlera deposit since we have also collected similar samples during our field surveys. It is a dark grey diagenetic chert with yellow carbonate inclusions of a fibrous texture. The cortex is also yellow in colour. The fourth sample can be described as a chert with a cryptocrystalline base, rich in 'ghosts' of microfossils, usually round and elongated, which we assume are sponge spi-

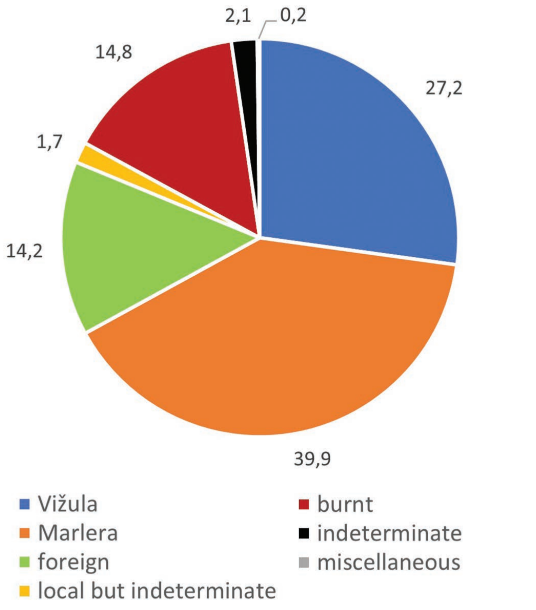

Fig. 14. Raw material present in the analysed assemblage from the Middle Neolithic horizons of Kargadur.

cules (Fig. 24.A and 24.B). The fifth sample is also a chert of cryptocrystalline base, with round 'ghosts' of microfossils from the primary structure and possibly sponge spicules (Fig. 24.C and 24.D).

Local chert of unknown origin

This raw material is a grey coarse-grained chert of poorer quality with white inclusions. Sample 1 is a cryptocrystalline chert rich in 'ghosts' of microfossils, namely ostracods, foraminifera, spicules of sponges (Fig. 25.A and 25.B). Sample 2 is very similar to the previous one, and is rich in 'ghosts' of microfossils. The base is cryptocrystalline, with parts that contain macrocrystalline quartz (Fig. 25.C and 25.D). These samples are very similar to the fourth and fifth Marlera samples, and therefore it is possible that this raw material is also originally from the Marlera deposit.

Comparison with other Neolithic sites in Istria and Dalmatia

The results of the lithic analysis of the knapped stone artefacts from the Kargadur and Vižula sites showed some similarities and differences between them. The main goal of the reduction strategy at both sites was flakes. Flakes were also the most frequent find at the Early Neolithic site of Vrčevan, located to the north of Kargadur and Vižula. However, due to the small number of lithic finds (12) in general (*Komšo 2004.17*), we must take this data with caution. Pupićina Cave in Vela Draga is represented by its *ad hoc* flake industry during the early phase of the Middle Neolithic, while prismatic blades became more common only during the later phase of the Middle Neolithic (*Forenbaher 2006.250*). Flakes and blades were equally represented at the Istrian site Vela Gromača near Kavran, where an Early Neolithic layer with 36 lithic artefacts[2], along with pottery and bone finds, was excavated beneath a Bronze Age burial (*Baćić 1973; Kačar 2019a.508*). This is a clear difference to the other Neolithic sites in Dalmatia, which were oriented to the production of blades from the earliest Neolithic (see *Kačar 2019b.360* and the bibliography listed there).

The presence of exogenous chert is also different between the two analysed sites. While at Kargadur exogenous chert is represented by between 1.4% of the artefacts in the Early Neolithic and 14.2% during Middle Neolithic (this does not take into account the obsidian fragments mentioned earlier), exogenous chert makes up 0.1% of all artefacts at Vižula (three pieces, with the total number of artefacts being 2834). It is interesting to note that the amount of raw material from Vižula decreases in the Middle Neolithic horizons at Kargadur, compared to the presence of this raw material during the Early Neoli-

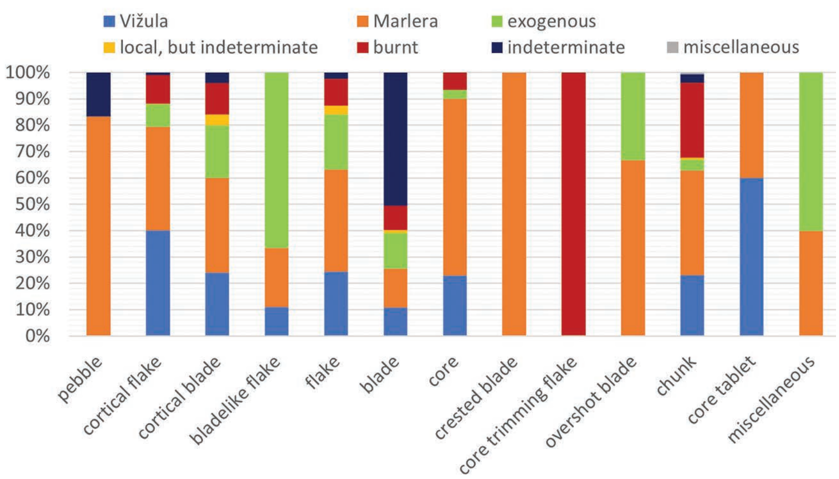

Fig. 15. Chart showing the percentage of technological categories in the Middle Neolithic horizon of Kargadur according to raw material.

2 Baćić (*1973*) initially reported 40 pieces.

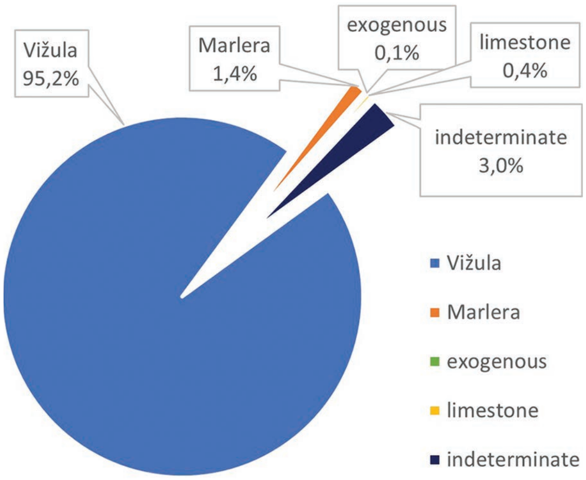

Fig. 16. Raw material present in the analysed assemblage from Vižula.

thic. At the same time, the percentage of exogenous raw materials, as well as raw materials from Marlera, increases. A similar strategy for obtaining raw materials was also used by the inhabitants of Pupićina Cave in the Vela Draga canyon. During the older phase of the Middle Neolithic, the representation of local raw materials is dominant, and the situation changes during the younger phase of the Middle Neolithic, when 'light' (exogenous) cherts are represented up to 58%. Obsidian also appears in the Late Neolithic phase of Pupićina Cave (*Forenbaher 2006.238*). The opposite is true for Vela Cave, which is located across from Pupićina. In the Late Neolithic phase, the representation of 'light' cherts decreases compared to the Middle Neolithic phase, and the representation of local 'dark' and 'reddish' cherts increases (*Forenbaher, Nikitović 2007–2008.14*). This can be explained by different activities being carried out at the two contemporaneous sites (*O.c.22*). The communities at Vrčevan and Vela Gromača also relied heavily on local chert (*Baćić 1973; Komšo 2004; Kačar 2019a*).

There is only a small number of cores from exogenous raw material recorded at the analysed sites: two cores in the Middle Neolithic horizon of Kargadur, one at Vižula. Cortical flakes and blades of exogenous chert are only recorded in the Middle Neolithic phase of Kargadur. Almost a quarter of all the blades from Kargadur are from exogenous chert and a slightly higher percentage of blades were made from Vižula and Marlera chert. Judging by this data, with the absence of crested blades and only one overshot blade of exogenous raw material recorded in the Middle Neolithic phase of Kargadur, exogenous blades were probably made off-site and brought to Kargadur in this form, but we cannot exclude the possibility that they produced blades on site as well. This was also probably the case with exogenous chert from the Middle Neolithic layers of Pupićina Cave (*Forenbaher 2006.248)*, but not on Neolithic sites in Dalmatia where Gargano chert was brought in the form of prepared or semi-prepared cores (*Kačar 2019b.361*). There are a total of nine blades recorded in the Vižula sample; eight of them were made from Vižula chert, and one from Marlera chert; no exogenous raw material.

Another indicator of trade in the northern Adriatic, more precisely between Kvarner and distant places during the Middle Neolithic period is represented by two finds of chert from the Vorganjska Cave on Krk (*Sirovica* et al. *2021*). Recent research has found two flint artefacts; one flake from the layer with Danilo pottery and one blade from a secondary context, both of which visually correspond to flint deposits recorded in northern Italy and on the Gargano peninsula (*O.c. 14–15*).

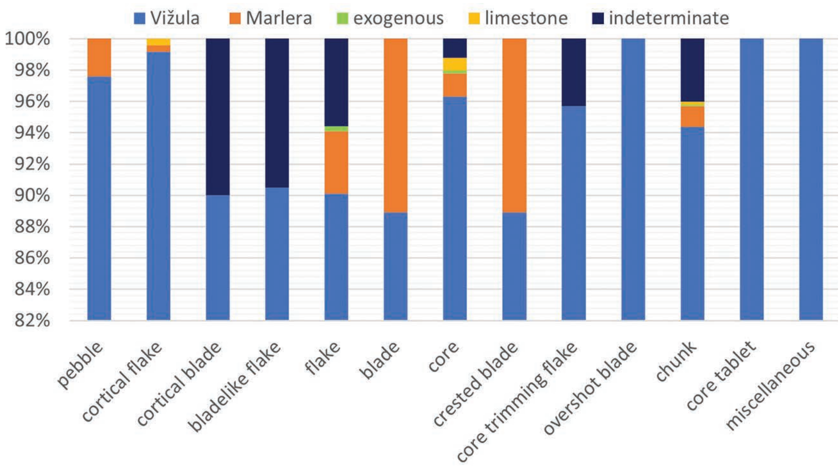

Fig. 17. Chart showing the percentage of technological categories according to raw material.

All the mentioned Neolithic sites in Istria – Kargadur, Vižula, Vrčevan, Pupićina Cave, Vela Cave – had locally available chert within an aerial distance of four kilometres or less, except Vela Gromača. For Pupićina and Vela Cave, these are the deposits established by P. Pellegatti through field surveys: Gabrova gorica, Gradec and Kupice on the southern slopes of Ćićarija. There are also primary chert deposits on the southern slopes of Učka mountain (*Pelle-*

gatti 2009; Šprem 2022.36–42; 2023.11–18). For Kargadur, Vižula and Vrčevan, the closest locally available deposits are Marlera, Vižula, Runke Cape, Polje Bay and Kala Bay (*Šprem 2022.46–57; 2023.21–30*). Nevertheless, all 36 pieces from Vela Gromača are of local chert grey in colour (*Kačar 2019a.508)*. Primary decortication of the local raw material was carried out both at Kargadur and Vižula, since cortical flakes are among the most represented technological categories. At Vrčevan, on the other hand, the decortication was done away from the site (*Komšo 2004.18).*[3]

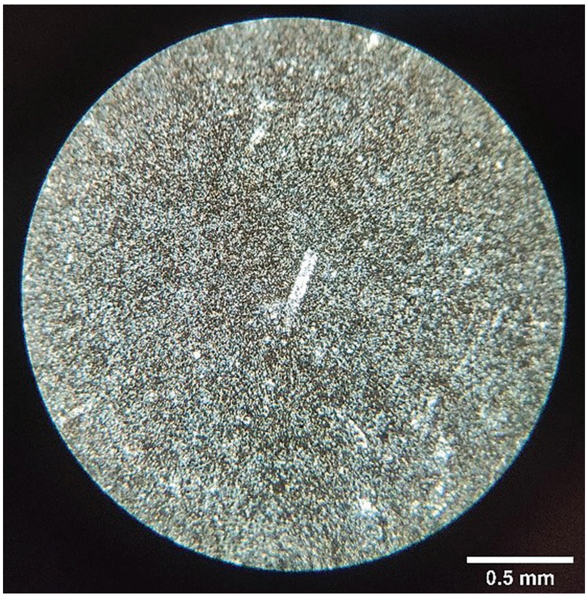

Fig. 18. Photography of Vižula sample 1. XPL, magnification 40x.

The difference between Kargadur and Vižula can also be found in the number of retouched artefacts. While at Kargadur the percentage of tools in the Early Neolithic horizon is 8.3% and in the Middle Neolithic 10.2%, at Vižula the percentage of tools is very low – only 3.3%. Very little investment into retouching the blanks at Vižula has also been observed by other authors (*Andreasen 2009.57).* The most common tool at both sites is a retouched piece. These are so-called *ad hoc* tools that were made according to the current need. On the other hand, Pupićina Cave yielded almost 30% of tools in the assemblage, with scrapers being the most frequent one. Almost half of all the tools were made on blades or bladelets and a third were made on flakes (*Forenbaher 2006.237*), while on Kargadur and Vižula tools were mostly made on flakes and cortical flakes.

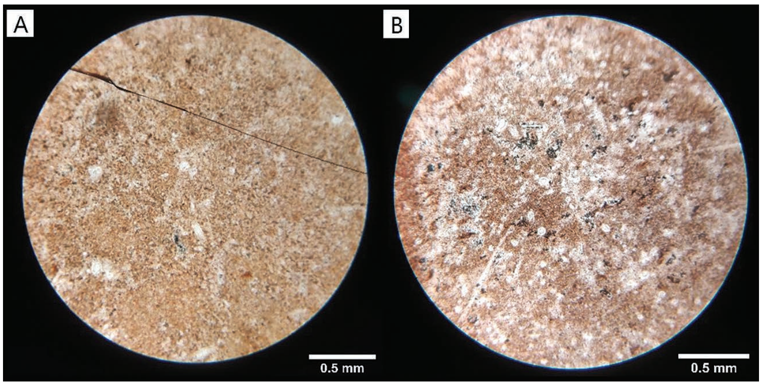

Fig. 19. Photography of Vižula sample 2 (A) and sample collected at Vižula deposit (B). PPL, magnification 40x.

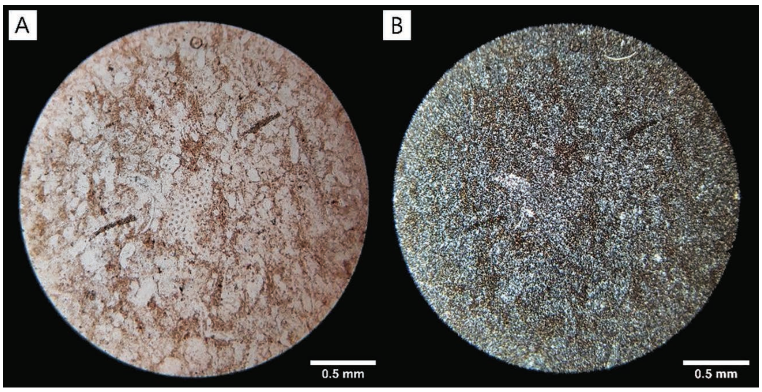

Fig. 20. Photography of Vižula sample 3. Primary structure can be seen. PPL, magnification 40x.

It is assumed that the Early Neolithic farmers who migrated to Dalmatia from Apulia and spread agriculture did not have knowledge of local chert deposits, so they brought chert with them from well-known deposits. Therefore, the transition to agriculture also marked an almost complete transition to exogenous high-quality chert from the Gargano deposit (*Forenbaher 2021.128–129*). Stašo Forenbaher cites the example of Nakovana cave, where chert from Gargano was used to a greater extent than local chert, starting from the earliest Neolithic until the end of the Bronze Age, when it disappeared from use (*Forenbaher, Perhoč 2015.65–66*).

One of the earliest Neolithic sites in Dalmatia – Rašinovac – which dates back to the first century of the 6th millennium

3 This is just a hypothesis since the number of lithic artefacts is too small to make any conclusions.

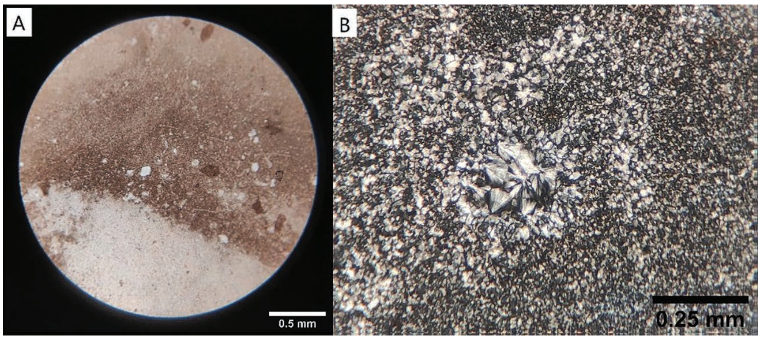

Fig. 21. Photography of Marlera sample 1. **A** ***Zoning in the sample, PPL, 40x.*** **B** ***Chalcedony in the sample, XPL, magnification 100x.***

BC, yielded 70 lithic artefacts, along with impresso pottery (*Podrug* et al. *2018*). Most of the raw material could not be determined petrographically, but the cherts that could were identified as local diagenetic cherts from Lower Eocene or Middle Eocene, as well as cherts from the Gargano deposit on the western Adriatic coast (*Podrug* et al*. 2018.70–73*). The analysis of raw materials from other Neolithic sites in Dalmatia, including Danilo, Smilčić, Pokrovnik, Crno Vrilo and Velištak, is currently underway. Nevertheless, preliminary data already indicates that chert from Gargano was a frequently used and favourite raw material of the Neolithic period in Dalmatia (*Forenbaher 2021. 128–129*).

When it comes to the reduction process, a characteristic of the Neolithic on the Eastern Adriatic coast is the focus of the reduction strategy on the production of blades (*Kačar 2019b.360*). Such blades in Dalmatia were probably made using a pressure technique that is different and more complex than that used during the late Mesolithic and in Castelnovien industry (*Kačar 2021.806*). Although the pressure technique had been known since the Upper Palaeolithic (*Inizan* et al*. 1999.32*), it became widespread only in the late Mesolithic (*Kačar 2019b.358* and the bibliography cited there). However, the pressure technique using a lever, recorded at sites in southern Italy and Greece, is certainly a Neolithic innovation that came from the East (*Kačar 2021.806–807*). There is no sign of any pressure technique in the reduction strategy of the analysed assemblages from Kargadur or Vižula.

Conclusion

The lithic analysis of knapped stone artefacts from the sites of Kargadur and Vižula made it possible to draw some hypotheses about the circulation of raw materials during the Neolithic in the south of the Istrian peninsula. Kargadur is a site from the Early and Middle Neolithic not far from Ližnjan, Istria, Croatia. The analysed set of stone artefacts from trench 3 numbers 1482 pieces. The main goal of the reduction strategy by the communities during both the Early and Middle Neolithic was flakes. Judging by the presence of a large number of cortical flakes, the raw material was brought to the site where the core preparation was done. It seems that some of the blades were also made at the site, judging by the presence of crested and overshot blades. Exogenous raw material was also brought to site during the Middle Neolithic, the cores prepared there, and flakes and blades knapped.

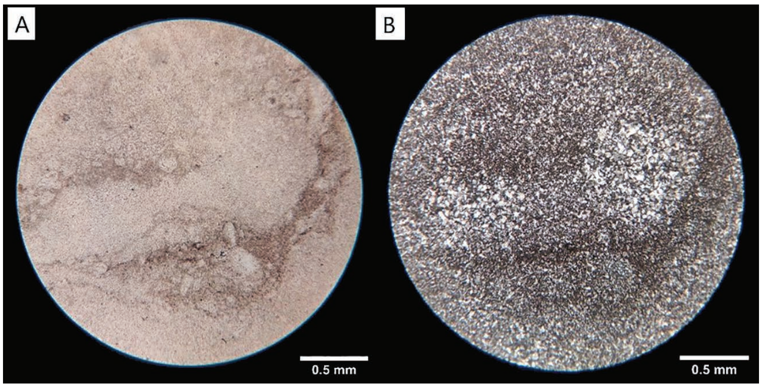

Fig. 22. Photography of Marlera sample 2. Cryptocrystalline and microcrystalline quartz in the sample. **A** ***PPL, magnification 40x,*** **B** ***XPL, magnification 40x.***

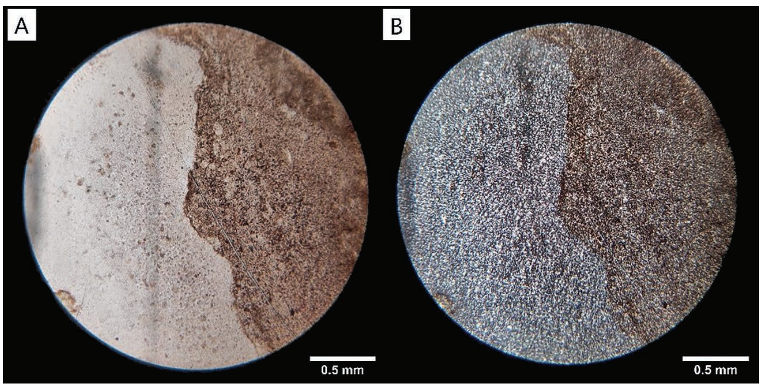

Fig. 23. Photography of Marlera sample 3. **A** ***PPL,*** **B** ***XPL. Magnification 40x.***

Flakes were also the main goal of the reduction strategy during the Early Neolithic at Vižula. Debris is represented by almost a third of all the analysed pieces, which is not surprising considering the low quality of the local raw material used extensively at the site. Blades are represented by nine pieces, all made from local chert.

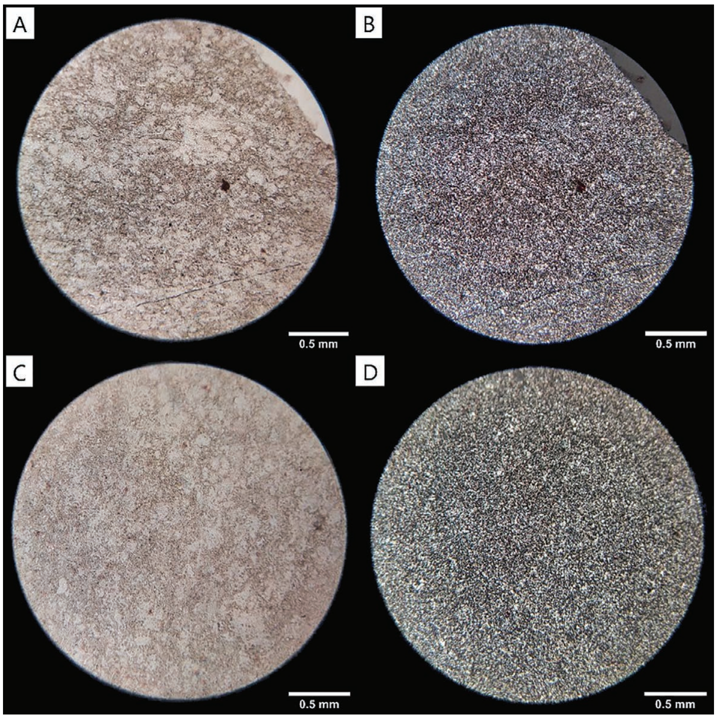

Fig. 24. Photography of Marlera samples 4 (*A *and* B*) and 5 (*C *and* D*). Relics of microfossils can be seen in the samples.* A, C *PPL,* C, D *XPL. Magnification 40x.

As was established earlier, communities at Kargadur and Vižula, as well as at Vrčevan and Vela Gromača (*Baćić 1973; Komšo 2004; Kačar 2019a*), relied heavily on local chert, with exogenous chert only gaining in popularity during the Middle Neolithic phase of Kargadur. Reliance on local chert seems to be a characteristic of the Early Neolithic in Istria (*Baćić 1973; Codacci 2002; Komšo 2004; Šprem 2022*). Nevertheless, exogenous chert was present at the Early Neolithic horizons both at Kargadur and Vižula, albeit in small numbers, which can be interpreted as these communities either being familiar with deposits of exogenous high-quality chert or a part of the already established distribution networks, and not as *"evidence of limited familiarity with the surrounding environment"* (*Andreasen 2009.57*). Istrian peninsula was located outside the Gargano distribution network, and more oriented towards Northern Italy, which our data seems to confirm. This would suggest that the Neolithisation of the Adriatic was indeed not a single, but a multilinear process (*Kačar 2021.809–810*).

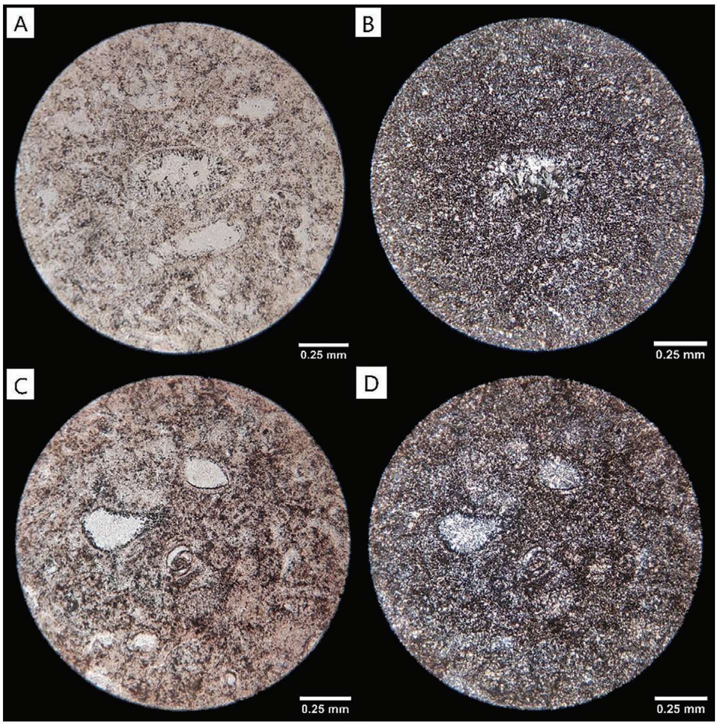

Fig. 25. Photomicrographs of samples of local chert of unknown origin. Relics of microfossils are frequently seen.* A, B *sample 1,* C, D *sample 2.* A, C *PPL,* B, D *XPL. Magnification 100x.

The site of Kargadur shows us that Middle Neolithic brought a clearer shift towards exogenous chert. This is also testified in Pupićina Cave where 'light', exogenous chert is prevalent (*Forenbaher 2006).* The Istrian peninsula gravitated towards Northern Italy with its deposits of high-quality chert. It was also outside of the Gargano distribution network, a raw material present and very popular from the earliest Neolithic on Dalmatian sites. The presence of obsidian in the Middle Neolithic layers of Kargadur coming from the Aeolian islands also give evidence to a branched network of raw material exchange.

This analysis also shows the complexities of using micropetrographic analysis for provenance studies of Istrian chert. All local chert in Istria is diagenetic, meaning it is silicified limestone, therefore the primary structure can be seen in the samples more or less clearly. However, none of them stand out at a microscopic level; the differences we see macroscopically (the colour, the zonations, the laminations) are usually also there to be seen through a microscope. We suggest we might get better results with geochemical analyses, which already showed some promise in our case (*Šprem 2022; 2023).*

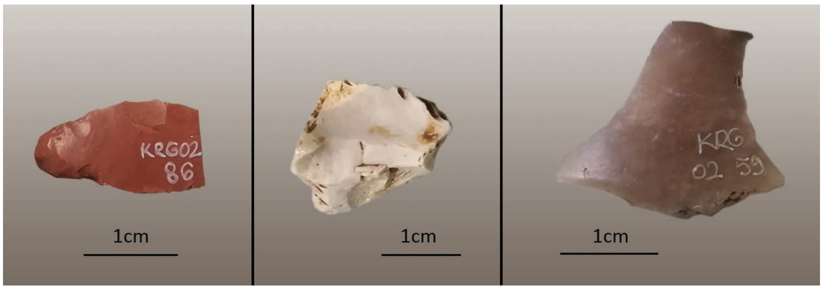

Fig. 26. Lithic finds from Kargadur made from exogenous raw material assumed to be from Monti Lessini, Italy.

We would also suggest taking all these hypotheses with caution, since our analysis was conducted on a limited number of artefacts from the sites, and not whole assemblages, which was impossible to do at the time due to the pandemic. Nevertheless, this analysis is an important step for researching the Neolithic period in the Istrian peninsula, since it deals with often overlooked set of finds which can enrich our knowledge of the period in question. After more analyses are done, we can have a better understanding of the lithic production in the Istrian Neolithic.

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Early Iron Age urbanism in the south-eastern Alpine region: a case study of the Pungrt hillfort

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ABSTRACT – *Large-scale excavation at the Iron Age and Roman period Pungrt hillfort (8th century BC to 2nd century AD) has revealed a distinctly urban character of the settlement in its best-preserved Late Hallstatt phase from the 6th to 4th centuries BC. This study provides an important contribution to the understanding of the settlement's internal organization and its socio-economic development. By examining the previously unaddressed phenomena of settlement nucleation, population aggregation and urbanism along with the possibility of early-state formation, the paper broadens the narrative on the fundamental social and political development in the south-eastern Alpine region during the Early Iron Age and contributes to the wider field of early urbanism research.*

KEY WORDS – *south-eastern Alpine region; Iron Age; Roman period; hillfort; early urbanism*

Urbanizem jugovzhodnega alpskega prostora v starejši železni dobi: študijski primer gradišča Pungrt nad Igom

IZVLEČEK – *Obsežna arheološka izkopavanja železnodobnega in rimskodobnega gradišča Pungrt (8. st. pr. n. št. do 2. st. n. št.) so v njegovi najbolj ohranjeni fazi, ki jo uvrščamo v mlajše halštatsko obdobje (6.–4. st. pr. n. št.), razkrila izrazit urbani značaj naselbine. Predstavljena raziskava pomembno prispeva ne le k poznavanju notranje organizacije naselbine, temveč tudi k razumevanju njenega družbeno-gospodarskega razvoja. Z naslavljanjem pojavov kot sta centralizacija in urbanizacija, ki sta med drugim privedla tudi do oblikovanja zgodnjih držav, ponovno odpiramo razpravo o družbenem in političnem razvoju jugovzhodnoalpskega prostora v starejši železni dobi in hkrati poskušamo prispevati k razumevanju širše slike pojava zgodnjega urbanizma.*

KLJUČNE BESEDE – *jugovzhodnoalpski prostor; železna doba; rimsko obdobje; gradišče; zgodnji urbanizem*

Introduction

European Iron Age hillforts provide information on the emergence and characteristics of Europe's earliest cities and processes of centralization, urbanization, and even early state formation (*e.g., Fernández-Götz 2015; 2018; Fernández-Götz, Krausse 2017a; Bintliff 2018*). For more than a hundred years, hillforts in Slo-

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venia have been the subject of landscape and settlement studies that revealed their central role within the prehistoric landscapes. However, the lack of sufficient data on their internal organization hindered the study of early urbanism associated with this settlement type. The recent excavations at the Pungrt hillfort – the largest excavations of any hillfort in Slovenia – have not only filled this gap but also revealed a distinctly urban character of the settlement. This groundbreaking discovery opens up the possibility of studying Iron Age urbanism in the south-eastern Alpine region of present-day Slovenia and marks a significant milestone in our understanding of its early settlement history.

To contextualize the discovery, we begin this paper with a brief historical outline of hillfort research in Slovenia, and provide an overview of the site's environmental and archaeological setting. We then present the results of excavations conducted at the site in 2020 and 2021. These are given in a chronological order, from burial activities in the 10th century BC to the building of the first rampart in the 8th century BC, through its main flourishing phase from the 6th to 4th century BC, up until its gradual decline in the mid-2nd century AD. In addition, the excavation data are complemented by the geophysical survey results of select unexcavated sections of the site.

The main aim of this paper is to examine the results of excavation and geophysical survey from the perspective of early urbanism by discussing urban attributes identified at Pungrt, which range from the site's size and estimated population density through the settlement's defence system, layout and distinct social and economic features. In doing so, we provide important insights into the Early Iron Age urbanism in the south-eastern Alpine region, and suggest that the area would have undergone the processes of centralization, urbanization and perhaps even early state formation concurrently with other regions south of the Alps, such as Etruria and Latium Vetus (*Fulminante 2014*; *Stoddart 2020*), on which the discussions of early urbanism in Europe have mainly been focused.

A brief history of hillfort and early urbanism research in Slovenia

Hillforts are, due to their monumental remains, one of the most recognizable elements of prehistoric landscapes in Slovenia. The oldest date back to the Late Neolithic and Copper Age, but most were raised in the (Late) Bronze and/or Early Iron Ages (*e.g., Teržan 1990; Dular, Tecco Hvala 2007; Dular 2021*). Although known to intellectuals and antiquarians in the preceding centuries, the first scientific research of hillforts took place in the second half of the 19th century. The researchers of the time (*e.g.*, Carlo Marchesetti) and the first professional archaeologists (*e.g.,* Josef Szombathy) studied them mainly by topographic surveys, mapping their defensive systems and occasionally digging test trenches (*Marchesetti 1903; Szombathy, Tagebuch. Büchel Krain I [Fundaktenarchiv NHMW]*). At that time, major archaeological excavations centred on prehistoric (barrow) cemeteries, which yielded rich finds for then-developing museum collections. The first large-scale excavations of hillforts took place in the first half of the 20th century under the leadership of Walter Schmid (*Schmid 1915; 1937; 1939*). However, the majority of them have not yet undergone a comprehensive study or publication (*e.g., Teržan 1990; Dular 2013*). In the years 1967–1974, Stane Gabrovec and co-workers executed a prominent and, for its time, extensive and methodologically advanced excavation at the Iron Age hillfort of Stična. Even though 22 test trenches almost exclusively targeted the remains of defence structures, the results of their campaigns and subsequent studies of the finds marked an important shift in the study of the Iron Age settlements (*Gabrovec 1994; Grahek 2016*). Trial trenching of defence systems was also the approach taken in the subsequent excavations at Libna (*Guštin 1976*), Kučar (*Dular* et al. *1995*) and Cvinger near Dolenjske Toplice (*Dular, Križ 2004*). Among these, Kučar near Podzemelj stands out with three excavated Iron Age buildings. Another fundamental study on Iron Age settlements was the result of the extensive survey project conducted across SE Slovenia by Janez Dular and co-workers. Their survey began in 1989 and was focused on examining and dating numerous hillforts and their fortifications. Although crucial for the understanding of the broader role of hillforts in the region (*Dular, Tecco Hvala 2007; Dular 2021*), the research provided scarce data on the hillfort interiors.

Hillforts have also played an important role in the theoretical and methodological development of landscape and settlement archaeology in Slovenia. While pioneering works can be traced back to the beginning of the 20th century (*e.g., Marchesetti 1903*), the site catchment and settlement hierarchy studies of Karst hillforts stand out as particularly important (*Slapšak 1995; Novaković 2003*). The rapid technological and methodological developments in recent decades have led to further shifts in the study of hillforts and their wider landscape settings. Recent advances have focused on interdisciplinary research and the use of non- as well as low-invasive methods, particularly airborne laser scanning (ALS), multi-method geophysical prospections, and geochemical mapping in combination with coring and trial trenching (*e.g.*, *Črešnar* et al. *2015; 2020; Črešnar, Vinazza 2019; Mušič* et al. *2022*).

Despite its long history, hillfort research in Slovenia has never been concerned with prehistoric urbanism. In fact, until recently an urban character has been ascribed only to Tribuna in Ljubljana. The site was located in a strategic lowland position along the Ljubljanica River and represents the lower town, which was associated with a hillfort on the Ljubljana Castle hill. Significantly, the urban character of Tribuna was recognized during a large-scale, development-led excavation covering 4200m^2, which unearthed a section of the Late Bronze and Iron Age settlement displaying an exceptionally well-organized orthogonal layout of contiguous buildings with intermediate streets, roads and squares (*Vojaković 2014a; 2014b; 2023; Novšak* et al. *2017*; for more on contiguous housing see *Smith 2014*). In addition, large-scale excavations have revealed several urban elements at the Late Bronze Age and Early Iron Age settlement in Ormož and at the Iron Age settlement at Most na Soči. However, researchers have so far been reluctant to interpret these sites an urban (*Dular, Tomanič Jevremov 2010; Dular, Tecco Hvala 2018.90–92; Tecco Hvala 2020;* for a contrasting opinion see *Teržan 1999.106–107; Zamboni* et al. *2020.17*).

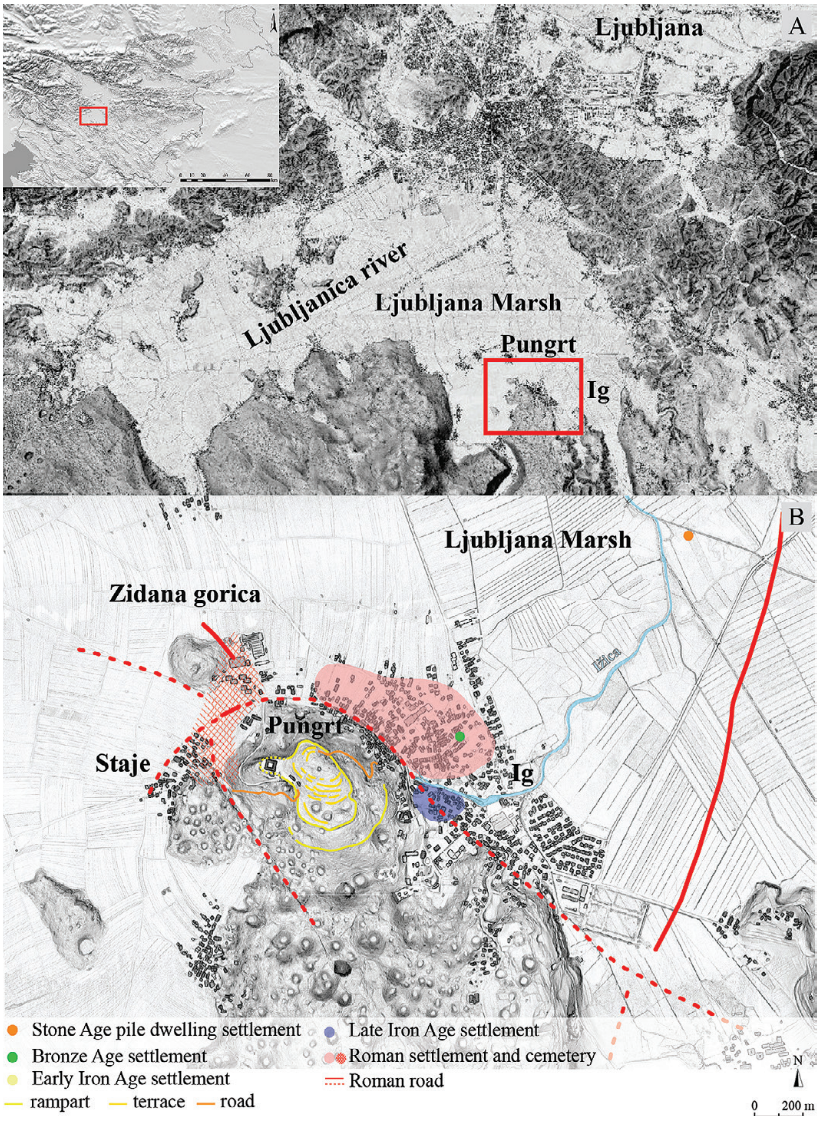

Fig. 1. Pungrt hillfort:* A *location, and* B *wider archaeological context (figure by the authors; open source base maps by the Environmental Agency of the Republic of Slovenia).

Pungrt hillfort and its archaeological setting

The hill of Pungrt (366m asl) rises above the small town of Ig some 10km south of the capital Ljubljana. Located on the southern edge of the Ljubljana Marsh, it belongs to the larger Krim-Mokrec hill range (Fig. 1.A).

The wider area of Ig is of significant archaeological and historical importance due to the numerous archaeological discoveries made here. The peatland north of Ig was inhabited during the Neolithic and Eneolithic periods, as attested by a number of pile dwelling settlements (*Velušček 2006; Leghissa 2021; Achino, Velušček 2022; Velušček* et al. *2023*). In the area of Iška Loka and Ig Bronze Age lowland settlements have been found (*Velušček 2005.73–89; Draksler 2015.417–423; Grahek 2017.101–122*). Prior to the excavations, the existence of an Early Iron Age fortified settlement on the Pungrt hill was only assumed based on topographical observations (Fig. 1.B). On the other hand, Roman literary sources suggest that in the Late Iron Age, a port for the transfer of goods existed in the marshy area at the north-eastern foot of the hill (*Šašel 1959*). As with the nearby *Nauportus* (Vrhnika) (*Horvat 1990; 2020*), the area is thought to have retained this function well into the Roman period. Information on the Roman settlement of Ig is, likewise, scarce. Unlike the tombstones from the Roman colony of *Iulia Emona* (Ljubljana), which belonged mostly to the Italian colonizers, the Roman tombstones at Ig reveal the presence of the local population without Roman citizenship (*Šašel 1959; 1975; Vuga 1980a; 1980b*). The personal names on the Ig gravestones suggest a population of 'pre-Celtic' character, which managed to preserve its distinct linguistic identity well into the Roman period (*Repanšek 2016*). The origin of these personal names can be traced back to at least the Early Iron Age – a time when the Pungrt hillfort might have played a significant role in the wider cultural landscape due to its location at the junction of three different cultural groups: the Dolenjska, Gorenjska-Ljubljana and Notranjska-Kras Hallstatt groups.

Archaeological research at the Pungrt hillfort

The topography and ALS data for the Pungrt hill reveal a fortified settlement enclosed by two ramparts (Fig. 2). The first or inner rampart can be clearly traced around he entire hilltop except for the narrow promontory where the Ženek (also Sonnegk or Sonnegg) castle was built in the 15th century (*Stopar 2003.170*). In places where the rampart is best preserved, it still reaches 3m high. The settlement seems to have had two entrances, one in the west and the other in the north-east. The inner rampart bounds an area of approximately 10ha, which is divided into several terraces. The second or outer rampart is more damaged and cannot be delineated in its entirety. It stands only up to 1m high and can be identified only in the area to the south, where it encloses an additional area of approximately 6ha, although the entire area would originally have been larger.

In 2020 and 2021, development-led rescue excavations were carried out on the south-western slope of the Pungrt hill, in the area of the first five terraces along the inner rampart. Over the course of 10 months, $8800m^2$ of the 16-ha hillfort interior were uncovered (Figs. 2, 3). The fieldwork revealed several settlement phases spanning from the beginning of the Early Iron Age (8th–7th century BC) to the Roman period (mid-2nd century AD) (Fig. 7), while individual finds indicate habitation up until the 4th century AD. Parallel to the fieldwork, rigorous and extensive geoarchaeological sampling was carried out for the purpose of integrated geoarchaeological (*i.e.* micromorphological, micro-refuse and physio-chemical sediment analyses), archaeobotanical and archaeozoological research. Notably, this is the first time that this methodology has been applied to settlement research in Slovenia. Some 200 micromorphological blocks and 1850 bulk samples were collected from the best-preserved settlement contexts, which makes this exercise comparable to some of the largest sampling programmes at prehistoric settlement sites across Europe (*e.g., Mateu* et al. *2019; Brönniman* et al. *2020; Golanova 2023; Tomé* et al. *2024*). As such, it allows for detailed high-resolution analysis of the Pungrt hillfort's long-term biography (*e.g., Milek, Roberts 2013; Wouters 2020; Prijatelj* et al. *2024*).

Excavation results and settlement history

The earliest remains at the site consisted of a burial of a 30 to 40-year-old man documented at the easternmost edge of the excavation area (Fig. 3.A and B). The deceased was laid down in a prone position within the large burial pit (4.5m×2.5 m×0.85m), with his head facing west. The grave was covered with limestone boulders (up to 50cm in size), forming a small mound

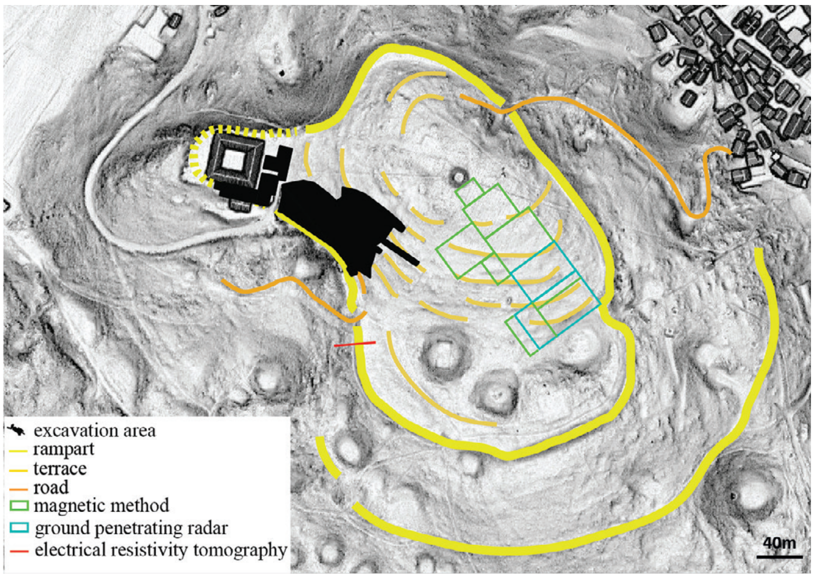

Fig. 2. Pungrt hillfort. ALS data interpretation (figure by the authors; open source base maps by the Environmental Agency of the Republic of Slovenia).

(Fig. 4.A). Radiocarbon analysis dates the burial to the 10th century BC (Fig. 7), *i.e.* the end of the Late Bronze Age period. Some individual pottery fragments found in colluvial layers and pits, mainly in the third and fourth terraces, represent other ephemeral traces of human presence from this period.

Despite the grave's earlier date, the first substantial settlement remains date to the Early Hallstatt period (8th/7th century BC), when the site was fortified for the first time. A massive stone wall, just over 2m wide, with a corresponding outer earthen embankment enclosed the settlement (Figs. 3.A and B, 5.B). The faces of the wall were constructed of large unworked limestone boulders (up to 80cm in size), and its interior filled with a mixture of stone rubble and earthen material. Behind the wall, the preservation of the settlement remains varies considerably. This is due to the different construction techniques chosen to suit the natural conditions of the site. The first terrace was the area with the deepest natural soil sequence at the site. Over time, the settlement stratigraphy rapidly built up atop of it, due to the extensive use of levelling deposits in the course of every building renovation and regular spreading of gravel material across the accumulated dirt on the road and alleys. This, in effect, led to the de-

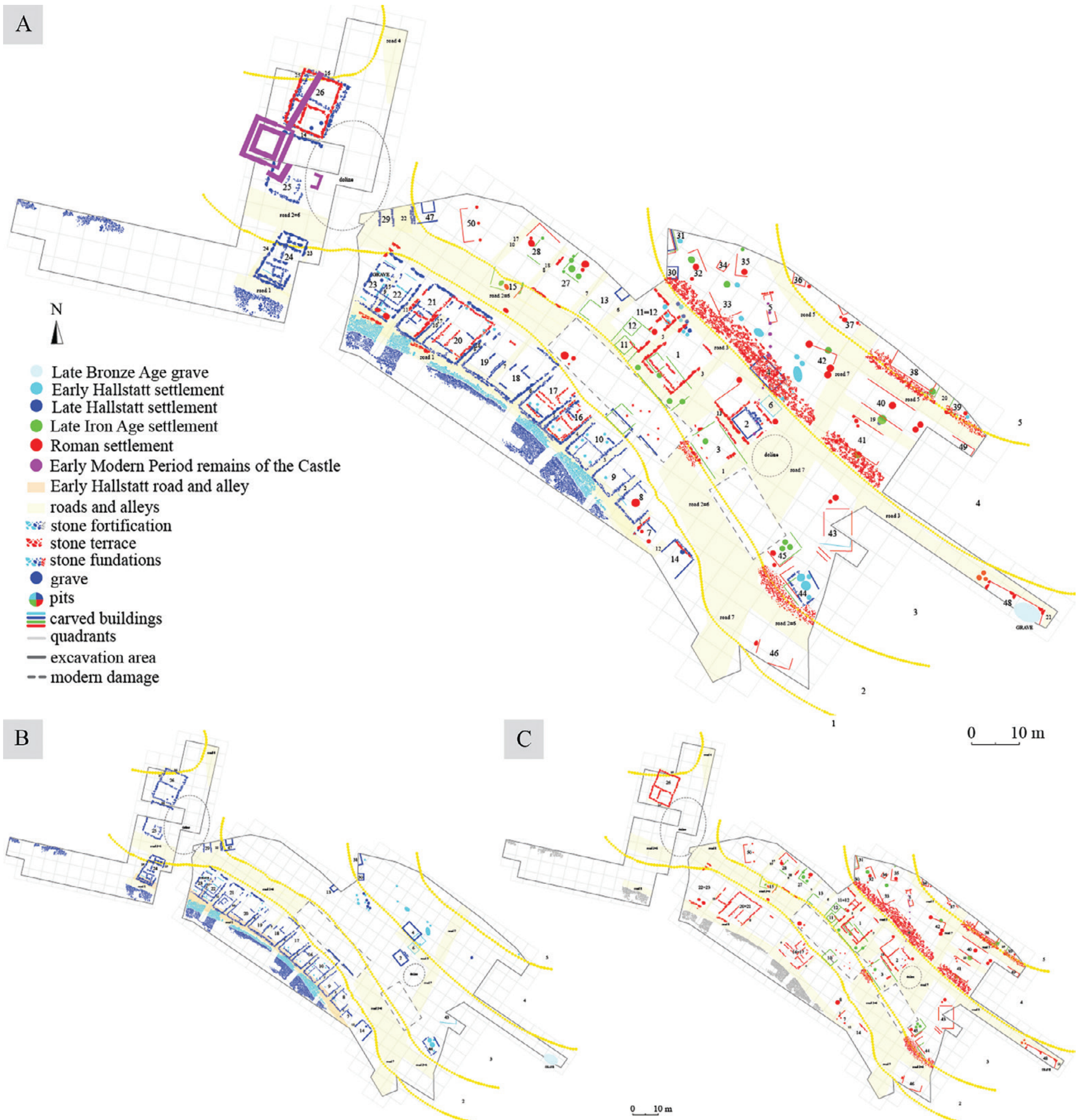

Fig. 3. Pungrt hillfort. Composite plan of the excavated area:* A *all phases;* B *Early and Late Hallstatt period;* C *Late Irona Age and Early Roman period (figures P. Vojaković).

velopment of deep and well-preserved stratigraphy on the first terrace.

In contrast, the limestone bedrock lay close to the surface or was exposed on the eastern side of the first terrace and the area of the second, third and fourth terraces. Here, the buildings and roads were built directly on the bedrock, which was partly chiselled and levelled out for this purpose. The practice of positioning of all constructions directly on the bedrock was maintained throughout the centuries, which effectively led to the preservation of almost exclusively the youngest structural remains associated with the Roman period.

Despite the well-preserved stratigraphy on the first terrace, the remains of the first building phase were scarce and poorly preserved due to reworking by later building activities (Fig. 3.A and B). As a result, the layout of the oldest settlement phase is hard to discern. Nevertheless, the ephemeral traces suggest that the buildings were concentrated on the first, second and third terraces, where they were erected with earth fast post-construction and timber-framed construction techniques. In addition, along the road running parallel to the wall, there was a series of hearths and furnaces with slag remains (Fig. 11.7), suggesting that the area of the lowermost terrace was used for metallurgical activity.

The settlement underwent several major changes at the beginning of the Late Hallstatt period (early 6th century BC). These were mainly reflected in the layout of the first terrace (Figs. 3.B), where a new, even more imposing stone rampart was built atop the old one. It was almost 3m wide and offset 1m outwards (Fig. 5.A and B) with corresponding outer embankments. In contrast to the old rampart, the faces of the wall were made of small carved limestone blocks (up to 40cm in size), while the interior was again filled with stone rubble and earthen material. Post holes for vertical beams discovered under the wall suggest a timbered rampart (*Ralston 2006; Krausz 2019*), similar to the one dicovered in Stična (*Gabrovec 1994.144–165, Fig. 135a*) as well as a few other sites in south-eastern Slovenia *(Dular, Tecco Hvala 2007.91–97*).

The road along the wall was also moved one metre outwards so that enough space would have been provided for the newly erected buildings on the first terrace, 14 of which were uncovered during the excavation. The rectangular (approx. 6m×10m) timber-framed buildings with stone foundations were regularly spaced (Figs. 3.B, 5.A and D) along the road with their shorter ends facing it. Between them ran narrow (*c.* 1m wide) alleys perpendicular to the road (Figs. 3.B, 5.A, C and D). Each house was renovated and rebuilt several times, indicating a continuous use of the building plots and the longevity of their layout. Fragmentary preserved traces of such a regularly structured layout were also uncovered on the higher three terraces. If not inherited from the Early Hallstatt period, the road infrastructure represented by Roads 1, 2, 4 and 7 was established during the Late Hallstatt settlement restructuring.

The rebuilding of the fortification and the dense building development on the first terrace would have re-

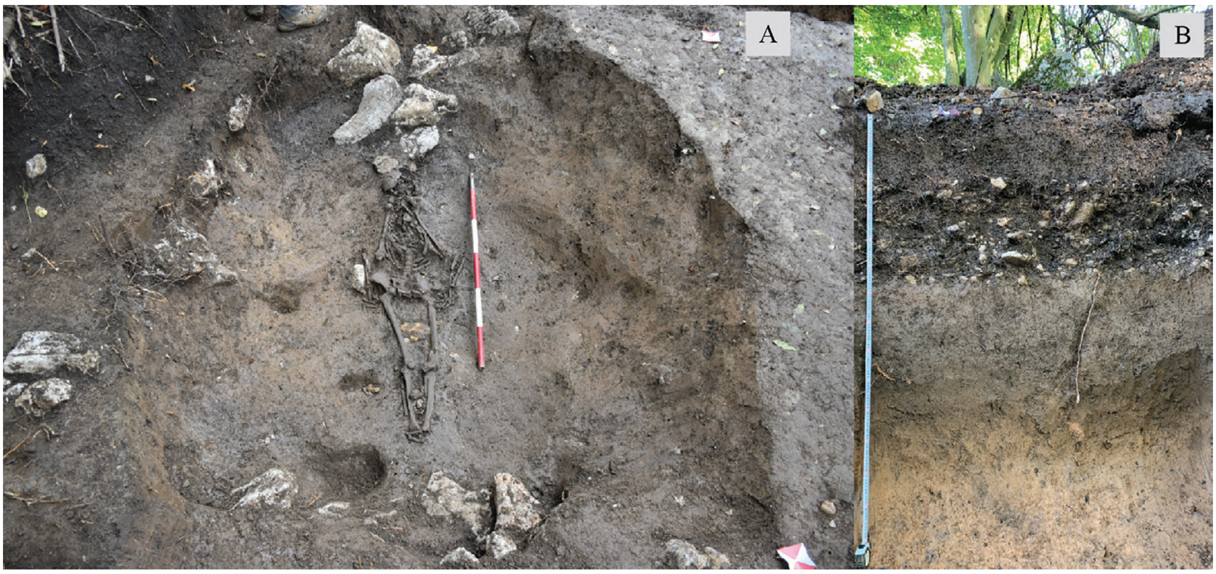

Fig. 4. Pungrt hillfort. Late Bronze Age burial:* A *skeleton grave and* B *exposed section next to the grave (photos N. Ciglar, Arhej d.o.o., and L. Gruškovnjak).

flected settlement-wide changes. These would have probably been related to the population growth and the accompanying political and social changes signifying the flourishing of the settlement. A combination of macro- and micro-finds indicates that the inhabitants of buildings on the first terrace were involved in craft activities, such as weaving, spinning, bronze casting and blacksmithing (*Vojaković* et al. *2023; Gruškovnjak* et al. *2024a*).

The organization of the settlement during the Late Iron Age remains unclear due to a combination of highly fragmentary preservation and currently unresolved problems in local typo chronology. While the regular road network was undoubtedly retained, the layout of contemporary buildings remains challenging to ascertain. According to the current typo-chronology, none of the buildings on the first terrace seem to continue into the Late Iron Age. However, given that a series of radiocarbon dates suggest the settlement continuity (Fig. 7), it is more likely that we are currently unable to differentiate between the Late Hallstatt and Late Iron Age pottery production at least up until the 2nd century BC.

Even at this stage, it is apparent that some changes in the settlement layout and building typology did occur during the Late Iron Age. These changes are reflected in a new architectural feature, identified as large rectangular cuts (around 3m×3m or smaller and 0.15–0.5m deep) into the limestone bedrock. These are presumed to be cellars, which represent a new type of distinct storage facility below the larger ground floor of buildings to which they belonged (also known as *Casa dei dolii*, see *Zupančič, Vinazza 2015.696, Fig. 5*). Still, understanding these and related changes is difficult because only the parts cut into the bedrock were preserved, while any structures above or any contemporary buildings without cellars were absent from the archaeological record. The cellars appear to be randomly scattered across the third and fourth terraces (Figs. 3.C, 6.C), which might indicate that the regular building layout was no longer maintained at the time. The changes reflected in this new type of architecture began in the transition between the Early and Late Iron Age, as demonstrated by the cellar in Building 31 dated to the end of the Late Hallstatt period. Material typical of the 2nd and 1st centuries BC was found in most of the cellar fills, suggesting that this architectural feature

Fig. 5. Pungrt hillfort. First terrace and its arrangement:* A *position of Late Hallstatt rampart, parallel road, rectangular buildings and alleys between them;* B *cross-section through the Early and Late Hallstatt ramparts;* C *Late Hallstatt buildings perpendicular to the road;* D *floor plan of Late Hallstatt building 24 (photos B. Plohl and N. Ciglar, Arhej d.o.o.).

continued to be used until the Roman occupation of the area in the mid-1st century BC (*Horvat 1999.219*).

Further changes in the settlement layout were recorded for the Early Roman period (Figs. 3.C, 6). At this time, all the terraces were reworked to a degree, evidenced by the newly constructed retaining stone walls and associated levelling deposits. The buildings were constructed in the same way as those in the Late Hallstatt period, while their layout, dimensions, internal partitioning somewhat changed. Larger buildings had several rooms. In the vicinity of the buildings were large pits, some of which were interpreted as water reservoirs carved into the bedrock. It is also quite possible that the Late Hallstatt rampart was still in use. During the Roman period, the Iron Age road infrastructure was preserved to a large degree with the addition of the newly constructed Roads 3, 5, and 8. The most significant change in the road layout is evident in the positioning of Road 3, which was laid over an area where no other remains were documented except for the 10th century BC grave, above which a building was erected.

Geophysical surveys results

In order to understand the internal organization and the defensive structure of the entire hillfort, we employed an integrated suite of prospection and detection methods. In view of the expected variety of prehistoric settlement remains with a wide range of magnetic susceptibility values, magnetometry was the preferred geophysical method. The magnetic survey was carried out in the unexcavated eastern part of the hillfort over an area of 10 200m^2 with parallel transects spaced 0.5m apart, using a Geometrics G-858 magnetometer in gradient mode. The apparent magnetic susceptibility was measured at the present-day surface and, as expected, there was a strong contrast in the magnetic susceptibility of limestone (0.1–0.2x10^{-3} SI) and topsoil (0.6–1.2x10^{-3}SI). The difference in magnetic susceptibility predicted a good contrast in magne-

Fig. 6. Pungrt hillfort. Upper terraces and their arrangement:* A *crossroads of the road, the upper fortified stone terrace and the remains of buildings cut into the rock;* B *the new Roman road;* C *building and infrastructure layout on the third terrace (photos B. Plohl and N. Ciglar, Arhej d.o.o.).

tic anomalies between the drystone walls and surrounding soil, which was confirmed by the results of the magnetic measurements.

Based on the results of the magnetic survey, we can relatively clearly identify the otherwise poorly preserved dry-stone wall remains of Late Hallstatt buildings in a row, which have similar ground plan shapes and dimensions to those found during archaeological excavations (Figs. 3, 8). The results also clearly show linear magnetic anomalies along the folds of the terraces, which is probably due to the reinforcement of the terrace edges with retaining walls. In addition, areas of relatively strong magnetic anomalies due to larger depressions in the limestone filled with soil variations and/or burned clay with high magnetic susceptibility (and therefore very different from the immediate surroundings) are clearly recognizable from the magnetic survey results in several places. There are also relatively many strong, 'punctual' magnetic anomalies that can be attributed to iron objects. These cannot be clearly defined as the magnetic effect of archaeological objects, as they may also be smaller pieces of modern iron than are usually found on cultivated surfaces.

On a smaller scale of the same eastern part of the hillfort (an area of approximately 4300m^2), ground-penetrating radar (GPR) measurements were carried out with the GSSI SIR3000, 400MHz antenna. The results, together with the previously positive archaeological results of the magnetic method, indicate building remains in a row, similar to those found during the archaeological excavations (Figs. 3, 8, 9). With the help of georadar measurements, we independently verified the findings based on magnetic measurements and supplemented them with precise data on the depth range in which the dry stone remains of the Late Hallstatt buildings are located. Similar to the magnetic measurements, the georadar measurements also revealed stronger anomalies due to consolidation at the edges or folding terraces (Figs. 8, 9).

Compared to other geophysical techniques (*e.g.*, magnetometry, GPR), electrical resistivity tomography (ERT) offers slightly more flexibility in performing measurements and is the best choice for mapping defence structures such as ramparts with walls and ditches (*e.g., Horn* et al. *2018; 2019; Črešnar* et al. *2020; Horn 2024*). For this reason, we measured the 2D profile ERT-1 over the rampart on the west side of Pungrt (Fig. 10.A and B) using a dipole-dipole electrode array with a spacing of 0.8m, which gave us a vertical and horizontal resolution of about 0.4m in the shallower part of the ERT model (Fig. 10.C). The remains of the defensive wall appear to be present in depression D3, where we can observe a high resistivity anomaly with a thickness of up to ~1m and a width of ~2m above the low resistivity sediments (which may as well contain archaeological material). Further ruins of the defensive circuit may also be present to the west of the wall in the form of a high resistivity anomaly (dimensions ~0.7m×1m) covering the possible small ditch as an extension of D3 to the west. Another low resistivity anomaly, which could represent the ditch, is marked D2 and located about 7m to the west of the rampart. It is ~1.5m deep and probably ~1.5m wide, perhaps even wider, as it may be partially covered by gravitationally redeposited weathered limestone on its eastern side. Towards the east of the rampart (between 24m and 30m of the profile distance) we can recognize anomalies with high resistivity that lie directly on (partially weathered) limestone bedrock. It is not clear

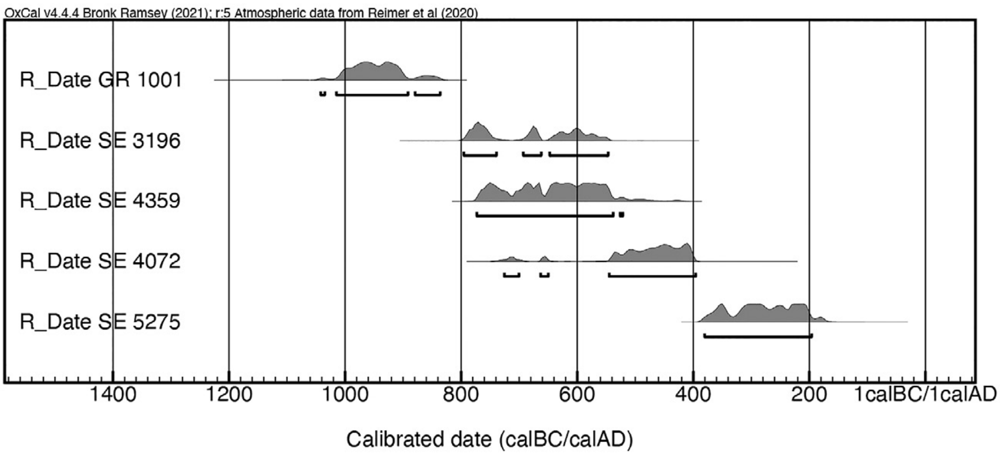

Fig. 7. Pungrt hillfort. Cumulative diagram of selected Late Bronze Age and Iron Age radiocarbon dates (figure T. Leskovar).

whether they are related to archaeological stone remains or to the shape of the bedrock, which could also be anthropogenically reshaped. Depression D4 is up to 1.7m deep and may contain a higher amount of archaeological remains (including stone).

Geophysical surveys revealed the regular pattern of similarly sized rectangular buildings arranged side by side on further consolidated terraces in the eastern part of the unexcavated hillfort (10 200m^2). The regular grid provides evidence of a carefully planned and densely populated hillfort. The surveys also confirmed that the preservation and depth of the remains diminish towards the top and that a possible defensive ditch lies at the foot of the embankment.

The nature of urbanism at the Pungrt hillfort

Hillforts in Slovenia have long been examined in the wider context of landscape and settlement studies, which have revealed their central role in prehistoric landscapes. Until recently, however, there was little or no data on their internal organization. The development-led excavation and ongoing research at the Pun-

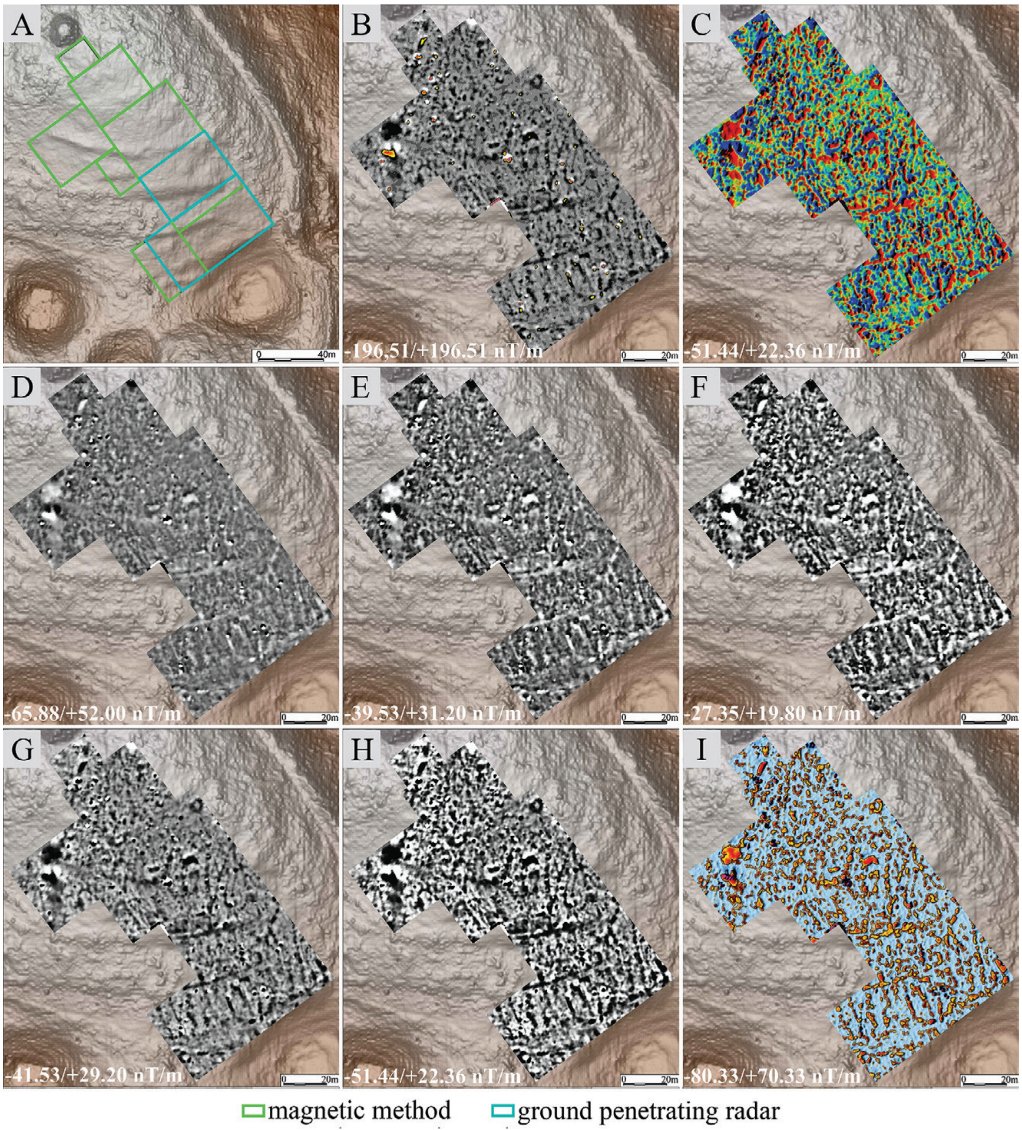

Fig. 8. Pungrt hillfort. Position of the area surveyed by magnetometry on the eastern slope of Pungrt settlement with terraces (A). Results on magnetic prospection applying a Geometrics G-858 total field magnetometer in gradient mode. Gradient data after applying Gaussian filter and grey scale and colour scale display using a linear distribution (B, D, E, G and I) and Histogram equalization (C, F and H). On the most south-eastern part of surveyed area are several nearly parallel lines indicating the remains of prehistoric houses. The clearly discernible area also shows terrace walls, areas with relatively stronger anomalies of supposed thermoremanent magnetization of burnt clay and several small, almost circular, very strong anomalies because of small iron objects (figures B. Mušič).

grt hillfort have been the first to reveal a settlement layout that, on the one hand, appears distinctly urban for its temporal and geographic context and, on the other, is comparable to other contemporary urban settlements in temperate central Europe. The discovery is highly significant for two reasons. First, because of the importance of the phenomenon of early urbanism itself, the process of urbanization acts as one of the great turning points of human societies across history, leading to social and material complexity, which are at the core of today's civilizations (*Raja, Sindbæk 2020*). In the context of temperate Europe, the emergence of urban settlements in the Early Iron Age signifies the rise of the first cities related to the processes of centralization and even early state formation (*Fernández-Götz 2015; 2017; 2018; Bintliff 2017; Fernández-Götz, Krausse 2017a*). Second, the urban character of Pungrt is important given that much of the discussion on the early prehistoric urbanism in Europe has centred on the area south of the central Alps (Italy) (*e.g., Fulminante 2014; Stoddart 2017; Pearce 2020; Zamboni 2021*) and on the area north of the Alps (France, Germany and Czech Republic) (*e.g., Fernández-Götz, Krausse 2013; 2017a; Fernández-Götz 2015; 2018*). Meanwhile, the south-eastern alpine region of present-day Slovenia has so far been absent from the ongoing discourse.

Past urbanism is notoriously hard to define. At the same time, it is also challenging to analyse because of

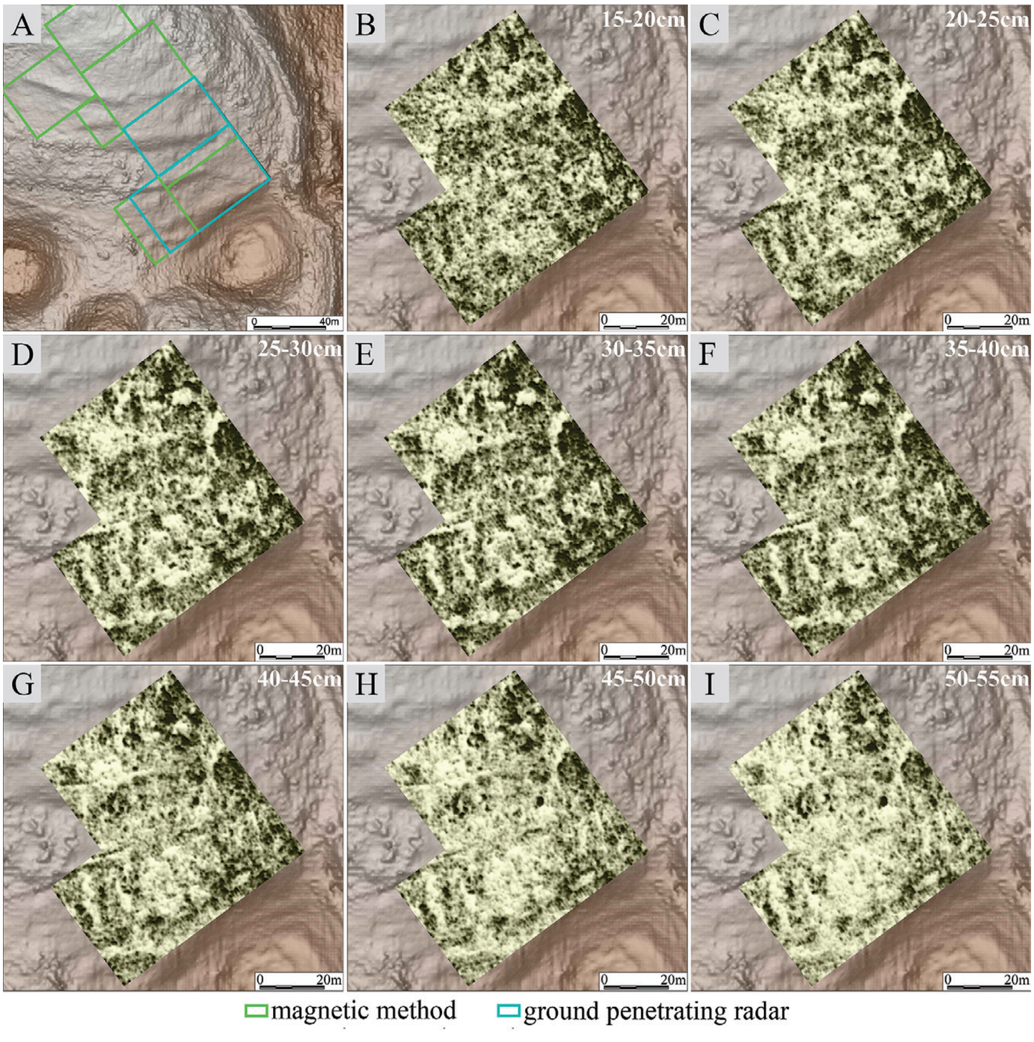

Fig. 9. Pungrt hillfort. Position of the area surveyed by the georadar method on the most southern part of eastern slope with terraces (A). Diagram of time slices, with equal amplitudes of the reflections in the same time range of the return waves (B-I). Similar to the results of the magnetic method, the results of the georadar method also show relatively clear parallel lines of stronger anomalies, which represent relatively stronger reflections at the locations of the dry stone remains of prehistoric houses. They are best visible at a depth interval of 20–45cm (C-G), which represents the prehistoric archaeological layer with dry-stone remains (figures B. Mušič).

its complexity. No single best definition of urbanism exists, and its expressions vary considerably within and between past urban traditions (*Stoddart 1999; Smith 2017; 2020; Fletcher 2020*). Traditionally, the debate on early urbanism in temperate Europe was limited by definitions based on classical urban traditions. Such approaches, however, hindered the exploration of significant societal developments across Europe at the turn of the 2nd and 1st millennia BC, which did not fit the classical criteria (see *Collis 2017; Pearce 2020; 2023; Zomboni 2021*). In the last decade, the work of various researchers has, nevertheless, significantly changed this perspective (*e.g., Fernández-Götz, Krausse 2017b; Gyucha 2019; Zamboni* et al. *2020*), demonstrating that exploring early urbanism demands a flexible and context-dependent approach that enables us to view and understand the complexity of the studied societies in a new light.

Adopting such a flexible approach, we address here the nature of early urbanism at the Pungrt hillfort and its implications for understanding the local Early Iron Age societies by examining the characteristics of the hillfort's best-preserved Late Hallstatt phase. Our discussion is based on two different sets of urban attributes that lend themselves to exploring the Early Iron Age cities. The first is the list of twelve attributes (Tab. 1) proposed by Carolyn Heighway (*1972.8–9*) for studying medieval settlements and determining their town status. Like pre-Roman settlements in temperate Europe, medieval towns do not fit the classical criteria for urbanism and, in fact, show more similarities with their prehistoric predecessors (*Danielsova, Mařík 2012; Pearce 2020.20–21*). Notably, settlements with three or four of the listed attributes are usually considered towns within the medieval contexts (*Pearce 2020.21*). The second is a provisional list of attributes proposed by Michael E. Smith (*2016*) designed specifically for exploring the nature of early urbanism and worldwide comparative urbanism studies (Tab. 2). The list has already been applied to the Early Iron Age hillfort at Heuneburg, Germany (*Smith 2016.Tab. 10.3*), whose urban characteristics have already been explored in great detail (*e.g., Fernández-Götz, Krausse 2013; Nakoinz 2017*). Considering its great wealth of data, Heuneburg provides an impor-

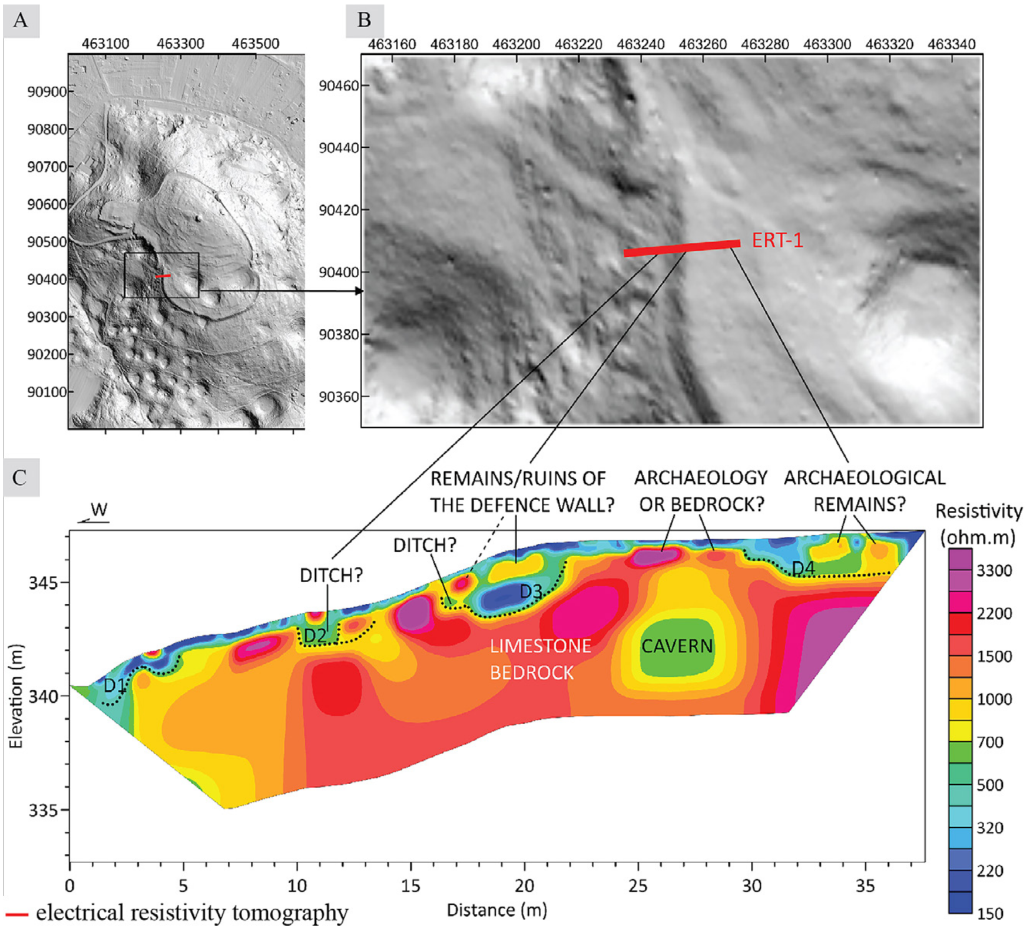

Fig. 10. Pungrt hillfort. **A, B** ***the position of the ERT-1 profile on a Lidar map;*** **C** ***interpreted inverse resistivity model of the profile ERT-1 (figures B. Horn).***

tant point of reference in the present discussion on the urban attributes of the Pungrt hillfort, including its settlement size, population density and structuring of settlement space, as well as a number of its social and political aspects (Tabs. 1 and 2).

Settlement and population size

The size of the Pungrt settlement can currently only be estimated based on the area enclosed by its fortification system, which consists of the inner rampart built in the 8th/7th century BC and the outer one of unknown date. The former encloses an area of about 10ha, while the latter encloses an additional area of at least about 6ha, with the overall hillfort size totalling at least 16ha. The estimation is considered provisional, as the full extent of the outer rampart, its dating and the presence of an extramural settlement remain unknown. Based on the available data, the estimated size of 10ha places the Pungrt hillfort among the largest hillfort settlements in Slovenia (*e.g., Dular, Tecco Hvala 2007.Fig. 88*).

There are many approaches to estimating population size and density in archaeology, all of them with distinct strengths and weaknesses (*Hanson, Ortman 2017.302; Schumann 2019.173*). To calculate the population size and density at the Pungrt hillfort, we employed the data on the number of buildings in the best preserved Late Hallstatt phase (24 buildings) within the excavated area (8800m^2) with the assumption that a household consists of five people on average, which is a well-established estimate based on studying ancient demographics (*Hanson, Ortman 2017.306,308; Bintliff 2019.190; Schumann 2019.176*). However, to make the calculations comparable with those at Heuneburg, we also included an estimate of seven persons per household, which was employed in calculating its population size. These figures have been extrapolated to the 10ha surrounded by the contemporary inner rampart, within which the area so far covered by the geophysical survey displays the same form of built environment. The area between the inner and the outer walls has been excluded from these calculations because its characteristics and the date of the outer wall are currently unknown.

In this way, we can estimate the population density to have been within the range of *c.* 136–191 persons per hectare, with the total population reaching *c.* 1364–1909 people. These estimates are only approximations, however, without consideration of temporal variations in settlement size and spatial variations in building density and function (*e.g., Bintliff 2019.191; Schumann 2019.196*), as these remain unknown at present. In fact, because only the preserved building remains are included in the calculation, it unrealistically assumes the second and third terraces were mainly empty, probably underestimating the population size at the time and overestimating the empty space within the settlement. Nevertheless, the two numbers can still serve as useful reference points for wider comparisons (see *Smith 2023.60–64*). For example, the estimated population density at Pungrt is well within the range of Greek city-states (*Hansen 2000a.155–156,172; Morris 2003.33–34; Bintliff 2019.191*), ancient cities in general (*Hanson, Ortman 2017.304*) and European medieval towns (*Pearce 2023.101*). In addition, this is within the range where most settlements can stably exist for a long period of time (*Fletcher 2020.41*).

Compared to Heuneburg, the settlement size at Pungrt is drastically smaller, while its population density is notably higher (Tab. 1). This is primarily related to the state of research at both sites. For a long time the extent of the Heuneburg settlement was, similarly to Pungrt and hillforts in general, judged on the extent of its fortification enclosing a small area of 3ha. It was only after the discovery of the lower city and the extramural settlement covering around 100ha that its actual extent was realized (*e.g., Krausse* et al. *2019; Schumann 2019*). This clearly dictates caution in estimating and comparing hillfort settlement sizes, and demonstrates the need for research beyond their fortified boundaries. Nevertheless, the dimensions of the Pungrt hil-

		Pungrt
1	Urban defences	X
2	A deliberately planned street lay-out	X
3	Presence of a market	?
4	Presence of a mint	?
5	Legal recognition	?
6	Central position in a network of communications	X
7	High density and size of population compared with surrounding places	X
8	Concentration of crafts and evidence of long-distance trade	X
9	Houses of urban rather than rural in form	X
10	Wide range of social classes	?
11	Complex religious organisation	?
12	Judicial centre	?

Tab. 1. Pungrt hillfort. Table of archaeological urban attributes after Heighway (1972). Note: ? absence of data.

Attributes	Type of variable	Pungrt	Heuneburg (*Smith 2016*)
Settlement Size			
population	M	1364-1909	5000
area (ha)	M	10	100
density (person/ha)	M	136-191	50
Built Environment			
fortifications	P/A	X	X
gates	P/A	?	X
connective infrastructure	P/A	X	X
intermediate-order temples	P/A	?	?
residences, lower elite	P/A	?	X
formal public space	P/A	X	?
planning of epicenter	P/A	?	X
Social Impact (urban functions)			
royal palace	P/A	?	?
royal or high aristocratic burials	P/A	?	X
large (high-order) temples	P/A	?	?
civic architecture	S	?	1
craft production	S	2	2
market or shops	S	?	?
Social & Economic Features			
burials, lower elite	P/A	?	X
social diversity (nonclass)	P/A	X	X
neighborhoods	P/A	X	X
agriculture within settlement	P/A	?	X
imports	S	1	2

Tab. 2. Pungrt hillfort. Table of archaeological urban attributes compared with those at Heuneburg (after **Smith 2016*****). Notes: type of variable:*** **M** ***quantitative measurment;*** **P/A** ***presence/absence;*** **S** ***measurment scale (1 low; 2 moderate; 3 high);*** **?** ***absence of data.***

lfort enclosure alone clearly highlight the highly significant role the settlement had in its local setting.

The comparison of population densities at Pungrt and Heuneburg needs to take into account two factors. The much lower density at Heuneburg is due to the relatively low density of *c.* 35 people per hectare within the extramural settlement, while the density within the fortified enclosure could be estimated at 3333 (*Krausse* et al. *2019*) or 1666–3333 people per hectare (*Schumann 2019*). Both sites thus display a similarly compact settlement with similarly high population density within the fortified enclosure, which clearly sets them apart from contemporary rural villages and is, therefore, a very clear qualitative indication of urbanization (*cf. Nakoinz 2017.90*). Crucially, because there is a relationship between population size and social complexity, the estimates provided represent a proxy for social organization. Namely, they demonstrate an aglomeration of people which fundamentally influences social and economic structures and goes far beyond the threshold at which corporate communities such as, for example, Greek city-states start to emerge (*Carneiro 1987; Bintllliff 2000; 2019; Morris 2003.42–43; Nakoinz 2017; Rassmann 2019*).

However, an important difference between the two sites can be observed in the duration of their distinctly urban phase. At Heuneburg, the latter is limited mainly to the period of the mudbrick wall (*c.* 600/ 590–540/ 530 BC) that lasted for some 50 years and met a violent end followed by a significant population drop (*Kurz 2006; Arnold 2010; Fernández-Götz, Krausse 2013; Nakoinz 2017; Krausse* et al. *2019*). At Pungrt, the clearly urban settlement flourished between the 6th and 4th centuries BC, after which its trajectory becomes unclear due to uncertainties in regional chrono-typology and fragmentary survival of subsequent settlement remains. Nevertheless, the distinctly urban period seems to have lasted at least three centuries without any evidence of social upheaval, which has important implications for the development of social and political structures at the site. More specifically, a growing population in an urbanizing town would have required changes in organizational structures that would have allowed for the stability of such an agglomeration (*Bintliff 2000; 2017; 2019; Nakoinz 2017*). A quick and sudden end of the urbanizing phase at Heuneburg indicates that the social system was not able to keep up with rapid population growth (*Nakoinz 2017*). At Pungrt, on the other hand, adaptations seem to have been more successful, allowing for a much longer period of urban development. However, the way the social system adapted remains unknown even though a type of clan politics seems the most likely (*Terrenato 2011; Bintliff 2017; 2019; Stoddart 2020.114*) and would fit well with some interpretations of contemporary funerary evidence (*e.g., Teržan 2008; 2010*).

Fortification

In addition to the settlement and population size, the presence of a fortification is often considered an essential attribute of a city, which distinguishes it from its rural surroundings. Even though the validity of such traditional assumptions has rightfully been questioned (*Reymann 2020*), the functional, symbolic and ritual importance of an Iron Age hillfort's fortification cannot be denied. Archaeologically, this is often expressed by various structured ritual deposits related to the physical boundaries of the settlement, with ritual offerings providing a means of taking possession of a certain space and strengthening the identity of the local community (*Smith 2007.36; von Nicolai 2020*). For example, in the Roman tradition the city boundary was delineated with great ceremony, and fortifying it was an essential process in the city's foundation. Its interior represented not only a residential but also a religious space, which would have played a vital role in the process of early city-state formation (*Terrenato 2011.241–242; Fulminante 2021.22; Rüpke 2021*). Similarly, a walled city was also an essential part of the concept of the Greek *polis* and demarcated the *polis* (in the sense of town) from its *chora* (in the sense of hinterland) (*Hansen 2000a.160,162*).

In this light, interpreting monumental fortifications as manifestations of social and cultural transformations becomes even more tangible (*e.g., Arnold 2010*). The act of construction itself is highly significant as it reflects an important aspect of political dynamics within ancient societies and requires an extensive amount of labour along with labour organization (*Smith 2007.36; Reymann 2020.11*). At Heuneburg, for example, the construction of the mudbrick wall on a stone foundation enclosing an area of 3ha is estimated to have required two work seasons and a formidable workforce of over 400 people at peak moments (*Krausse* et al. *2019.180; cf. Arnold, Fernández-Götz 2018.149*). However, building a mudbrick wall is much cheaper and quicker compared to a stone wall (*Arnold 2010.105*). From this perspective, the construction of the inner stone wall at Pungrt in *c.* 8th/7th century BC, enclosing an area of 10ha, can be viewed as an extraordinary and symbolically charged community investment and achievement suggestive of a high degree of planning (*cf. Smith 2007.23–24*). Its renovation in the 6th century BC, resulting in an even more massive wall, would have been another highly significant event in the city's development. The same could be said for the addition of the outer wall, whose dating and construction techniques still need to be established. The delimitation of the inner and outer spheres by constructing a wall would have been especially significant in such an urbanizing city with a growing population in which the lifeworld would be becoming increasingly more internalized into itself as it reached a size (>500 people) at which it could have gained possession of almost all its resources and became an endogamous community that would begin to take on *mini-state* attributes of communal organization (*Bintliff 2000.27; 2019.191*).

Settlement layout

One of the most archaeologically apparent elements signalling the process of urbanization at the Pungrt hillfort is its combination of well-defined connective infrastructure and regularly sized building plots, which were maintained over a long period of time. They were coordinated with the layout of the city wall, roads, and terraces, which followed the terrain. The building plots shared orientation and arrangement in reference to the road network and city walls, providing strong evidence for urban planning (*Smith 2007.4,8*). The site yielded neither evidence of an integrated orthogonal plan in which buildings were aligned orthogonally with respect to one or more large-scale features, which suggests a high level of planning (*O.c.15*), nor of semi-orthogonal urban blocks, created from the practicality of building in relation to existing rectangular buildings (*O.c.14–15*). Instead, the settlement at Pungrt had a distorted orthogonal layout, which was distorted/modified due to local topography (*Grant 2001.219–220; Smith 2007.16, Fig. 12*).

The layout of the settlement is indicative of central urban planning (*Smith 2007.21*), which seems to be supported by the fact that the buildings were equal in size and that their size and position were maintained over a long period of time, as evidenced by the regular rebuilding within the same plot boundaries. We could interpret this in terms of formal planning and division of the space within the settlement, which was successfully maintained and reinforced over time. This, in turn, has implications for the social organization and structure of the settlement. The formality and longevity of the layout suggest efficient governing bodies, while the regular size of the building plots indicates that the community living in the excavated part of the settlement was not strongly differentiated. On the other hand, the presence of inner and outer walls would imply the intentional limitation of access to the inner parts of the city, which could be related to social differences (*O.c.23–25,35–37*). In fact, social practices designed to artificially flatten social differences, which were common in Iron Age Europe, could be responsible for the undifferentiated residential structures (*Thurston 2010*). Furthermore, an orthogonal layout is most often found in societies where power and wealth are concentrated by a centralizing authority, and town planning itself is even more indicative of centralization than urbanism *per se* (*Grant 2001.220–221,237; Morris 2003.49*). All these aspects of planning are highly significant for the interpretation of an early city and indicative of centralized, not necessarily autocratic, authority and perhaps of an emerging city-state. In this regard, it is important to note that even some Greek classical cities, such as Athens, were not strongly planned except for the public spaces (*Bintliff 2014. 269*).

Buildings

In past societies, the household was typically the basic and most important social and economic unit, which is therefore fundamental for studying the relationship between housing and society (*Smith 2014.208*). Following the housing typology presented by Smith (*O.c.209–216*), the Late Hallstatt buildings at Pungrt do not readily fall into any of the proposed categories, including individual houses, house groups, contiguous houses, walled compounds and apartment buildings. They stood detached in densely and formally arranged rows along the roads, with buildings separated only by the narrow alleys, therefore displaying strong spatial association with the road network and among themselves. As such, they cannot be regarded simply as individual houses, which are not spatially associated with other dwellings; instead, they are often accompanied by external features for domestic tasks, craft production and leisure, and are typical of rural settlements and low-density cities. At the same time, they also escape the definition of contiguous houses, which are formally arranged along a street, share at least two walls with adjoining buildings and are typical of densely built urban environments. However, the formal and dense configuration of the houses at Pungrt is a characteristic they share with the contiguous type. The layout of individual buildings that seem to be standardized, therefore, indicates a very dense urban environment created through deliberate planning of individual settlement zones (see *Hansen 2000a.162; Izzet 2007.151,161,171; Gailledrat 2021.358*). Such urban planning could be used as a proxy to infer the political organization of a city, as it is more common in collective regimes characterized by greater citizen participation, as opposed to autocratic regimes (*Smith 2014.218; 2023.117–121*).

The Early Iron Age buildings at Pungrt were mostly two- or three-room houses. The entrance into the buildings was presumably located on the short side facing the road (*Gruškovnjak* et al. *2024b*). In two-room houses, the interior was divided into a room in the front and another in the back, while in three-room houses, these would be joined by a third room on the side. Such an internal division indicates a desire to differentiate between internal activities and spaces. However, this probably should not be interpreted as strict functional division between the individual rooms. Due to their small number and the dynamism of the social use of space, all of them would have been multi-functional (see *Lang 2005.20,24,26,30; Izzet 2007.158–159*). In Building 24, for example, which is one of the most thoroughly analysed buildings so far, it was established that the first room was used for both craft (a blacksmith's workshop) and domestic activities, while the room in the back is presumed to be mainly domestic in nature (*Gruškovnjak* et al. *2024a*). A similar division into a more working, public multifunctional space in the front and a more private and domestic space in the back can probably be anticipated in other buildings as well.

It is also interesting to note that even though the buildings were renovated and rebuilt several times during the Early Iron Age, their size and layout remained largely unchanged. Therefore, the sociobiological cycles of marriage, reproduction, death, and the changing of generations, along with developments and changes in household activities over two to three centuries, had almost no impact on housing, which indicates its regulation by the government of the city. It is only during the Late Iron Age and the Roman period that some changes to the housing types occurred, probably indicating significant changes in social and economic structures within the settlement (see *Lang 2005.18,20,24*)

Open empty space

In urban areas, deliberately empty spaces may be encountered at many different scales, such as the household, neighbourhood and city. They can be charged with particular meanings and provide insights into corresponding levels of urban interactions (*Smith 2008*). Within the excavated area at Pungrt, the open empty space at the household level was conspicuously absent, suggesting that most activities and uses on that level, such as domestic and productive activities, storage, hosting, and keeping animals (*e.g., O.c. 220*), were confined to the buildings' interiors. The main type of open empty space currently evident within the densely built environment at Pungrt are streets and alleys, which were primarily used for transport, waste disposal, and possibly for some craft activities such as weaving. Without the waste infrastructure established at the site, streets and alleys would also have been places where human and animal faecal matter would have accumulated (see *O.c.219–220,224–225; Gruškovnjak* et al. *2024a; 2024b*).

A portion of a much larger empty space in the settlement, which would have been significant on a civic scale, has probably been uncovered at the easternmost edge of the excavation area, located in the central part of the hillfort. The most significant feature of this area is the Late Bronze Age burial. The excavation uncovered no remains dating to the Iron Age but only a Roman period building and road covering the grave and the surrounding area, which lies on a pocket of deep soil. All other such places within the excavated area were characterized by very deep and well-preserved settlement stratigraphy. Therefore, the absence of Iron Age remains in the area surrounding the grave is conspicuous. The possibility of eroded Iron Age stratigraphy can be excluded as the area is not at all steep, and the deep soil indicates a depositional or stable microtopographic location (see *Johnson 1985; Gruškovnjak 2024*). The possibility of (Late) Iron Age or Roman Period interventions in the form of removal of earlier building remains also seems unlikely, considering that at the time, the use of levelling deposits was the preferred method, and no evidence of such behaviour has been detected anywhere else within the excavated area. The most likely explanation thus seems to be that this place would have been intentionally preserved and maintained as a distinct open space in which no buildings or roads were constructed throughout the Iron Age.

Compared to the empty spaces of roads and alleys, the absence of accumulated refuse suggests a very different kind of public behaviour in this part of the settlement. We could, therefore, interpret it as a communal space which was highly significant at the civic scale. As such, it would have probably been created and maintained by the city's authorities (see *Smith 2008.223, 225,228*). Especially striking is the fact that the area remained empty for a whole millennium, from the 10th century BC to the end of the 1st century BC or the beginning of the 1st century AD, when a building and a road were constructed over it. This suggests a continuity in the way this area was used, perceived and maintained, pointing to a long-lasting social memory of its community (see *Van Dyke 2019*), and signals significant changes in the political and social setting in the Roman period.

The social memory tied to the area of the grave could perhaps have been related to some kind of a foundation myth, which would have been kept alive by recurring rituals and ceremonies. Such myths played an important role in the placement of early urban sites within the landscape and in the cohesion and legitimation of their communities. Founding hero or heroine myths, in particular, played a central role in the ideologies of 1st millennium BC communities in Europe. Furthermore, the supposed burial places of founding heroes were often located in the public spaces within the settlement and acted as foci for religious and political gatherings. This is clearly attested through written sources in the Mediterranean and there are archaeological indications of this phenomenon in temperate Europe where Iron Age sanctuaries and assembly spaces within cities are often linked to older burial monuments (*Almagro-Gorbea 2017; Fernández-Götz 2021;* see *Guidi 2014.644; 2016*).

The open empty space containing the Late Bronze Age burial within the Pungrt hillfort can be understood as yet another such indication. The presence of an older burial at the site may have played an important role in the cultural memory of people living in the area, influenced the later placing of the hillfort at this location, and taken on a role in the construction of memories of a common past, perhaps tied to a mythical founding hero, and thus served as a powerful cohesive mechanism of the community (*Fernández-Götz 2021. 8–9*). However, it is important to note that the grave cannot be interpreted simply in terms of ancestral memories tied to an older Late Bronze Age burial ground, as it is highly atypical for the time, *i.e.* the Urnfield Period, which was characterized by cremation burials (*e.g., Teržan 1999*), with very few exceptions (Obrežje and Dobova sites in Slovenia, *Stare 1975.25, gr. 97, 202,305a,354a; Mason, Kramberger 2022.gr. 81,317, 253*). Only in the Early Iron Age did inhumation burials become common in south-eastern Slovenia (Dolenjska Hallstatt group) or appear alongside cremation burials in some cemeteries in central and west Slovenia (Gorenjska-Ljubljana and Notranjska-Kras Hallstatt groups) (see *Urleb 1974; Gabrovec 1999; Dular 2003; Teržan 2021; Škvor Jernejčič* et al. *2023; Škvor Jernejčič, Vojaković 2023*). Pungrt hillfort is located on the border between all three regions or Early Iron Age cultural groups, and the 10th-century BC inhumation within the hillfort may represent an early expressions of changes occurring during the transition between the Late Bronze Age and Early Iron Age. It may even be linked to the beginnings of settlement at the site, indicated also by some sporadic Late Broze Age finds. This would push the beginning of the settlement back to an earlier date than the building of the first wall in the 8th/7th century BC and the oldest settlement remains in the excavated area suggest.

Religious functions

The burial within the settlement and related empty space, which were probably the focus of ritual and ceremonial activities, allude to the importance of religion within the emerging city. In fact, foundational myths and religion may represent important factors in the development of early cities. Religion itself plays a vital role in urbanization, which in turn leads to religious change (*Rüpke 2021.7–8; 2023*). As part of the urbanization process during the Early Iron Age, we could, for example, expect the emergence of buildings that served a cultic role for the whole community and a growing complexity of ritual activities that ultimately lead to the state-organized religious practices (see *Guidi 2014.643; Fulminante 2021.15*).

The religious sphere, however, remains largely absent from the archaeological record at Pungrt. None of the buildings have been identified as having a cultic role, and no deposits related to ceremonial activity have been identified beyond the household level. Nonetheless, the presence of cultic activities within the settlement is indirectly but clearly indicated by a single find – namely, a bronze half-round ornamented disc belonging to a stick or sceptre (Fig. 12.5). In Slovenia, such sceptres are known from rich female burials of the 6th and 5th centuries BC in the Dolenjska region (*Stare 1973; Tecco Hvala 2012.334–338*). Their form and method of manufacture were similar to those from the burial sites in Este (*Chieco Bianchi, Capuis 1985. Tab. 69:29, 85:6, 119:17, 137:51, 214:23, 249:13, 262:5, 6, 263:7, 274:11, 295:205; Capuis, Chieco Bianchi 2006.Tab. 51:47, 54:29,30, 65:38,39, 97:22, 148:21, 180:26,27*) and Padua (*Gambacurta 2005.354, Fig. 13:54*) in Italy. Female burials with sceptres are typically interpreted as those of priestesses. The sceptre as a sign of the priest was already mentioned by Homer and is also indicated in several finds and representations on Pontic and Etruscan vessels (*Stare 1973. 731*). The discovery of an artefact related to a priestly function thus indicates the presence of such religious offices at the Pungrt hillfort, even though buildings or areas intended for religious ceremonies within the settlement still need to be identified.

Social hierarchy

The association of the sceptre with elite female burials also indirectly alludes to the presence of social hierarchy within the city, which otherwise remains mainly invisible within the excavated area. However, Early Iron Age funerary practices clearly indicate the presence of social differentiation within contemporary communities, even though they are expressed somewhat differently in each cultural group. It is most pronounced in the Dolenjska and Štajerska Hallstatt groups, expressed, for example, through the quantity and luxury of grave goods in Dolenjska (*Dular 2003; Gabrovec, Teržan 2008/2010; Tecco Hvala 2012; Križ 2019*) and through the funerary architecture of burial mounds in Štajerska (*Teržan 1990; Teržan, Črešnar 2021*). In the Gorenjska-Ljubljana, Notranjska-Kras and St Lucia Hallstatt groups, where significant elements of Late Bronze Age funerary traditions were preserved, social differentiation is less pronounced but nonetheless present (*Urleb 1974; Guštin 1979; Teržan* et al. *1984–1985; Škvor Jernejčič 2017; 2018; Škvor Jernejčič, Vojaković 2021; 2023; Škvor Jernejčič* et al. *2023*).

Although there are reasons for caution in interpreting the presence of elites from funerary assemblages (*Nakoinz 2017; Schumann 2019*) and the burial grounds of Pungrt hillfort's inhabitants still need to be discovered, the chronological and regional context suggest that distinct social stratification can be expected within its community. After all, social stratification often plays an important role as an agent of urbanism (*Fulminante 2021.10*) and is probably indicated in the settlement's significant reorganization in the 6th century BC. Similar reorganizations have, for example, been documented at Heuneburg and various Etruscan towns. There, they were interpreted as the result of a planned political decision or as adaptations to new social needs and requirements for effective use of internal space within the emerging urban environment (*Fernández-Götz 2015.13; Stoddart 2017.309*). A governing urban elite would have sponsored the investment of resources into community features and constructions (*Smith 2007.5,30*), such as the planning, building and upkeep of the settlement's defensive system, road infrastructure and individual neighbourhoods like the potential craftsmen's quarters in the excavated area. Buildings belonging to the upper social class (*e.g., Fernández-Götz 2015.18–19*) may therefore be expected within the settlement and/or in the surrounding countryside (*e.g., Thurston 2010.225*), but are yet to be discovered. After all, it is the elite who would have been the main driver in the process of centralization, urbanization and early state formation during the Iron Age (*Terrenato 2011; Bintliff 2017; Fernández-Götz, Krausse 2017a*).

Craft and trade

Although not directly visible, the elites would have made use of craftsmen and traders, and thus been the driving force in craft specialization and long-distance trade, which are often considered as some of the main attributes in defining urban centres (*e.g., Fernández-Götz 2015.15; Fulminante 2021.11–12; Gailedrat 2021. 361–363; Zamboni 2021*). Indeed, in the current state of research it is the craftsmen who are the most visible social class at Pungrt hillfort. In fact, the first terrace within the excavated area appears to be a craft quarter, as suggested by numerous discoveries of craft-related artefacts, such as moulds (Fig. 11.6), melting pots (Fig. 11.4), bronze semi-finished products (Fig. 11.8), tuyeres (Fig. 11.1), spindle whorls, loom weights (Fig. 11.2), and bobbins (Fig. 11.3). The integrated micro-archaeological research has revealed a blacksmith's workshop in Building 24, which further confirms our hypothesis (*Gruškovnjak* et al. *2024a*). The presence of a craft-workers' quarter would simultaneously indicate the presence of different neighbourhoods in the settlement, which is another distinctly urban characteristic (*Smith 2010*).

Finds evidencing long-distance trade or the exchange of goods indicate the presence of traders operating within the city. Contacts with the Baltic region are suggested by the presence of amber beads (Fig. 12.4; *e.g., Tecco Hvala 2012.280–287*), while links with the Aegean or south Adriatic region are indicated by an Eastern amphora (Fig. 12.3; *Whitbread 1995*). Matt-painted pottery with ornaments typical of the Subgeometric Ofanto IIa or Daunia II period (550/525–475/450 BC) points to contacts with Southern Italy (Fig. 12.1; *De Juliis 1977*), while black and red coated ware (*i.e.* Este type *situlae* or *pithoi*) suggests trade with Northern Italy (Venetian area of Padua and Este) (Fig. 12.2; *Tecco Hvala 2014.329–336*).

Amphora-shaped glass beads are related to networks which may go as far as the Black Sea region. They were produced in workshops in the Mediterranean or Black Sea region between the end of the 5th century and the beginning of the 3rd century BC. The beads are usually made of translucent glass paste, but the examples from Pungrt (Fig. 12.6), which are made of cobalt blue or turquoise glass paste, belong to a rare variety occasionally found both in the areas close to the Mediterranean workshops (*e.g.*, Slovenia) and in more distant places (*e.g.*, Slovakia or Moravia). They are usually discovered in women's and children's graves and interpreted as cultural goods (based on diplomatic agreements between the leaders of different communities, gift or/and hostage exchanges, matrimonial alliances) (*Rustoiu 2015.365,370*).

The discovery of graphite schist, which would have been imported from the area of Tisa-Dacia or the EasternAlps, is yet another indication of Pungrt's involvement in long-distance trade networks (*Gruškovnjak* et al. *2024a*). Trade is also indirectly indicated by the discovery of ingots, several of them belonging to shaft-hole axes (Fig. 11.5). Their manufacture and use can be dated between the 10th and 8th centuries BC (*Teržan 2008(2010).297–298*), but their circulation as pre-monetary currency and their storage in hoards continued as late as the 5th century BC (*Pavlin, Turk 2014.48–49; Svoljšak, Dular 2016.Tab. 40:9; Laharnar 2022.261*). According to some views, objects that serve as money first emerged to facilitate exchange, while according to others, their origin is related to state formation and their use as units of account (see *Smith 2004.90–91*).

Pungrt hillfort from regional and supraregional perspectives

The broader Iron Age landscape in which the Pungrt hillfort was situated is under-researched, so we currently do not know how the site fits into the settlement dynamics of the Ljubljana basin in central Slovenia. However, the site is located on the border of the exten-

Fig. 11. Pungrt hillfort. Craft-related finds from Pungrt hillfort (photos J. Skorupan).

sively and thoroughly researched Iron Age landscape of south-eastern Slovenia (Dolenjska Hallstatt group), where significant changes in settlement patterns at the beginning of the Iron Age point to settlement nucleation and population aggregation. Most of the smaller fortified and unfortified Bronze Age settlements were abandoned, and new, larger Early Hallstatt hillforts were established during the 8th century BC. This resulted in the reduction of the number of fortified settlements by half while, at the same time, the total area of hillforts doubled as their average size increased dramatically (from 1.1 to 5.9ha). The newly established hillforts were constructed to their complete extent in single campaigns, although the development of their extramural settlements, which are known to exist, is still not well understood. They would go on to represent centres which played a key role in the region's development throughout the Early Iron Age. It was only in the Late Hallstatt period that a new wave of colonization was reflected in the appearance of new, smaller hillforts, which were not strongly fortified or unfortified (*Dular, Tecco Hvala 2007*).

The data for other regions is more fragmentary. Research in northeastern Slovenia indicates that most of the sites which developed into Early Iron Age centres have their beginnings in the Late Bronze Age (*Teržan 1990; Dular 2013.122*). However, in one of the most thoroughly explored microregions there, the Pohorsko Podravje, the investigations revealed a picture similar to south-eastern Slovenia. The rural Late Bronze Age lowland settlements were abandoned in the late 9th to the early 8th centuries BC, when the Poštela hillfort, over 6ha in size, was established. The hillfort acted as a major regional centre, accompanied by newly established smaller rural settlements (*Teržan, Črešnar 2021.572–579*).

The data for western Slovenia (Notranjska-Karst Hallstatt groups) suggests that the building and development of hillfort settlements reached its peak in the Late Bronze Age and especially in the Early Iron Age, to which the majority of their monumental dry-stone walls can be dated (*Laharnar 2022.251–261,351–355*). However, the settlement pattern may be more complicated than the model of a central hillfort surrounded by lower-ranking settlements would suggest (*O.c.355; cf. Slapšak 1995*).

The overall picture suggests that hillforts that took on the role of micro-regional centres, emerged during the Late Bronze Age and the beginning of the Early Iron Age. Where data is sufficient, it implies a simultaneous abandonment of previous settlements, which points to the demographic process of urbanization and the political process of centralization. The construction of the first wall at Pungrt hillfort in the 8th/7th century BC could be seen as part of a similar development, namely the establishment of an Early Hallstatt centre to which the population from the surrounding territory aggregated. However, the burial discovered at the site could perhaps point to still earlier beginnings, in the 10th century BC. In fact, the nearby centre in Ljubljana originated as early as the 13th century BC, while its extramural settlement, characterized by an orthogonal layout of contiguous houses, developed in the 11th–10th

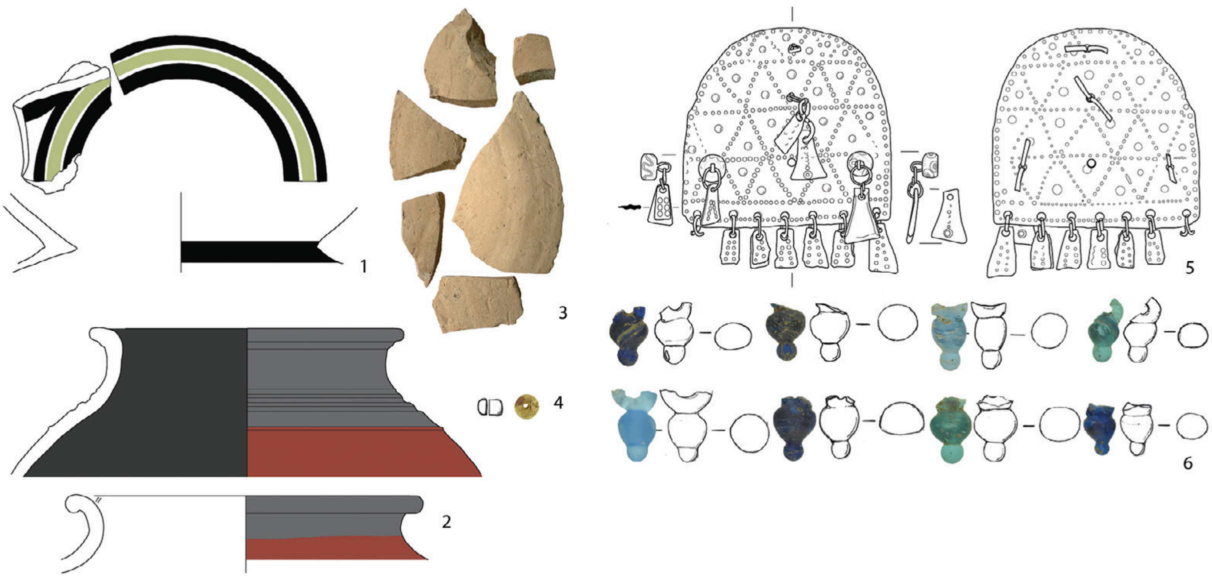

Fig. 12. Pungrt hillfort. Long-distance trade and cultic finds from Pungrt hillfort.* 1–3 *pottery;* 4 *amber;* 5 *bronze;* 6 *glass. M = pottery 1:3; bronze 1:2; glass and amber 1:1. (photos J. Skorupan, drawings J. Brečić).

century BC (*Vojaković 2023*). Both sites in the Ljubljana basin suggest that urbanism was an integral part of demographic and political changes reflected in the emerging central settlements.

The overall picture is reminiscent of developments in northern and central Italy. In south Etruria, the majority of small villages were abandoned from the mid-9th to the mid-8th centuries BC, and the population coalesced into centres, which had their beginnings in the 12th–10th centuries BC (*Stoddart 2017.308*). A similar and more or less contemporaneous pattern is evidenced in Latium (*Fulminante 2014.46,217*) as well as in the Po valley (*Guidi 2006; Rondelli 2008; Zamboni 2021.398*). At first, the Etruscan central settlements retained the characteristics of the previous Bronze Age villages composed of irregularly laid out ovoid huts built in wattle and daub technique. In the 7th century, rectangular buildings with stone foundations began to replace them, and more regular layouts began to appear until orthogonal layouts with individual or contiguous houses became common in the 5th century BC (*Izzet 2007.148–151,171,174; Stoddart 2017.309*). An almost identical transition to an urbanized form of the built environment is also evidenced in 6th–5th century BC Rome (*Sauer 2021.123–125*). Interestingly, a comparable change in settlement pattern, seen in the abandonment of smaller scattered settlements and population nucleation at central hillfort sites, is apparent in the south-eastern Alpine region (south-eastern Slovenia and Pohorsko Podravje). Furthermore, a similar major restructuring of the settlement's interior into a planned layout during the 6th century is evidenced at Pungrt hillfort.

These developments in Etruria and Latium represent trajectories in the formation of early city-states between 1000 and 500 BC (*Guidi 2006*). Archaeologically, these political changes are most reliably traced through settlement change, first taking the form of a shift from dispersed to nucleated settlement, and followed somewhat later by evidence of internal reorganization and the emergence of urbanism (*Stoddart 2010.31,36–37;* see also *Campagno 2019*). In the south-eastern Alpine region, the first type of change is evidenced in the best-researched regions in Slovenia at the beginning of the Early Iron Age, while the second type is evidenced at Pungrt hillfort, the first settlement of this type that has been researched to the degree that allows such a change to be traced. This, currently still fragmentary evidence, leads us to speculate that the Early Iron Age cultures in Slovenia underwent similar demographic and socio-political developments to those in northern and central Italy. In fact, these trajectories, as detected archaeologically, are fairly similar to those of the Greek *polis*, which are eponymous with the concept of the city-state (*Hansen 2000a; 2000b*).

The *polis*, in the sense of a city-state, was formed either by colonization or settlement nucleation. It first appeared in the 8th century BC colonies in Sicily and only later in the homeland (*Hansen 2000a.147–150,162*). Except for some colonies where the urban centre could be carefully planned from the onset, with the earliest examples from Sicily dating to the 8th century BC, organization in accordance with a rectangular street plan followed only later (*O.c.162; Morris 2003.40,49*) and discernible urbanism in mainland Greece prior to the late 4th century BC was rare (*Rönnlund 2023.754*).

The Early Iron Age polities of Etruria, Latium Vetus, and Greek *poleis* (*Cornell 2000; Hansen 2000a; Torelli 2000*) are especially significant as they provide the only contemporaneous and geographically relatively close ethnohistoric parallels available that can aid us in interpreting the exclusively archaeological data on settlement nucleation, urbanization, and the emergence of early urbanism in the south-eastern Alpine region during the same period. In all of them, these changes are seen as closely related to the process of early state formation, which led to the development of city-states and city-state cultures. In this context, the city-state is understood as a micro-state represented by a town and the immediate hinterland it controls. These types of states typically do not form in isolation but instead form regional city-state cultures, which in turn often appear in neighbouring regions, thus forming clusters of city-state cultures (*Hansen 2000b*). Furthermore, studies show that although early urbanism and early state formation are two separate processes, they are often tightly linked as one follows the other in all civilizations where written sources supplement the archaeological remains (see *Stoddart 1999; Hansen 2000b.15; Daems 2021.23–26; Feinman 2023.355; Smith 2023.100–138*). In fact, some researchers have suggested that during the first half of the 1st millennium BC there was a general trend of early state formation among the Iron Age societies in Europe (*Bintliff 2018*), which appear to have shared overarching similarities in political ideologies that favoured various forms of corporate states with heterarchical structures (*Thurston 2010*).

These parallels suggest that communities in the south-eastern Alpine region may have also undergone processes of early state formation or developed some other form of similarly complex society (see *e.g., Grinin 2003*). Such a view is prompted by the correlation between the increasing group size and socio-political complexity (see *e.g., Carneiro 1987; Bintliff 2000; Feinman 2011; 2023; Shin* et al. *2020; Daems 2021. 94–97; Smith 2023.59–98*). The process of population aggregation at hillfort sites in the south-eastern Alpine region indicates some type of new socio-political logic (see *Campagnolo 2019.219; Gyucha 2019*), and the population size estimated for Pungrt hillfort entails the development of some type of corporate society (*Bintliff 2000*). Its urban character also represents a proxy for high social complexity and indicates that numerous hillfort sites in the region might also represent similar early urban centres. What type of socio-political changes these sites represent is an important question that will need to be more fully addressed in future research.

Conclusions

This study demonstrates that the Early Iron Age hillfort at Pungrt displays a set of distinct urban features. Observed in a comparative framework of similar sites in temperate Europe, the settlement can be identified as an early urban town or city (the terms are used as synonyms in this text, see *e.g., Hansen 2000b; Pearce 2023.96–97*). The site shows three or four of the attributes needed to determine the town status of medieval settlements, and shares many characteristics with the Heuneburg hillfort, which represents one of the flagships of Early Iron Age urbanism in temperate Europe (Tabs. 1, 2).

Through these attributes and characteristics, we can begin to define the nature of Early Iron Age urbanism in the south-eastern Alpine region as it is emerging through research at the Pungrt hillfort. The hillfort's urban area was clearly defined by a monumental stone wall. The enclosed area was characterized by a well-defined connective infrastructure and regularly spaced and evenly sized building plots articulated with respect to the road system. The layout points to planning and formal division of the enclosed settlement area, which was successfully maintained or enforced for at least three centuries (6th to 4th century BC). Furthermore, the walled area was very densely built-up and probably divided into different neighbourhoods. There are indications of the presence of religious functions within the city, which were probably held by the resident elites. The settlement also had an important economic role as a centre of craft production and long-distance trade.

The Pungrt hillfort can be seen as part of wider settlement nucleation and population aggregation processes evidenced by the development of central hillfort settlements at the beginning of the Early Iron Age within the south-eastern Alpine region. A similar urban character can be expected at other such sites in the region. The changes in settlement logic, along with the emergence of early urbanism and estimated population size within the walled area of the hillfort, represent proxies for significant socio-political changes which may be comparable with contemporaneous changes in central and northern Italy and Greece, where they are interpreted in terms of early state formation. Our research at the Pungrt hillfort demonstrates the need for further detailed research of Early Iron Age hillforts in Slovenia, in order to improve our understanding of early urbanism and the related socio-political changes during this period in the south-eastern Alpine region.

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Dwelling architecture and flexible land-use strategies in the Prehispanic Sierras de Córdoba, Argentina

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ABSTRACT - *The article examines the evidence of architecture recovered from the Late Prehispanic Period of the Sierras de Córdoba (~1220–330 cal BP), Argentina. We explore the relationship between household architecture and the level of residential mobility, arguing that a flexible subsistence and mobility pattern followed the adoption of plant cultivation and not entirely sedentary farming. The architectural evidence presented structures made using low-energy construction techniques that were not intended for an anticipated long-term occupation. This architecture meets the expectation of a settlement pattern left by groups that were occasional food producers and used specific locations as seasonal campsites, indicating a flexible landscape-use organization.*

KEY WORDS – *Late Prehispanic Period; house features; pithouses; flexible mixed economy; sedentism; residential mobility*

Bivanjska arhitektura in prilagoditvene strategije rabe zemljišč v predšpanskih Sierras de Córdoba, Argentina

IZVLEČEK – *V članku analiziramo podatke o arhitekturi v poznem predšpanskem obdobju v Sierras de Córdoba (~1220–330 kalibrirano pr. n. št.), Argentina. Ukvarjamo se z odnosi med hišnimi gospodarstvi in stopnjo bivalne mobilnosti, pri čemer trdimo, da je fleksibilen način preživljanja in mobilnosti sledil prevzemu gojenja rastlin in ne povsem sedentarnega kmetovanja. Arhitekturne dokaze predstavljajo strukture, narejene s pomočjo nizkoenergijskih gradbenih tehnik, ki sicer niso povezljive s predpostavljeno dolgotrajno poselitvijo. Arhitektura je skladna s pričakovanim poselitvenim vzorcem skupin, ki so občasno pridelovale hrano in so izbrane prostore uporabljale kot sezonske tabore. To kaže na fleksibilno organizirano izrabo krajine.*

KLJUČNE BESEDE – *pozno predšpansko obdobje; hišne značilnosti; zemljanka; fleksibilna mešana gospodarstva; sedentizem; bivalna mobilnost*

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Introduction

A significant issue in the archaeological study of the spread of food-producing economies is delineating the different forms and levels in which prehistoric foragers adjusted their mobility strategies to the labour demands of plant cultivation, mainly when mobility serves to position them for the acquisition of the resources needed to survive (*Rafferty 1985; Hard*, *Merrill 1992; Kelly 1992; Silva*, *Frank 2013; Gibbs*, *Jordan 2016; Roth 2016; Ricci* et al. *2018; Schmader 2023*). Considering the relationships among the types of houses (everyday domestic residences) identified in deposits and mobility is essential in developing these archaeological interpretations, given that the durability and form of house construction are regular cross-cultural indicators of the frequency of residential moves (*Binford 1990; Diehl 1992*). All ethnographic and archaeological groups build some housing, with a wide range of mobility possibilities ranging from a full-fledged sedentary lifestyle to a high degree of group mobility. Thus, the style of a dwelling house, and especially the amount of energy spent on its construction, is a powerful tool for understanding a group's residential mobility strategies (*Binford 1990; Diehl 1992; Smith 2003*). Therefore, the analysis of this relationship offers a distinct perspective on studying the food-production transition that was little explored in Argentina, where the few archaeological investigations of house design have generally focused on groups that were wholly sedentary or assumed to be sedentary (*Raffino 1988; Nastri 2001; cf. Albeck* et al. *2010; García 2010; Callegari* et al. *2015; Ratto* et al. *2019*). Less attention has been given to the more mobile mixed foraging and cultivation groups that invested less energy in dwelling construction.

The excavation of habitation structures over the past 40 years in the Sierras de Córdoba (Fig. 1), a low-altitude mountain range (500–2800m) bounded by areas of early plant domestication in South America, provides an excellent opportunity to study the houses of groups that had a flexible mixed-economy adaptive strategy combining small-scale farming and broad-scale foraging (see *Recalde 2008; Pastor*, *López 2010; Pastor* et al. *2012; Medina* et al. *2014; 2016; 2020; Recalde*, *López 2017*). The house remains of the excavated sites allow examination of the relationship between the design and form of domestic architecture have with mobility, increasing the understanding of the role of houses in societies with a mobile form of socioeconomic organization that incorporates plant cultivation within the economy. Most of these sites were recently defined as semi-sedentary campsites or villages occupied during the growing season (October–April) by people following a spectrum of farming and foraging strategies that challenge any unidirectional scheme of cultural evolution (see *Medina* et al. *2016; 2020*). According to the model, the groups used pottery, maize, and other crops within a broad-spectrum foraging base that included high re-

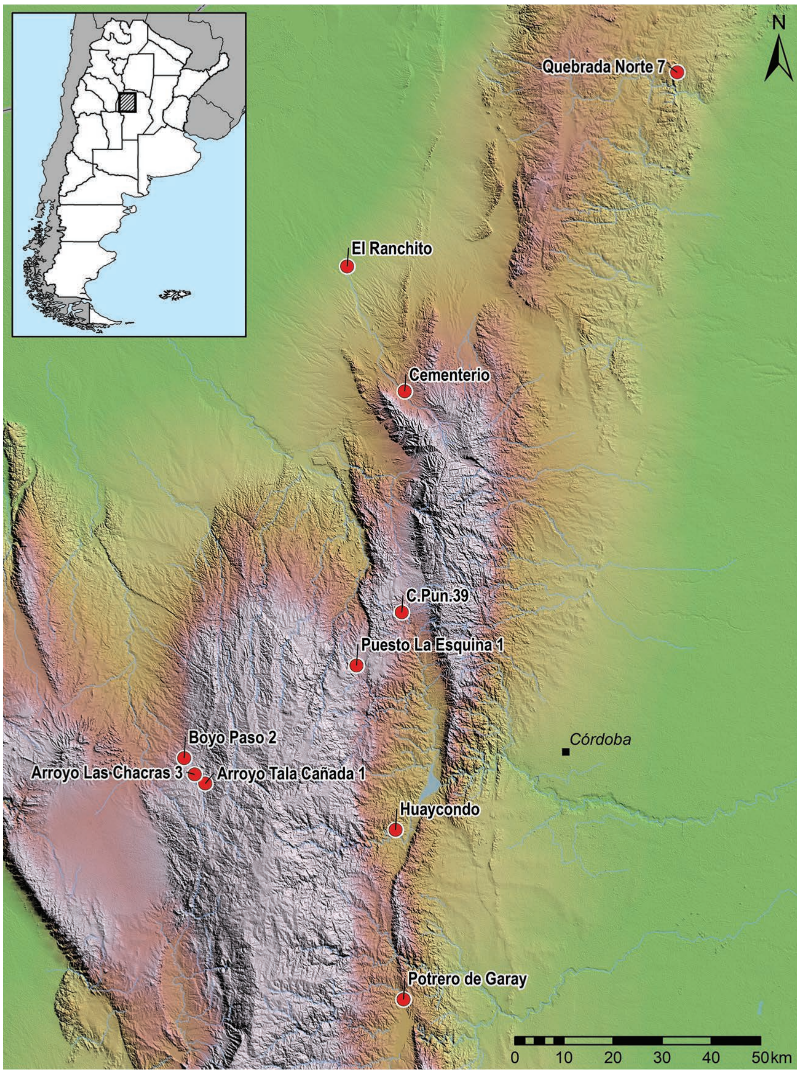

Fig. 1. Geographic locations of the archaeological sites referred to in the text.

sidential mobility, co-residential group fission-fusion mechanisms, and the temporary abandonment of cultivated fields to reduce their dependence on a single or few resources. In this context, the groups weighed the local resource abundance regarding the regional foraging potential (*Recalde 2008; Pastor* et al. *2012; Medina* et al. *2016; 2020*).

We think this seasonally sedentary model requires elaborating on details about the dynamic of base-camp occupations that have not yet been specified. This paper examines the evidence of the architecture remains recovered from the Late Prehispanic Period of the Sierras de Córdoba (~1220–330 cal BP, Argentina) to improve our understanding of local and regional mobility. Our objective is to explore what the presence of house remains in the archaeological record implies for the model of occupation persistency and landscape-use organization, assuming that group mobility strategies and the anticipated use-life are of significant importance to dwelling design and form (*Gilman 1987; Kent*, *Viedrich 1989; Diehl 1992; 1997; Smith 2003*). Thus, we explore the relationship between the architectural design of structures and the level of residential mobility. We focus on the assumption that a flexible subsistence and mobility pattern accompanied the adoption of domesticated plant cultivation and not entirely sedentary farming. We also analysed the kind of storage technology utilized at sites due to its influence on mobility strategies and the duration of occupations (*Kent*, *Viedrich 1989; Diehl 1992; Smith 2003*). We expect the results to help improve the current archaeological knowledge of the landscape-use organization in groups worldwide where the adoption of crop plants did not necessarily lead to a sedentary lifestyle. This pattern, commonly observed ethnographically, is challenging to identify from the archaeological record.

A series of innovative hypotheses drive our article. We propose that Late Prehispanic construction techniques vary according to the socio-environmental conditions dictated, and the identification of temporary structures has been biased towards more recognizable pithouses (semi-subterranean, single-room structures), with pithouse construction being episodic rather than continuous. We also suggest that the prevalence of less visible temporary structures in the record aligns more with the dwellings of people who did not reside at a single location for an entire year, reflecting a flexible settlement pattern. Furthermore, we argue that implementing low-investment extensive cultivation, which did not restrict group mobility, likely prevented the opportunity for extensive long-term storage. Therefore, we anticipate that short-term storage was used for food surpluses.

Architecture, storage, and mobility from a dynamic perspective

Archaeologists have long recognized that sedentary groups or people who anticipate a lengthy occupation of sites usually construct structures that require the investment of considerable time and energy (*McGuire*, *Schiffer 1983; Rafferty 1985; Gilman 1987; Kent*, *Viedrich 1989; Binford 1990; Kelly 1992; 1998; Rocek 1995; Diehl 1997; Panja 2003; Kelly* et al. *2005; Schmader*, *Graham 2015; Roth 2016; Schmader 2023*). In contrast, mobile people minimize the time and effort spent on domestic architecture due to its generally short use, resulting in ephemeral structures built using easily transportable or locally available materials requiring little preparation time (*Binford 1990; Diehl 1992*).

Cross-cultural ethnographic studies strongly support this assertion. For example, different case studies showed that more residentially mobile groups typically create low-cost habitation structures with a circular or semicircular plan that usually requires a limited amount of transportable or readily available perishable materials (*McGuire*, *Schiffer 1983; Kent*, *Viedrich 1989; Binford 1990; Diehl 1992; Kelly* et al. *2005*). Conversely, more sedentary groups generally build houses with rectangular plans, more durable materials (wood, mud brick, or stone), and higher initial construction costs. These houses can be easily maintained and subdivided for the differentiation of activities. However, cases in the middle would represent residential mobile people constructing substantial structures at specific locations for anticipated revisits over the years (*Kelly 1992*), a typical behaviour among Andean pastoralists (*Kuznar 1995; Yacobaccio* et al. *1998*). In these examples, the expectation of reuse over several years justifies the cost of the construction (*Smith 2003; Morgan* et al. *2017*).

Storage can extend the use of a seasonally abundant resource beyond its availability period. Thus, the presence or absence of storage facilities plays a vital role in the length of time groups occupy a location (*Kent*, *Viedrich 1989; Schmader 2023*). According to Carol Goland (*1991*), storage among food collectors and producers may range from the intensive large-scale accumulation of surpluses to a short delay in the use of resources. Specifically, the first strategy involves storing large quantities of a resource, usually in immovable, permanent facilities such as storage pits or granaries, to feed the group through food scarcity or until the next harvest (*O.c.*). Robust evidence for long-term storage has generally been linked to permanent, sedentary occupations (*Kelly 1992*). Mobile people also rely on immovable facilities for storage when they anticipate returning to locations (*Kent*, *Viedrich 1989; Graham 1994; Rocek 1995; Binford 2001*). However, the cost and risk of failure increase because stored food would be exposed to theft or destruction during site abandonment (*Howey*, *Frederick 2016; Roth 2016*). In contrast, short-term storage involves saving limited resources for more immediate needs and planting in subsequent years, often in portable containers such as pottery vessels or basketry. Short-term storage frequently occurs when resources are insufficient and predictable enough to sustain a group over a season of scarcity. During this time, the group needs to rely on other subsistence activities. To allow farming to persist as a viable economic strategy, small-scale farmers had to store a minimal supply of crop seeds.

Therefore, we need to consider the substantial amount of energy spent on the construction of habitation structures and the characteristics of storage facilities to provide archaeological clues concerning the duration of Late Prehispanic Period site occupation and the level of group mobility. According to the landscape-use model, it is expected that most of the Late Prehispanic house structures would indicate that little time was invested in their preparation. They would exhibit irregular or overlapping outlines, only identified by discretely packed floors and a few post-molds. Moreover, any information about the layout of house features would suggest using ephemeral organic construction materials, providing indications of the short-term duration of site occupation consistent with seasonal use. Something similar should occur with storage. Farming plots and wild fruit patches occasionally provide a minimal surplus that can be stored in portable containers such as pottery vessels or basketry. However, they do not produce enough stores consistently to feed the group from year to year. Thus, even with horticulture and storage technology, Late Prehispanic people were still tied to seasonal movements to forage wild resources and reinforce inter-group obligations, carrying stored seeds in portable containers for food and future planting. Long-term storage facilities would not be expected. Moreover, patches with seasonally predictable resources may remain repeatedly occupied, even when the resource does not furnish the surplus necessary for long-term storage and occupation.

Materials and methods

The database reviewed here consists of house features and presumed storage facilities excavated at ten sites within the region (Fig. 1). It contains entirely or almost wholly excavated remains interpreted as house features or presumed storage facilities for which descriptive reports are available in publications (*Berberián* et al. *1983; Berberián 1984; Laguens 1999; Pastor 2007; Laguens*, *Bonnin 2009; Medina 2015; Recalde, López 2017; Medina* et al. *2020*). The study also considers the unpublished excavation notes of Potrero de Garay obtained by Eduardo Berberián.

The investment in dwelling construction was measured at the coarse-grain resolution following the logical framework for evaluating the effort invested in construction proposed by Michael W. Diehl (*1997*), which applies to any region when archeologically known architecture remains are available for study. As such, this study considered the size of a structure, the number of post-molds, the kind of material used in construction, the formality of hearth construction, the depth of floors, the evidence of reoccupations, and so on to make inferences about the amount of time a structure was occupied based on the assumption that mobile people minimize the time and effort spent on construction (*McGuire*, *Schiffer 1983; Rafferty 1985; Gilman 1987; Kent*, *Viedrich 1989; Binford 1990; Kelly 1992; 1998; Rocek 1995; Diehl 1997; Panja 2003; Kelly* et al. *2005; Schmader*, *Graham 2015; Roth 2016; Schmader 2023*). The term 'post-mold' refers to the archaeological trace of a wooden post, regardless of whether it had decayed *in situ* or been intentionally extracted. It was crucial for our research because more extended interannual occupation increased the number of posts used to support the roof, and *vice versa*. Something similar occurred with the other indicator analysed here, where ephemeral features or raw materials were assumed to be used only for a few weeks and constitute evidence of high residential mobility. We also conducted a morpho-functional analysis of pottery vessels based on Philip J. Arnold (*1999*), Margaret E. Beck (*2009*), and Katherine M. Grillo (*2014*), taking the data about vessel morphologies from publications (*Dantas, Figueroa 2008; Medina 2010; Heredia 2015*).Radiocarbon age estimates also came from the literature and were used to assess evidence of site reuse (*Berberián 1984; Laguens 1999; Pastor 2007; Laguens*, *Bonnin 2009; Medina 2015; Recalde*, *López 2017; Medina* et al. *2020; Tavarone* et al. *2020*). We implemented radiocarbon models in OxCal 4.3 (*Bronk Ramsey 2009a*), using the calibration curve SHCal20 (*Hogg* et al. *2020*). Modelled dates and boundaries are presented in italics. We present only the medians and 95% probability ranges of the dates, rounded by ten years (*Marsh* et al. *2019*).

Sites and structures

Sites containing structures were found sparsely throughout the Sierras de Córdoba (Fig. 1). Unambiguous examples of house structures are uncommon at Late Prehispanic Period sites, and well-delineated house patterns are rarely found in excavations. Moreover, there was some debate or doubt concerning recognizing certain features as actual houses. Several sites, for example, have been reported with evidence of post-molds suggesting the presence of dwelling structures, but these do not often occur in an easily interpretable pattern (*Medina* et al. *2016*). Surprisingly, stones were not used for dwelling construction in the region, even when abundant in the landscape. Instead, they were used in historic times to build *puestos*, *ranchos*, and *estancias* (*Aparicio 1931; López 2021*). Thus, the relative invisibility of Prehispanic house architecture may relate to the high degree of mobility of the small-scale groups that resided in the region, a possibility that is explored further.

Potrero de Garay, an open-air site near Lake Los Molinos, stands out as one of the most archaeologically and extensively investigated sites in the Late Prehispanic Period (Fig. 1). It is particularly notable for its well-documented houses (*Berberián* et al*. 1983; Berberián 1984*). During the large-scale open-area excavations, Eduardo E. Berberián identified four semi-subterranean pithouses (Fig. 2). The houses were constructed on soft, easily deformed soil. Of the four houses completely exposed, three were rectangular pithouses. They had a mean length of 6.1m and a mean width of 4.7m, with straight or slightly rounded corners. The morphology of Unit 4 was fuzzy and failed to yield rectangular pristine outlines (Fig. 2). The pit walls formed the lower portion of the structures without any evidence of a stone wall foundation or columns that would suggest long-term use life. The 1.5m wide sloping entrance and walls were 0–40cm below the prehistoric ground surface. Post-molds averaging 15cm in diameter were placed around their perimeter to support the upper portion of the walls and the roof. However, the number of post-molds was not high, despite the relatively large size of the structures. Moreover, sometimes the post-molds were nearly 2m from each other (Fig. 2). There was no evidence of secondary posts reinforcing the corners, showing little effort invested in the construction and maintenance of the houses as observed in long-term occupied sites (see *Diehl 1997; Ellis* et al. *2015; Schmader 2023*). Central support posts were rare and only recorded in Unit 4. Such a layout suggested that the superstructure of dwellings was not particularly heavy or elaborated, a position consistent with the lack of collapsed roof deposits. The habitation floors were plain, consolidated, and a few centimetres thick, formed by daily domestic trampling (Fig. 3.a-b). Floors presented some *de facto* refuse and site furniture (for example, immovable or heavy ground stones and large vessels) for future reuse. The relative absence of small or expensive items might result from the depletion of abandoned assemblages. There were no storage pits indoors or outdoors and no evidence of formal interior hearth features. However, there were shallow charcoal-stained and oval-shaped (30–40cm) pits with fire-scorched earth and scattered-wood charcoal consistent with on-floor hearths (Fig. 3.a) (*Berberián 1984*). Berberián (*O.c.*) detected burials under the living floors, sometimes covered with a small structure made of stones and grinding artefacts or evidenced by the different coloration of the sediments, indicative of earth removal (Fig. 3.b-c). Aside from pithouses, Berberian also identified four small oval and basin-shaped habitation structures (~2.50m diameter), flimsy in roof construction and without indication of post-molds (*Berberián* et al. *1983*: *77*). However, information about the location of these informal constructions is not available in reports. The descriptions of the structures were consistent with ephemeral, easily constructed domed brush huts, showing multiple forms of residential structures and flexibility of house construction techniques utilized during the site occupation, with various levels of energy investment and probable length of stay. Pit structures appeared to represent a more substantial labour investment than smaller structures, which indicates greater mobility for the residents. Wood charcoals obtained from the living floor of Unit 2 were dated by Berberián (*1984*) at ~330 cal BP (500–...AD, 95%) (Tab. 1). However, radiocarbon dates recently obtained from human skeletal remains by Aldana Tavarone *et al*. (*2020*) shed light on the fact that the site represents several centuries of reoccupation. In line with other evidence described here, we think the site probably represented sequential episodes of seasonal occupation rather than contemporary and year-round occupied neighbouring households (Tab. 1). For example, radiocarbon dates from Unit 4 indicate that using the pithouse differed by several hundred years.

Boyo Paso 2 is an open-air site in Eastern Salsacate Valley excavated by Matías E. Medina (Fig. 1). Although soil strata were fairly uniform, the horizontal excavation revealed two overlying archaeological floors formed by unprepared-packed sediments that appeared fire-altered by multiple on-floor hearths (Figs. 3.d-e, 4 and 5). The upper floor was a thin level of compact ed sediments less than 2cm thick spread over the 55m^2 excavated (*Medina* et al. *2020*). Medina did not detect storage pits during excavations. However, he documented a roughly semi-subterranean structure in the southern portion of the excavated area, in close

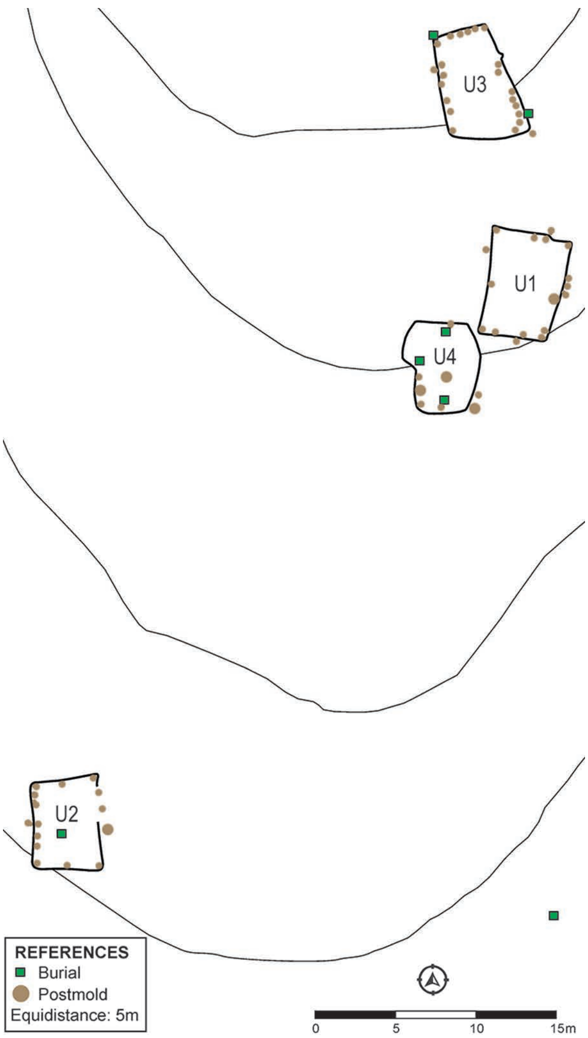

Fig. 2. Plan view of the pithouses and key features of Potrero de Garay. Key: **U1** ***Unit 1;*** **U2** ***Unit 2;*** **U3** ***Unit 3;*** **U4** ***Unit 4.***

association with more than 20 post-molds and undefined basin-shaped depressions, which contained evidence of multiple functions in connection with the abandonment process, including storage, caching tools, and trash disposal (Fig. 4; *Medina* et al. *2016; 2020*). A few centimetres below the upper floor, the change in the consistency of sediments led to the lower archaeological floor (Fig. 5), which presented a feature of unknown use made of 14 cobble-sized stones, basin-shaped depressions, and two post-molds. One of the post-molds had a fire-altered (burned) post inside (Fig. 3.e; *Medina* et al. *2020*). Medina *et al*. (*O.c.*) also noticed a pit feature of unknown function filled with uncompacted, fine-grey sediments in the northwestern corner of the excavation. The upper and lower floors were rich in scattered ash, ash by-products, charcoals, and some reddened earth rather than well-defined hearths, indicating multiple occupational and reoccupation events across decades (*O.c.*). Living floors also had abundant domestic refuse, including a high diversity of pottery, metal, stone, and bone tools, biological debris, and residues of time-consuming activities such as pottery making. The excavator also found functional artefacts on the living floors, suggesting that people planned to return to this location (*Medina* et al. *2016; 2020*). By detecting post-molds, we inferred the presence of habitation structures like pithouses, brush huts, or windbreaks over the living floor (Figs. 2 and 3). Post-molds were closely spaced on the upper floor (Fig. 4). They range from 22–27cm in diameter and 17–31cm deep. Two overlap, representing a time sequence or minimally multiple occupation events. It is unclear what this pattern represents, especially when well-defined outlines are not evident enough to identify the shape or size of the structures. The random distribution of artefacts and features on living floors had more in common with overlapping brush houses (see *Wheaton 2014*) than the pit structures overemphasized by the study of ethnohistoric sixteenth-century documents (see *González 1943; Serrano 1945; Berberián 1984*). The absence of well-defined hearth features made identifying houses even more complicated, reinforcing the hypothesis that there were multiple superimposed houses and no durable habitation residences for long-term occupation (*Medina* et al. *2020*). The fact that Medina *et al*. (*O.c.*) reported pottery sherds from the fill of at least one posthole also supports this assertion (Fig. 3.d) because they showed that debris accumulated during late occupations slid down on the posthole of the earliest occupation. A context with this characteristic challenged any interpretation of the finely reticulated stratigraphy of the archaeological record and forced us to accept the coarse chronological resolution of the floors. They (*Medina* et al. *2020)* published seven radiocarbon dates for the site (Tab. 1). However, two dates from the upper floor (~920 cal BP, 1060–790 AD, 95% and ~1360 cal BP, 1540–1170 AD, 95%) were outliers or dates made on old wood. Therefore, we excluded them from the analysis until more radiocarbon dates were obtained (Tab. 1). Assuming that the lower floor was older than the upper floor, a simple Bayesian model showed that the episodes of site occupations began around *800 cal years BP (1010–720, 95%, starting boundary)* and ended around *700 cal years BP (770–560 AD, 95%, ending boundary)*. The lower floor had medians of *760*, *780 cal years BP,* and the upper floor's three dates had medians of *720, 730, 740 cal years BP* (Tab. 1). The random distribution of post-molds combined with the radiocarbon dates suggested a palimpsest of free-standing dwellings without direct continuity from one construction episode to the next, consistent with a repeated seasonal occupation over at least a century. Unfortunately, knowing how many occupation episodes were represented on an ethnographical observation scale is challenging. Based on the evidence, we interpreted Boyo Paso 2 as a seasonal encampment where small groups sporadically coalesced during the growing season to do various activities. The presence of fau-

Site	Material dated	Context	Lab code	^{14}C age	±	Median	95% probability
Boyo Paso 2	Wood charcoal	Upper floor (37-40cm)	LP-2932	750	70	650	730–550 AD
Boyo Paso 2	*Phaseolus vulgaris* (seed)	Upper floor (37-40cm)	AA-110929	866	39	730	800–670 AD
Boyo Paso 2	*Zea mays* (seed)	Upper floor (37-40cm)	AA-110928	878	18	740	790–680 AD
Boyo Paso 2	Wood charcoal	Upper floor (37-40cm)	LP-3122	1060	50	920	1060–790 AD
Boyo Paso 2	Wood charcoal	Upper floor (37-40cm)	LP-3107	1500	80	1360	1540–1170 AD
Boyo Paso 2	Wood charcoal	Lower floor (49-56cm)	LP-3577	870	50	740	910–660 AD
Boyo Paso 2	Wood charcoal	Lower floor (49-56cm)	LP-3567	970	40	840	930–740 AD
Potrero de Garay	Wood charcoal	Archaeological floor, Unit 2	I-11697	310	75	330	500–... AD
Potrero de Garay	Human bone	Burial E1	MTC-14025	383	58	400	500–300 AD
Potrero de Garay	Human bone	Burial E3	MTC-13251	981	41	850	930–740 AD
Potrero de Garay	Human bone	Burial E4	MTC-14028	889	59	760	910–670 AD
Potrero de Garay	Human bone	Burial E6	MTC-13215	881	150	780	1060–540 AD
Potrero de Garay	Human bone	Burial E8	MTC-13246	995	161	870	1260–560 AD
Potrero de Garay	Human bone	Burial E9	MTC-13254	420	41	440	510–320 AD
C.Pun.39	Wood charcoal	C3 level 4 (30-40cm)	AA-62338	854	39	720	800–670 AD
C.Pun.39	*Phaseolus* sp. (seed)	D1 level 6 (50-60cm)	AA-64819	525	36	520	550–490 AD
C.Pun.39	Wood charcoal	C2 level 9 (80-90cm)	AA-62339	716	39	620	680–550 AD
Puesto La Esquina	Wood charcoal	H1 level 2 (10-20cm)	AA-64816	365	38	390	490–300 AD
Puesto La Esquina	Wood charcoal	H1 level 4 (30-40cm)	AA-64815	362	43	390	490–300 AD
Arroyo Tala Cañada 1	Wood charcoal	archaeological floor	LP-1511	900	70	770	920–670 AD
Arroyo Tala Cañada 1	*Phaseolus vulgaris* aff. var. *vulgaris* (seed)	plough zone feature	AA-64820	1028	40	870	960–790 AD
Arroyo Las Chacras 3	Wood charcoal	B1 level 5 (20-25cm)	AA-100670	917	37	780	910–680 AD
Cementerio	Wood charcoal	hearth feature	LP-422	310	90	320	500–... AD
El Ranchito	Wood charcoal	pit feature	Hv-17047	370	40	390	490–310 AD
Quebrada Norte 7	Wood charcoal	45cm	LP-3212	1280	80	1120	1280–960 AD
Quebrada Norte 7	*Zea mays* (seed)	35-4cm	AA107245	405	21	450	500–320 AD

Tab. 1. Radiocarbon dates from the archaeological sites. The three points of the 95% probability column imply that the date may extend out of the range of the calibration curve.

nal and botanical remains that indicated the site was occupied with a strong signal during the warm season (October–April), in combination with temporary organic structures and residues of activities that imply staying in a place for several weeks, supported this argument (see *O.c.*).

The presence of habitation structures in other open-air sites such as C.Pun.39, Puesto La Esquina 1, Quebrada Norte 7, Arroyo Tala Cañada 1, Cementerio, Huaycondo, El Ranchito and Arroyo Las Chacras 3 (Fig. 1) was noticed by the detection of packed surfaces with horizontally dispersed archaeological remains, ambiguous hearth features or firepits, soil stains, and post-molds. However, the reported features did not conform to expectations for substantial housing.

C.Pun.39 is located at Northen Punilla Valley (Fig. 1) and was excavated by Medina. House architecture was difficult to recognize on the modern ground surface.

Fig. 3. Examples of house architecture and features from the sites Potrero de Garay, Boyo Paso 2, and C.Pun.39. **a** ***extensive charcoal staining on the floor of Unit 2 of Potrero de Garay;*** **b** ***Unit 1 from Potrero de Garay;*** **c** ***burial from the Unit 2 of Potrero de Garay;*** **d** ***pottery sherds filling a posthole at the upper floor of Boyo Paso 2 (the dashed line indicates the outline of the posthole);*** **e** ***post-molds with a fire-altered (burned) post inside recorded at the lower floor of Boyo Paso 2 (the dashed line indicates the outline of the posthole);*** **f** ***possible archaeological floor from Sector 3 of C.Pun.39.***

As such, the excavations were developed in three sectors where the surface lithic scatter and ceramics exceeded five items per m^2 (see *Medina 2015*). In Sector 1, a packed surface was recorded at 27–40cm over the $4m^2$ excavated (*O.c.*). The floor deposit contained a few small, highly fragmented archaeological remains. It is suspected that a slightly built house structure existed, but there was no direct archaeological evidence for this despite the packed surface (*O.c.*). Something similar occurred with the $4m^2$ excavation of Sector 3, where Medina detected a slightly packed surface containing a few significant horizontally dispersed artefacts 20cm from the surface (Fig. 3.f; *O.c.*). No house features were discovered on the hypothetical floor, making any habitational structure hard to detect. Medina excavated $8m^2$ in Sector 2 until reaching sterile sediments at 90cm (*O.c.*). The deposit was homogeneous, with undistinguished stratigraphic layers. A high tool richness was documented along the stratigraphical sequence, including clay nodules with fingerprints interpreted as pottery-making by-products (*Medina 2010; Medina* et al. *2016*). Medina (*2015*) dated three charcoal samples from overlapping layers at ~520 cal BP (550–490 AD, 95%), ~620 cal BP (680–550 AD, 95%), and ~720 cal BP (800–670 AD, 95%), showing different occupation events across the Late Prehispanic Period (Tab. 1).

Puesto La Esquina 1 is located in a well-protected gorge of the Pampa of Olaen (Fig. 1). Five test pits over $5m^2$ (Sectors 1 to 5) were created by Medina (*O.c.*), which revealed that not all the site was intensively occupied. He concentrated excavations on the deposit of Sector 5, which showed high archaeological potential, unco-

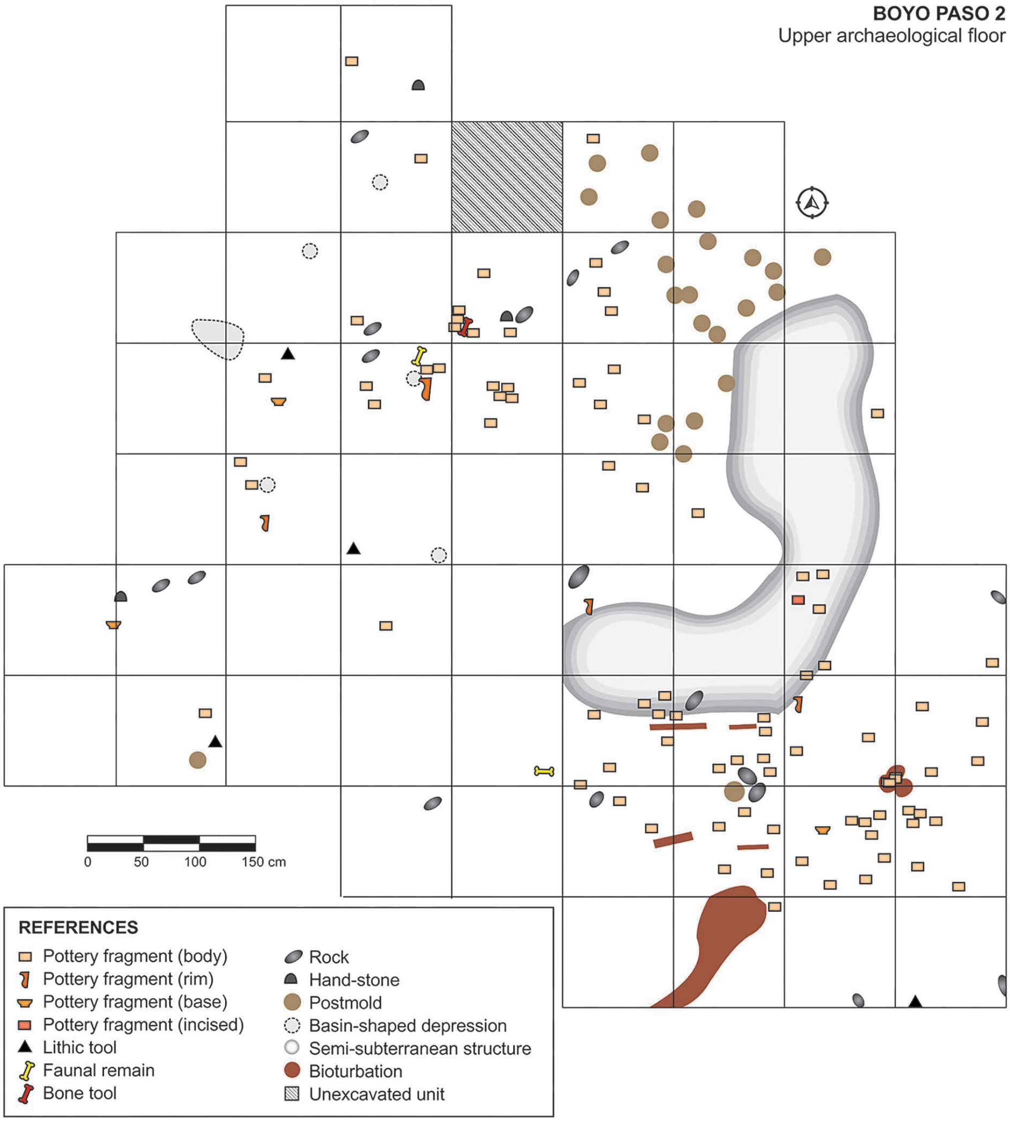

Fig. 4. Plan view of the upper archaeological floor of Boyo Paso 2 with the excavation units, post-molds, and critical features (from* Medina *et al.* 2020*).

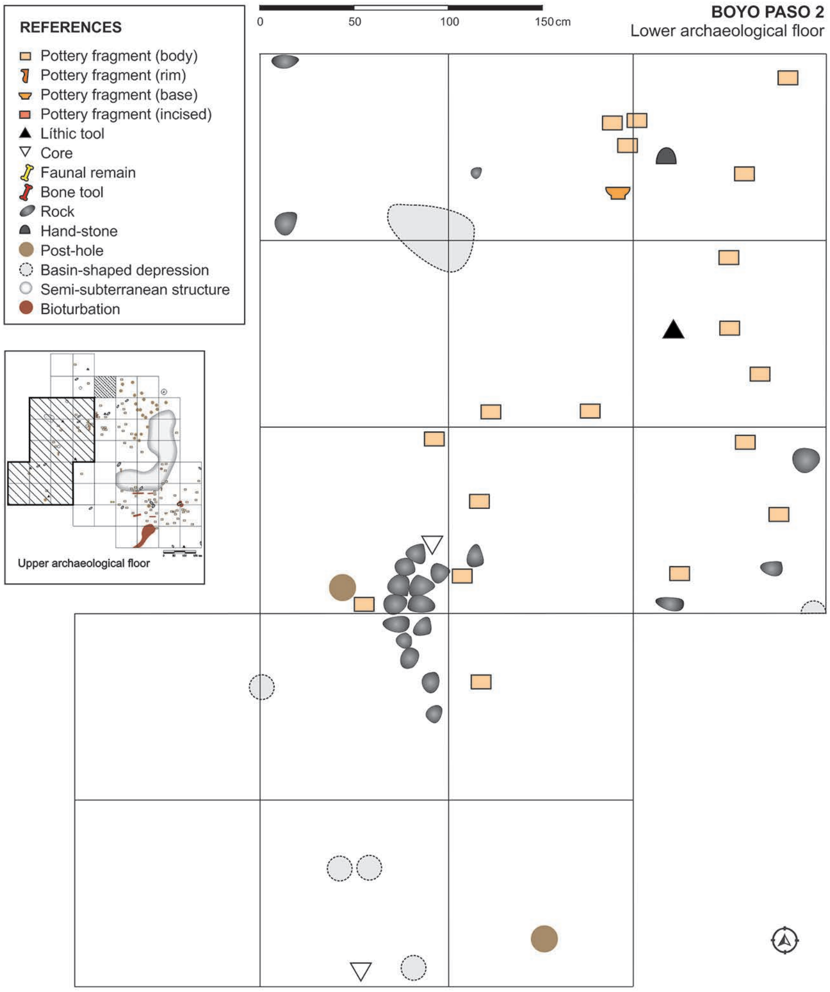

Fig. 5. Plan view of the lower archaeological floor of Boyo Paso 2 with the excavation units, post-molds, and critical features (from* Medina et al. 2020*).

vering 10m2 (*O.c.*). The excavation discovered a few horizontally dispersed cobble-sized rocks at 20 cm (Fig. 6.a). The constructors obtained and transported the stones from the stream adjacent to the site area. The feature was interpreted by Medina (*O.c.*) as an indoor hearth because it was associated with a high density of sherds, lithic tools, and bones assumed to be *in situ* floor trash (Fig. 6.b-c). However, the feature is diffuse and requires further exploration. At 35cm deep, Medina (*O.c.*) identified a circular-shaped (28cm diameter) and relatively shallow depression (5cm deep) in the soft soil (Fig. 6.d). The fill of the feature contained wood charcoal fragments, burned bones and reddened earth, and it was interpreted as an on-floor hearth feature contained wood charcoal fragments, burned bones, and reddened earth, and it was interpreted as an on-floor hearth. Here again, the small size of the feature did not support the notion of long-lasting, repetitively re-lit fires, and it was difficult to assess if such occurrence reflects an ephemeral habitation structure destroyed by post-depositional processes (*Medina* et al. *2016*). Medina (*2010*) also found pottery sherds and amorphous nodules of clay that evidenced on-site pottery manufacturing along the sequence. Medina (*2015; 2016*) dated two charcoal samples from overlapping layers at ~390 cal BP (490–300 AD, 95%) and ~390 cal BP (400–300 AD, 95%), indicating that most of the elements accumulated over a short period, probably as a seasonal-type occupation (Tab. 1).

Sebastián Pastor (*2007*) led the excavation of Arroyo Tala Ca-ñada 1 in Eastern Salsacate Valley and detected a slightly packed surface with primary refuse *in situ* and two post-molds around 30cm wide (Fig. 7). Based on these findings, he inferred the presence of a temporary habitation structure dated by wood charcoal with a median of 770 cal BP (920–670, 95%) (Tab. 1). He also recorded a plough soil feature with cultivated plant remains at 12m of the presumable house structure, including phytoliths of *Zea mays* leaves (Fig. 7). This type of feature had never been detected in the Sierras de Córdoba until Arroyo Tala Cañada 1, even when the planting of domesticated species was considered a significant landmark in recent prehistory. He dated a charred seed of *Phaseolus vulgaris* aff. var. *vulgaris* from the agricultural feature at ~870 cal BP (960–790 AD, 95%) (Tab. 1). The archaeological record of Arroyo Tala Cañada 1 supports the development of low-investment cultivation during the Late Prehispanic Period, with residential units dispersed across farming plots.

Test-pit works by Medina (*2015*) in the site Arroyo Las Chacras 3 identified spatially restricted archaeological strata, which offered an excellent opportunity to discover possible house features through open-area excavations. When fieldwork was accomplished, the archaeologist recovered a dense concentration of pottery fragments and scattered wood in a layer of about

Fig. 6. Examples of features from Puesto La Esquina 1 and Arroyo Las Chacras 3. **a** ***horizontally dispersed cobble-sized rocks from Puesto La Esquina 1 interpreted as a possible hearth;*** **b-c** ***Pampas deer (Ozotoceros bezoarticus) metapodials found in situ at Puesto La Esquina 1;*** **d** ***feature from Puesto La Esquina 1 interpreted as an on-floor hearth;*** **e-f** ***excavations in Arroyo Las Chacras 3.***

9m² and 10cm thick (Figs. 6, 8). He did not detect hearths, house remains, or clear living floors at the site. This absence does not necessarily imply that those features did not exist. The lack of associated features may result from intensive post-occupational disturbance caused by roots (Fig. 8) or other destructive processes. He interpreted the layout of pottery fragments and their refitting associations as abandonment refuse inside or nearby a house floor accumulated by a single component occurrence dated at ~780 cal BP (910–680 AD, 95%), probably as a seasonal-type occupation (Tab. 1). The pottery showed medium rounded morphologies (12–14cm wide at the mouth), which are optimal for transport, storage, and cooking a broad spectrum of resources (*Heredia 2015*). This pattern is reiterative in the other Late Prehispanic sites (Fig. 9; *Dantas*, *Figueroa 2008; Medina 2010*).

The stratigraphic excavations by Andres Laguens in the site Cementerio (Fig. 1) detected two hearths, a hearth-like feature made of rocks, two post-molds, and a burial (Appendix, Figure 1; *Laguens 1999*). Based on this evidence, the archaeologist hypothesized the presence of a not well-defined domestic residence (see *La-*

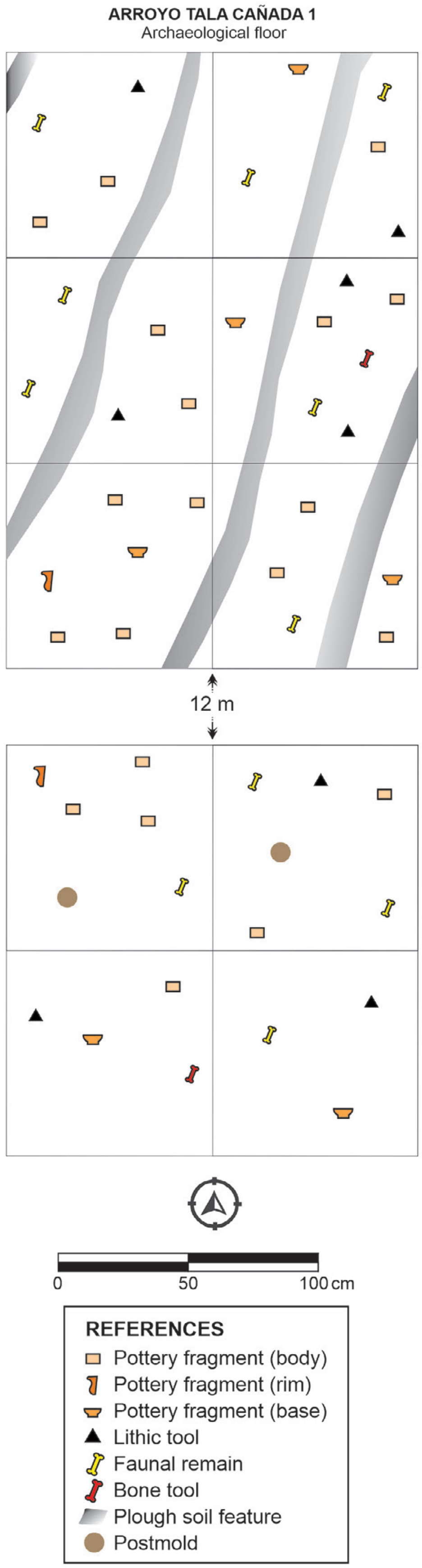

Fig. 7. Plan view of Arroyo Tala Cańada 1 with postmolds and key features.

guens, *Bonnin 2009*). Wood charcoals recovered in this stratum were dated at ~320 cal BP (500–... AD, 95%).

El Ranchito is an unusual site in size and composition (see *Laguens 1999; Marcellino 2001; Laguens*, *Bonnin 2009; Sario* et al. *2017*). It was surveyed and excavated by A. Laguens, who characterized the immense surface artefact assemblage of El Ranchito as a large open-air sedentary village. However, the excavation allowed the recovery of few archaeological residues and no house features, making it impossible to conclude year-round sedentism behaviour (see *Laguens 1999*). Most importantly, in the southwestern portion of the site Laguens discovered 112 clumped underground pit structures (Appendix, Figure 2), one of them dated at ~390 cal BP (490–310 AD, 95%) (Tab. 1). They were bell-shaped underground facilities approximately 90cm deep, 30–40cm in diameter at the top, and 80cm in diameter at the bottom (*Laguens 1999*). Such facilities are universally seen as storage pits (*Rocek 1995*), suggesting the collection of a wild or domesticated resource in sufficient quantities and stored for delayed consumption by sedentary groups (see *Laguens*, *Bonnin 2009.288*). Nevertheless, the pits were described as storage facilities without many supporting arguments despite the finding of charcoals, indeterminate charred seeds, rodent bones, or stained sediment (see *Laguens 1999*). There was no evidence to support the storage function. The interpretations as storage facilities are thus open to discussion, with roasting pits (which imply food processing, not an anticipated lengthy occupation) or cisterns for water collection, conservation, and decontamination seem to be better alternative explanations (see *Heider 2020*). According to the published evidence (see *Marcellino 2001; Sario* et al. *2017*), we interpreted El Ranchito as the result of multiple small short-term visits over 3000 years or more, which produced an extensive archaeological site deposit that resembles a multi-household nucleated settlement of entirely sedentary farmers (see *Medina 2015*). However, the hypothesis requires detailed open-area excavations of buried deposits to move forward and evaluate previous research models empirically.

Huaycondo is an open-air site in southern Punilla Valley (Fig. 1). During the open-area excavation (>30m^2) by Gisela Sario, the homogenous and organic-rich soil stratigraphy of the upper levels led at 30–40cm to packed reddened sediments that formed an archaeological floor (Figs. 10 and 11.a). The living floor revealed fourteen post-molds and irregular shallow pit features. The diameter of the post-mold varied between 11 to 20cm. Seven post-molds aligned fairly regularly and formed a slightly rounded corner. This layout seemed to reveal the remains of a surface-dwelling structure with straight-walled and right-angled alignments (Fig. 10). Whether the other post-molds are associated with the structure or represented other structures (not necessarily contemporary) requires further research. Moreover, these post-molds were sometimes in pairs or filled with tiny pieces of pottery, as in Boyo Paso 2, supporting the claim that multiple occupational events and site formation processes formed the site. Stripping large areas around the post-molds did not reveal any associated hearths, a typical pattern of open-air sites. Nevertheless, the packed surface was rich in scattered charcoals, amorphous ash stains, and reddened sediments, suggesting that multiple burning events affected the deposit. The floor also contained abundant archaeological remains *in situ*. Most findings, including bones and pottery sherds, lie horizontally or subhorizontally. No radiocarbon dates have yet been obtained from the floor. However, the small-stemmed triangular arrow points and numerous pottery fragments collected on the packed surface support logical association with the Late Prehispanic Period (Fig. 11.b-c).

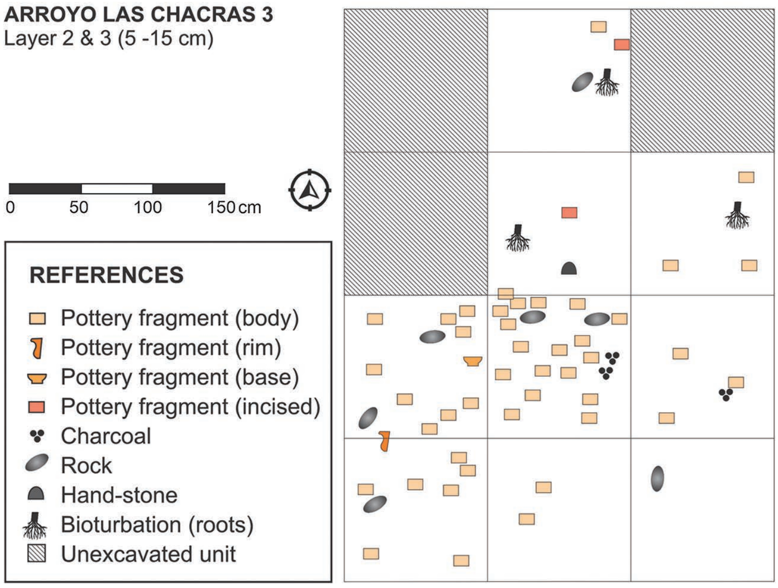

Fig. 8. Plan view of the excavation of Arroyo Las Chacras 3.

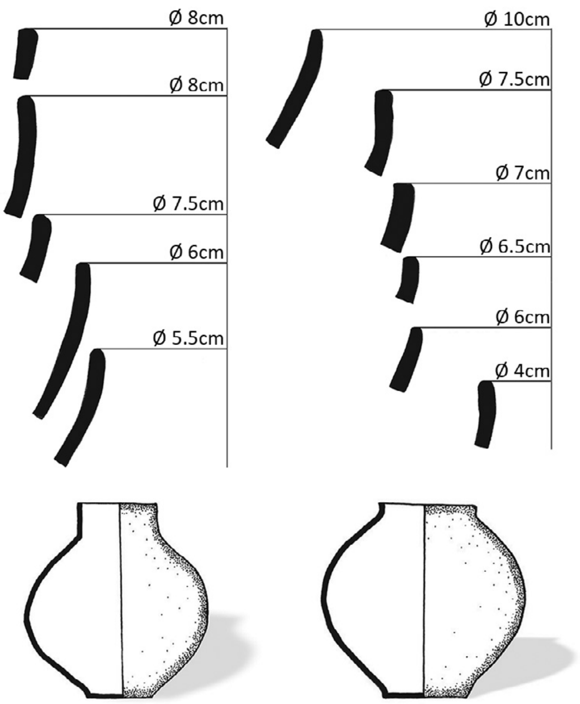

Fig. 9. Examples of globular-shaped pottery vessels recovered at C.Pun.39.

Finally, Quebrada Norte 7 is an open-air site at Sierras del Norte (Fig. 1). Excavations by Andrea Recalde covered 15m^2 with a maximum depth of 70cm (*Recalde, López 2017*). She recorded a dense concentration of pottery fragments, cultivated plants, wood charcoals, faunal remains, and bone, lithic, and grinding tools across the strata. The high tool richness and plant macro-remains suggested that domestic activities occurred on-site, including the short-term storage of wild fruits for delayed consumption (*O.c.*). Most importantly, the archaeologist noticed an archaeological floor at 45cm, but only restricted to a small area near the northwestern edge of the excavation (Fig. 12). Darkly compacted sediments formed the floor. No well-defined house features were noted. The only possible evidence to support the existence of a house structure was ambiguous and consisted mainly of on-floor hearth by-products (charcoals, ash, and oxidized sediments) and pottery sherds horizontally dispersed on the floor. Unfortunately, the floor was not discerned in the rest of the excavated surface, which was heavily affected by the root system of the trees that had grown over or near the excavated area (Fig. 12). Moreover, no direct radiocarbon date was obtained from the floor. However, wood charcoals recovered at the same floor depth were dated at ~1120 cal BP (1280–960 AD, 95%) (Tab. 2). In addition, a charred seed tentatively assigned to cf. *Zea mays* recovered at 35–45cm was

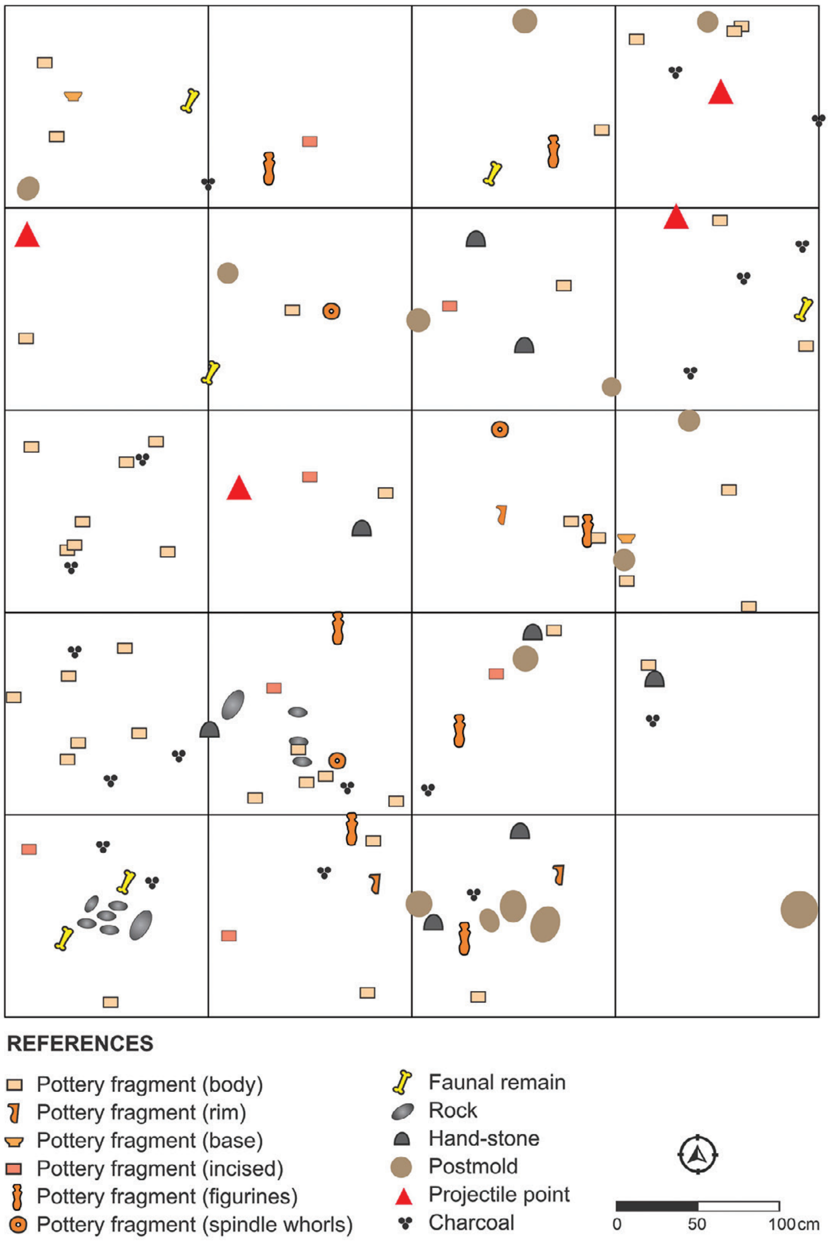

Fig. 10. Plan view of the archaeological floor of Huaycondo with the excavation units, post-molds, and key features.

dated at ~450 cal BP (500–320 AD, 95%), showing that Quebrada Norte 7 presented different occupation events across the Late Prehispanic Period (Tab. 2).

Table 2 synthesizes the archaeological record in open-air sites interpreted as seasonal base camps described above.

Discussion

The preceding review demonstrates that despite the small inventory of habitation structures, clear patterns emerge regarding the relationship between everyday domestic residences and the level of residential mobility. We observe that houses were not substantial, and their construction involved relalatively little investment. In this regard, the house features at Sierras de Córdoba generally consist of compacted archaeological floors, ambiguous hearth lenses, and post-molds. Evidence of pithouses was limited to Potrero de Garay, and the other sites show only one or a few post-molds. The scarcity of post-molds suggests that the superstructure constructed lacked an elaborate and formal design. The labour invested in such constructions and their flimsy characteristics indicate they were for short-use periods. They may have been simple huts, ramadas (sun shades), or windbreaks made from stacked brushes, grasses, and furs, such as those observed in ethnographic studies of mobile people from the early 20th century in central Argentina or even in modern times (Fig. 11. d; see *Aparicio 1931; 1932; 1937; Zamorano 1956; Katzer* et al. *2017*). Such low-cost domestic architecture implies seasonal occupation and high residential mobility. Sedentism has thus beensomewhat overstated in the archaeological narratives, and sites were not continuously used as was assumed for decades.

Domestic structures have rarely been directly dated via *in situ* post-mold radiocarbon dating as occurred on Boyo Paso 2. The available stratigraphic details and sequences of radiocarbon age estimates do not allow for the isolation of individual, periodic revisits at an ethnographic scale. Still, they do provide evidence of re-use over broader periods. For example, the excavations at Boyo Paso 2 delineated two archaeological floors or periods of use that suggest a punctuated pattern of reuse at a broad temporal scale. The radiocarbon dates of floors lacked the precision to isolate the age of the different periods of occupation. Moreover, overlapping post-molds on the upper floor and the record of a post-mold filled with sherds indicate the

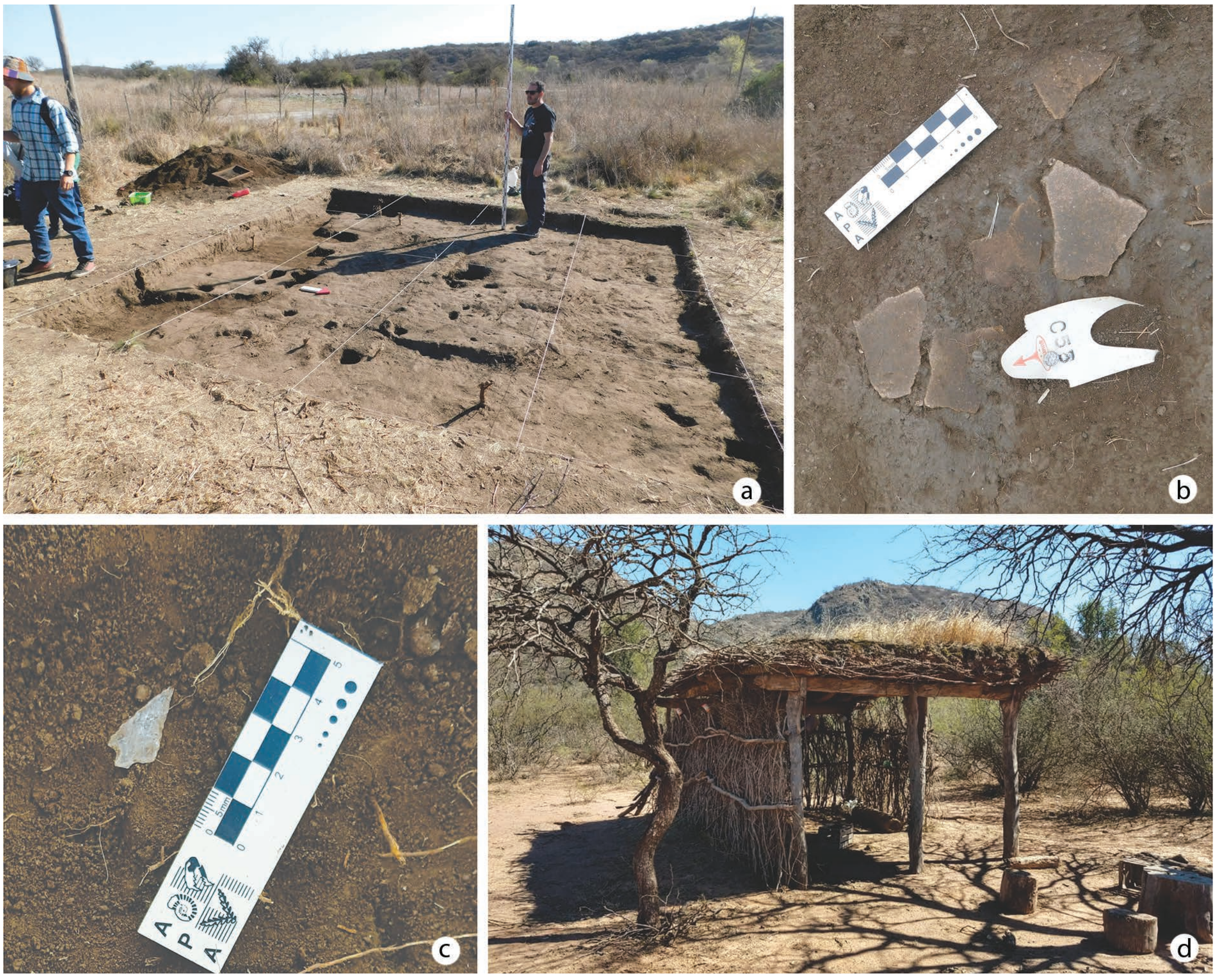

Fig. 11. The site Huaycondo and a photograph of a modern ramada (sun shade). **a** ***excavation at Huaycondo viewed from the East;*** **b** ***pottery sherds lying horizontally on the archaeological floor of Huaycondo;*** **c** ***Late Prehispanic Period chipped-stone arrow point lying horizontally on the archaeological floor of Huaycondo;*** **d** ***Ramada temporally used by modern farmers from the Departamento Juan Facundo Quiroga (La Rioja, Argentina, photo by S. Pastor in May 2021).***

reuse of the site, and that the assemblage was accumulated over different events of use. This implies that the site layout is not expressed at a scale of days or seasons suitable for being directly mapped. Therefore, treating all materials as a product of the same occupation would produce a mismatch in the scale between the behavioural dynamic of interest and the empirical evidence, since the site is a real palimpsest that averages multiple human behaviours and post-depositional processes.

The span of seven radiocarbon dates from Potrero de Garay also attests to repeated reoccupations, forming two probabilistic groups of dates suggesting that the site was intensively occupied for at least two episodes. The first group of estimates, defined by four dates with overlapping probability distributions and similar medians, dated 780–810 cal years BP. The second group, represented by three dates, occurred centuries later and had similar medians in the 410–440 cal years BP range. Assuming the estimates roughly represent when the site was occupied, the dates suggest a hiatus of nearly four centuries, indicating that the site was probably abandoned. We thus consider that Potrero de Garay also represents a palimpsest of a semi-isolated farmstead reoccupied over several centuries and not a year-round village of many clustered and integrated contemporary households, as was initially proposed by Berberián (*1984*) and claimed by Andres Laguens and Mirta Bonnin (*2009*). The lack of interior features, such as hearths may indicate warm-weather use of pithouses, an interpretation supported by the shallowness of pithouses and the faunal remains of prey with warm seasonal behaviour (see *Berberián 1984*).

In sum, the archaeological information suggests that sites encompassed a sequence of reoccupations (albeit during the same season) and post-depositional processes that made their conservation difficult because features and artefacts degraded fast due to the biological activity of the Sierra Chaco forest. Difficulties also arise when discussing the level of permanence at the sites. We have already proposed a period of occupation of two to six months, but this is purely speculative and presented solely to provide a frame of reference for ensuing discussions (*Medina* et al. *2020*). However, it is drawn from observations of durations of stay lasting ~121 days that typify people with similar dwellings who have been the subject of ethnographic study (*Diehl 1992.10*). Moreover, the identification of residues of pottery tool manufacturing on-site, an activity that implies staying in a place for several days or weeks to complete the pottery cycle, supports this argument. The exact periodicity of the reoccupation of sites is unknown and requires further research, but it may be related to the regeneration of the farming plots and wild food patches. Nevertheless, the seasonal duration of the occupations probably required only a short interval for the location to become suitable for reuse.

In our opinion, the architectural evidence reinforces the hypothesis that Late Prehispanic campsites were locations of seasonal occupations of residentially mobile people who practiced a flexible settlement pattern, especially concerning domestic architecture. The habitational structures represent informal and low-energy constructions typically expected for seasonal mobile people. Most structures, except the pithouses of Potrero de Garay, are not well-defined and are irregular in plan view. The lack of prepared or formal floors suggests they were created by mixing charcoal, artefacts, and other trash deposited during use. The superstructures appear to have been of local perishable materials, contrasting with the more elaborated and formal contemporary habitation structures of the Andean region, where groups were entirely sedentary farmers, and the use of rocks or other durable materials for house construction predominated (*e.g., Raffino 1988*).

Fig. 12. Photograph of the excavation of Quebrada Norte 7 showing the archaeological floor and the root system of trees that had grown over the site.

The lack of clear evidence for storage pits or other storage facilities suggests that the occupants did not practice long-term food storage. Because long-term storage would have been required for a year-round occupation, the sites were probably used for a few months before the residentially mobile groups had to move to a new patch. Perhaps more plausible is the idea that storage was largely aboveground and transportable, carrying a minimal surplus in pottery and basketry containers during the frequent changes in the location of the co-residential groups. The presence of large-sized vessels on-site challenges this suggestion, but they were always few in number compared to the medium-sized rounded morphologies that dominated the pottery assemblages (*Medina 2010*). Large-sized vessels may thus reflect caching in preparation for an anticipated return to sites rather than a year-round occupation strategy (see *Graham 1994; Rocek 1995; Schmader*, *Graham 2015; Roth 2016*). Although crop plant cultivation played an ancillary role, some storage would have been necessary to allow farming continuity. Storage was not at the extensive level that permitted a reduction of residential mobility or an increase in the duration of site occupation. Conversely, the Late Prehispanic people stored only for the short term, using such portable containers as globular-shaped pottery vessels, one of the most numerous artefact types represented in the archaeological record after lithic tools. Baskets and net bags were also used, even in combination with pottery vessels, though evidence of these perishable technologies is often elusive and was only identified by pottery sherds bearing impressions of basket containers (*Dantas*, *Figueroa 2010; Medina 2010; Cossani 2015; Abalos Luna 2020*).

The identification of *Rhea* spp. eggshells, small-vertebrate bones from prey that sug gest warm seasonal behaviour, crops, and wild plant remains support that Late Prehispanic villages were occupied with a

Site	Potrero de Garay	Boyo Paso 2	C.Pun.39	Puesto La Esquina 1	Arroyo Tala Cañada 1	Arroyo Las Chacras 3	Cementerio	El Ranchito	Huaycondo	Quebrada Norte 7
Excavated surface	~325m^2	55m^2	16m^2	15m^2	10m^2	9m^2	~9m^2	~12m^2	~31m^2	15m^2
Pithouses	X	–	–	–	–	–	–	–	–	–
Oval-shaped structures	X	·	·	·	·	·	·	·	·	·
Living floors	X	X	X	–	X	–	–	–	X	X
Post-molds	X	X	–	–	X	–	X	–	X	–
Post-mold alignments	X	–	–	–	X	–	–	–	X	–
Basin-shaped depressions	X	X	–	–	–	–	–	–	X	–
Refuse horizontally dispersed	X	X	X	X	X	X	X	X	X	X
Stone features (not walls)	X	X	–	X	–	–	X	–	–	–
Burials	X	–	–	–	–	–	X	–	–	–
Formal hearths	–	–	–	–	–	–	X	–	–	–
On-floor hearths	X	–	–	X	–	–	–	–	X	–
On-floor hearth by-products	X	X	X	X	X	X	X	X	X	X
Pit structures (unknown function)	–	X	–	–	–	–	–	–	–	–
Pottery making evidence	–	X	X	X	–	–	–	–	–	–

Tab. 2. Attribute list of the main characteristics of the open-air sites described in the text (an X indicates their presence on-site).

more robust signature in middle spring through early autumn (October–April), where planting, harvesting, and wild food were available around the sites (*Berberián 1984; Pastor 2007; Medina*, *Pastor 2012; Medina* et al. *2016; 2020; Recalde*, *López 2017*). Occupations during other seasons were also possible, and sites were probably used intermittently or occasionally visited for raw material provisioning on a broad temporal scale. Still, clear evidence of this is lacking (*Medina* et al. *2020*). If the houses had not been used in the winter, the evidence supports that late Prehispanic people were not following a wintering-over strategy where the entire winter was spent at a single location, which would have only been possible if long-term stores had been available. Conversely, overall data and settlement pattern survey data suggest that when harvest activities finished in early autumn, most coresidential groups dispersed for four or five months to forage resources elsewhere, collect information about their socio-environment, and maintain the sociopolitical fluidity upon which they depended to cope with environmental fluctuations. During the cold months food consumption relied on foraging wild resources, mainly the large game that inhabited the upper mountain grassland range, and on stored food partially transported from summer hamlets in portable containers (*Medina* et al. *2016*).

Conclusion

The recognition of habitation and pit features in Late Prehispanic sites has sparked diverse opinions concerning the duration of site occupation and whether long-term storage was practised. However, some hypotheses, such as those proposed by Laguens and Bonnin (*2009*), lack empirical discussion or detailed data analyses. In a recent regional synthesis, they argue that base camp occupation was sedentary, with groups living on food from storage pits and pottery. Arguments for longer-term occupations were generally supported, with a brief discussion, by the presence of presumable storage pits restricted to El Ranchito. The function of these pit features was attributed to storage by Laguens and Bonnin (*O.c.*), although without explaining why. In addition, the presence of any evidence of housing, even a post-mold or a packed floor that indicated a dwelling or other ephemeral architecture, was taken by many researchers as evidence of year-round sedentism, leading to an erroneous reconstruction of Late Prehispanic residential mobility (*González 1943; Berberián 1984; Laguens*, *Bonnin 2009*). The problem with these interpretations is that the data do not prove the existence of sedentarization, since such claims are based exclusively on negative evidence.

This paper takes a second, more empirically based interpretation, suggesting that open-air sites were campsites wherein small-scale groups with a mixed foraging and cultivation economy sporadically coalesced to carry out a wide range of activities. Nevertheless, we expect some fluctuation or variability in the length of stay at sites among the same social groups over time. For example, Potrero de Garay may have served as an episodic location for long-term occupations (for at least six to 12 months) because it appears to contain the remains of more substantial and formal structures than most in the Sierras de Córdoba sample. While extended periods without pithouse construction could result from many factors, the construction of different low-cost types of dwellings during the Late Prehispanic Period indicates a flexible landscape-use organization based on intermittent sedentism and a greater tethering or redundancy in the structure of mobility (see also *Kelly 1992; Rocek 1995; Schmader*, *Graham 2015*). Moreover, the fact that the construction techniques use for the habitations varied, including at the same site, questions any identification of a 'pithouse' based on a few architectural remains and highlights the possibility that 'pithouses' may have been an episodic house type that has been overemphasized by ethnohistoric and normative approaches rather than a common Prehispanic category. In addition, implementing low-investment extensive cultivation that did not constrain group mobility probably precluded the opportunity for extensive long-term storage. Short-term storage in medium-sized pottery vessels and basketry was thus essential to withstand the stress of a semi-sedentary lifestyle.

Archaeologists often assume that settlement and subsistence patterns followed an immutable patterned seasonal round. Less attention has been given to the tendency of many small-scale societies to show inter-annual behavioural changes (*Jochim 1991*). Indeed, ethnographic examples indicate that such a rigid view is oversimplified across the world, showing that occupation strategies can change significantly over time and that temporary shifts from farming to foraging, and *vice versa*, were common (*Jochim 1991; Layton* et al. *1991; Kelly 1992; Graham 1994; Chilton 1999; Smith 2001; Panja 2003; Hill* et al. *2008; Wheaton 2014; Ellis* et al. *2015; Schmader*, *Graham 2015; Roth 2016; Scancarello* et al. *2021*). However, the preference for normative rigid views blinded archaeologists in their understanding of the past flexibility of human groups to adjust settlement location and group size to local changing circumstances. In contrast, we interpret a mosaic of foraging and farming patterns among the broad temporal scale of the Late Prehispanic Period that did not involve all the region's people in the same ways. This view does not necessarily match paradigms that equate foraging with non-sedentary people and farming with sedentary people. The ethnographic record shows that occupational strategies were highly variable and occurred in different combinations, mainly at an evolutionary scale resolution. So, while most Late Prehispanic people occupied farmsteads during the growing and planting season, other small groups may sometimes have continued to be mobile to forage or occasionally settled in semi-permanent villages up to an entire year (six to 12 months) when conditions were suitable for farming, as probably occurred in Potrero de Garay. Farming activities were limited to field preparation using stone axes, planting, harvesting, and processing, so they did not interfere with foraging (*Medina* et al. *2016; 2020*). If a crop failed or high-return wild resources became available, the settlement technology could fall back on higher mobility or dispersion as a description of Late Prehispanic adaptability to changing conditions. These settlement patterns led to arguments for greater residential mobility for the Late Prehispanic groups residing in the Sierras de Córdoba. Seasonal settlement rather than year-round sedentism might thus account for the archaeological record of the open-air residential sites, with clear signs of a flexible settlement strategy, especially as regards the domestic architecture, which was temporary, required a low investment of time and effort, and was not intended for long-term occupation.

We concluded that the material culture, particularly architecture, follows the expectation of a settlement pattern left by groups organized as seasonal or occasional food producers that used specific locations as campsites for a few months. Pottery vessels reflect not only storage, but instead were multipurpose containers whose design constitutes a compromise in response to several performance requirements, something that would come under intense pressure within a residentially mobile setting (*Medina 2010; Heredia 2015; Carosio* et al. *2021*). Based on such evidence, the Late Prehispanic villages were formed by a few extended family reoccupations during the growing and planting season. The repeated overlapping outlines of ephemeral houses occasionally create the illusion of large, deep, and extensive archaeological site deposits that resemble the multi-household nucleated settlements of entirely sedentary agriculturalists. However, these represent semi-isolated habitational structures discontinuously reoccupied over several centuries by a small-to-medium-sized group that practiced flexible land use and a mixed subsistence strategy. As such, the settlements were small, dispersed, and provisioned, contrasting with the classic view supported even by Laguens and Bonnin (*2009*) of permanently settled agricultural villages. According to this view, the Late Prehispanic Period record reveals a messy settlement and subsistence pattern in time and space, where flexibility was one of its defining straits. It is now time to dispense with rigid cultural classifications that ignore the fact that evolutionary change is not unidirectional, and to replace them with the recognition that the ability to move between subsistence and mobility strategies was an expected behaviour in the past. Archaeologists must rely on a flexible approach that seeks to balance suites of evidence and ethnographically derived models, addressing how to increase our understanding of where a mixed foraging and cultivation economy should be expected and what the archaeological consequences of such flexibility might be. Once we accept this perspective, then the Late Prehisnic cultural process's with regard to settlement variability and high dynamism will be more clearly understood.

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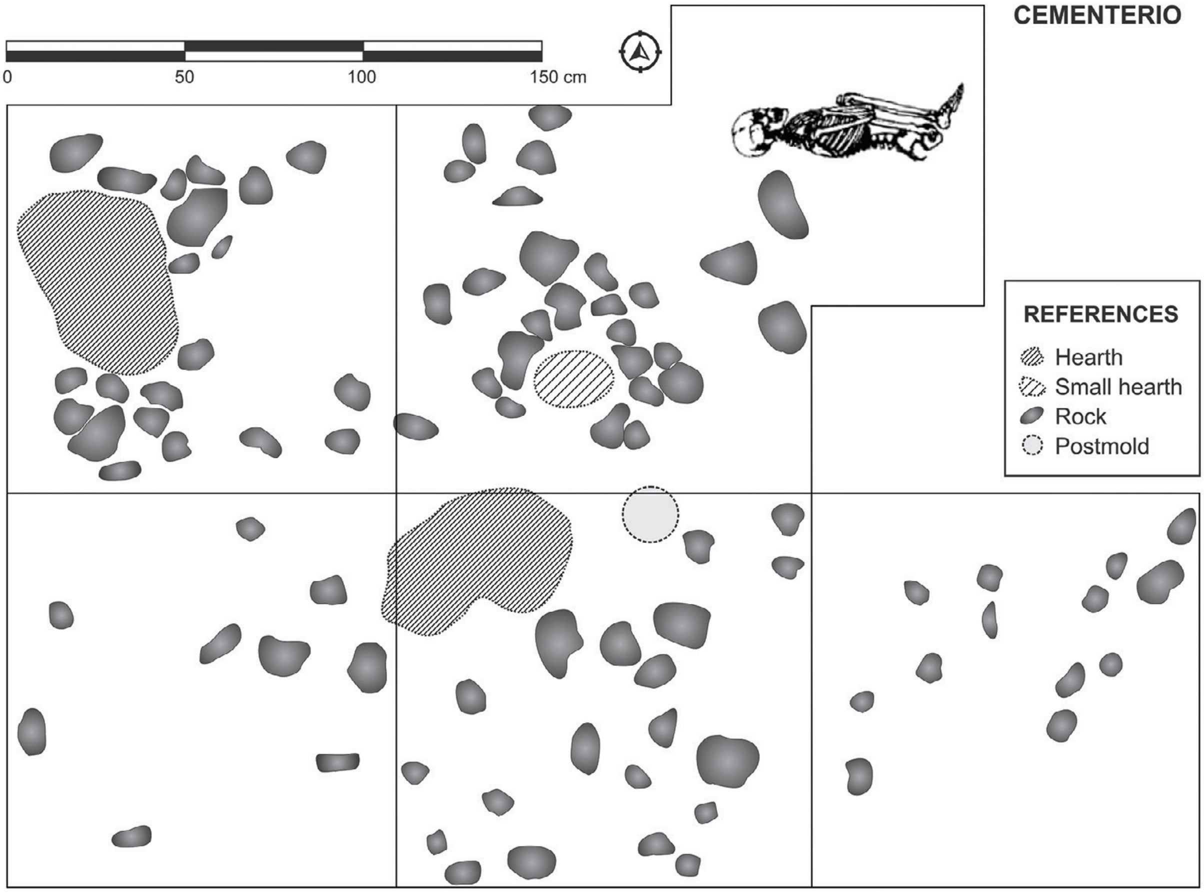
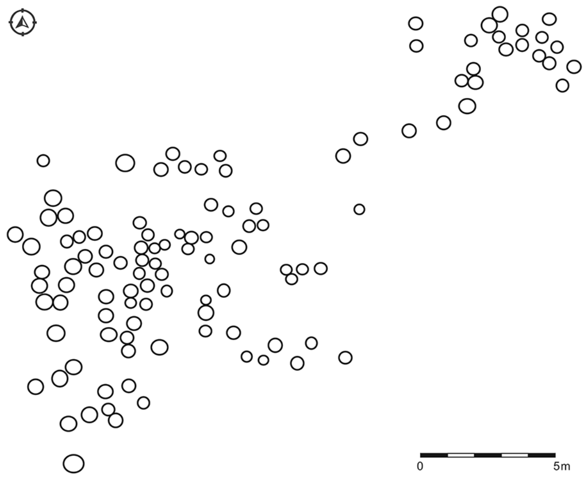
Appendix



Appendix Fig. 1. Plan view of Cementerio with the excavation units, post-molds, and critical features (taken from* Laguens, Bonnin 2009*).



Appendix Fig. 2. Plan view of the pit structures from El Ranchito (taken from* Laguens 1999.99*).

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A multi-embankment Chalcolithic walled enclosure: new insights from the usage of remote sensing in archaeological surveys (Ota, Western Portugal)

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ABSTRACT - *Ota, a key part of the Chalcolithic walled enclosure phenomenon in Portuguese Estremadura, represents a unique settlement strategy within the actual territory of Portugal. The architecture and social dynamics of this site remained largely unexplored until 2019. This study marks a significant shift in its study, utilizing a synergistic approach of archaeology and geotechnologies, embodied in the using an Unmanned Aerial Vehicle equipped with LiDAR. This innovative combination successfully penetrated the dense vegetation, revealing 21 previously unknown archaeological features. The results from the fieldwork unveiled a novel type of walled enclosure at Ota, characterized by a series of four embankments. This discovery prompts a re-evaluation of the roles and practices of 3rd millennium BC communities in Portuguese Estremadura. Furthermore, the proven efficacy of this methodology paves the way for its application in similar archaeological contexts. The paper presents a comprehensive analysis of the recent fieldwork, integrating interpretations from LiDAR data, material studies and ^{14}C dating.*

KEY WORDS – *remote sensing; archaeological methodology; Chalcolithic walled enclosures; Portuguese Estremadura; LiDAR analysis; Unmanned Aerial Systems (UAS)*

Bakrenodobno obzidje z več nasipi: nova spoznanja o uporabi daljinskega zaznavanja pri arheoloških raziskavah (Ota, zahodna Portugalska)

IZVLEČEK – *Ota, ključni del fenomena bakrenodobnih ograd v Estremaduri, predstavlja edinstveno strategijo poselitve na ozemlju Portugalske. Arhitektura in družbena dinamika tega najdišča sta ostali skoraj neraziskani do leta 2019. V študiji predstavljamo pomemben premik v raziskavah, ki temeljijo na sinergiji arheologije in geotehnologije in uporabi drona, opremljenega z LiDARjem. Inovativna kombinacija je omogočila prodreti skozi gosto vegetacijo in odkriti 21 doslej neznanih arheoloških struktur. Te predstavljajo nov tip ograjenega prostora z nizom štirih nasipov. Odkritje omogoča novo oceno delovanja in praks skupnosti iz 3. tisočletja pr. n. št. v portugalski Estremaduri. Dokazujemo učinkovitost te metodologije in utiramo pot njeni uporabi v podobnih arheoloških kontekstih. V prispevku celovito predstavljamo nedavno terensko delo, ki vključuje interpretacijo lidarskih podatkov, analizo materialne kulture in ^{14}C datiranja.*

KLJUČNE BESEDE – *daljinsko zaznavanje; arheološka metodologija; bakrenodobne ograde; portugalska Estremadura; LiDAR analiza; dron*

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The 3rd millennium BC walled enclosure phenomenon in Portuguese Estremadura, focusing on the Ota archaeological site

Archaeology is continually propelled forward by the development of new theoretical frameworks, technologies, and methodologies. However, some areas of study prove more resistant to change, primarily due to the absence or invisibility of data. This is particularly true for the study of the 3rd millennium BC walled enclosure phenomenon in Portuguese Estremadura. During the Chalcolithic period, profound anthropogenic changes occurred in this region's landscape, manifested in new sites characterized by strategic hilltop locations offering extensive visual control over their surroundings (*Soares 2013*).

These sites, known as walled enclosures, were typically connected to watercourses that served not only as food and raw materials sources, but also as means of communication and connection with other areas and social networks (*Kunst 2010*). The architectures and construction techniques of these sites are distinctive, giving rise to a phenomenon that encloses sites up to five hectares in area with walls, towers and gates, made with the use of the dry-stone technique, putting stone on stone without binding elements (*Cardoso 2010*).

To date, twenty-two such enclosures have been identified in Portuguese Estremadura. However, the phenomenon is not limited to this region, with sporadic examples in northern and southern Portugal, such as Castanheiro do Vento (*Ramos-Pereira* et al. *2020*), São Pedro (*Mataloto 2010*), and Santa Justa (*Gonçalves 1989*). A similar pattern emerges in Spanish Extremadura, particularly in Tierra de Barros (Badajoz Comarca, Spain), which hosts approximately five dozen walled enclosures. Due to their size or complexity, sites like Cortijo Zacarías, Las Mesas, San Blas, and Palacio Quemado have gained some fame (*Hurtado, Odriozola 2009*).

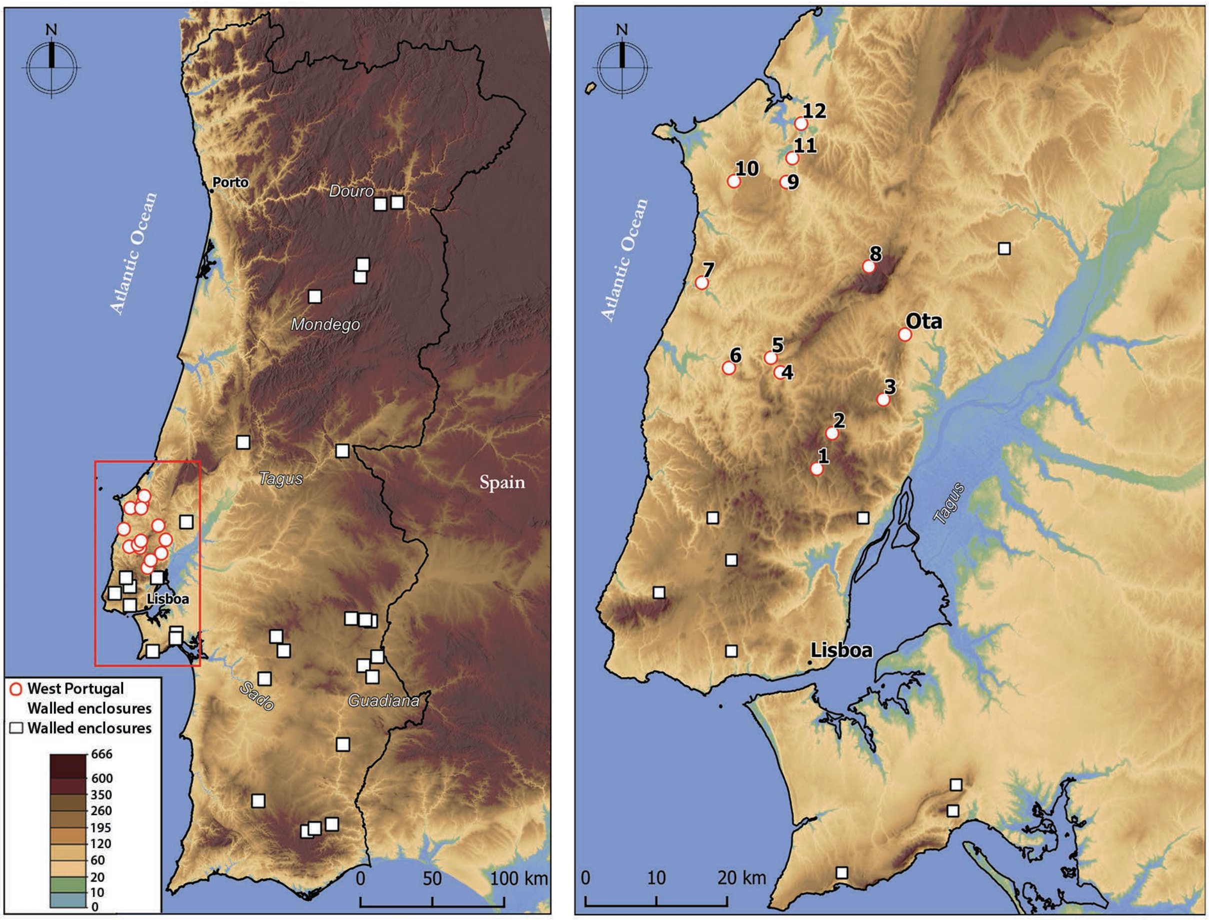

Fig. 1. Distribution of walled enclosures in Portugal (*a*) zooming in on the western cluster (*b*), where the Ota archaeological site is located. The sea level reconstruction is based on Lord* et al. *(*2011*).* 1 *Moinho do Custódio;* 2 *Castelo;* 3 *Pedra d'Ouro;* 4 *Penedo;* 5 *Fórnea;* 6 *Zambujal;* 7 *Pitagudo;* 8 *Pragança;* 9 *Columbeira;* 10 *Paço;* 11 *Outeiro de S. Mamede;* 12 *Outeiro da Assenta.

Besides these regions, Andalusia (Spain) is also notatable, housing the second-largest aggregation of such sites, including prominent enclosures like Cabezo de los Vientos de la Zarcita and Los Millares (*Molina, Camara 2005*). In other Spanish regions, namely Murcia, Valencia, and Castilla y León, fewer than five enclosures have been detected.

The common characteristics that these sites exhibit across Estremadura were identified in the early phases of Portuguese archaeology. Consequently, the documentation and excavation of many of these sites date back to the transition between the 19th and 20th centuries, which complicates new interpretations of the archaeological contexts. The age of the data also influences interpretative approaches to these sites, predominantly suggesting that walled enclosures represented settlements marking the commencement of a sedentary path in prehistoric communities, with increased social complexification (*Gonçalves* et al. *2013*). Adding to this idea, most scholars who have studied this phenomenon suggest it is related to the emergence of ideas of ownership and borders, used to justify possible intergroup tensions. This is thought to create a hostile environment, hence the need for 'defensive walls' (*Kunst 2006*).

Recent data, mainly retrieved from the Walled enclosure of Ota (Alenquer, Portugal), illustrates that there seems to have been an overvaluation of specific contexts and data from already excavated sites (such as Zambujal, in Torres Vedras). By using new excavation and recording methodologies, the archaeological site of Ota has shown that new narratives might apply to this social phenomenon, with a lot of data sources still hidden under the dense vegetation.

Refocusing on the Portuguese Estremadura, although this could be understood as a cohesive cultural whole during the 3rd millennium BC, it can also be subdivided into sub-regions to allow a more focused assessment of regional and social dynamics. Even though these division are mainly defined by contemporary and artificial criteria, they also materialize past socio-cultural behaviours.

One such area is the western region, the focus of the current study. Here a minimum of ten sites with walled enclosure features were identified, thereby constituting the largest cluster of the entire Portuguese Estremadura. However, while mimicking the broader Estremadura walled enclosure phenomenon, some more localized behavioural patterns can be noted, possibly influenced by the Montejunto Hill. This 666-metre-high hill forms a significant NE-SW geological feature that not only shapes the landscape but also plays a central role in the cultural milieu of the surrounding areas (*Basílio, Texugo 2017*).

Montejunto's prominence is also crucial, as it sources many of the rivers in the western area, such as the Judeu stream and the Ota, Real and Alcabrichel rivers. These watercourses played a decisive role in shaping the human landscape of the 3rd millennium BC, with several wall enclosures built along their courses. Montejunto was also recognized as a symbolic landmark of rituality, ancestry, and death during the 3rd millennium BC, with its natural caves playing an active funerary role since at least the 5th millennium BC, as noted at Algar do Bom Santo (*Carvalho* et al. *2019*).

The archaeological site of Ota

Located in the Portuguese Estremadura, the archaeological site of Ota is, along with 22 other sites, part of the 3rd millennium BC walled enclosure phenomenon. Dominated by Mesozoic sedimentary rocks interspersed with Cenozoic sediments, the hilltop in which Ota is located provided the raw materials – limestones, sands, and clays – that shaped the area's architectural and artefactual history (*Ramos-Pereira* et al. *2020*). The landscape itself, characterised by a mix of mountains, hills, plateaux, plains, and coastal platforms, especially pronounced around Montejunto Hill in the west, plays a significant cultural and physical role (*O.c.*).

Paleoenvironmental studies from the early Holocene indicate initial meaningful anthropogenic impacts on regional vegetation around 5400 BC, marked by the onset of cereal growing. This period also saw stable sea levels and coastlines from 9300 BC to 2900 BC, with notable periodic floods that evolved with ongoing marine transgression (*Lord* et al. *2011*). The Chalcolithic climate was similar to the modern climate of Estremadura: a hot-summer Mediterranean climate, with average temperatures around 17°C and annual precipitation ranging from 700mm to 900mm (*Mora, Vieira 2020*).

Vegetation over the hilltops, including at Ota, consists predominantly thin soils specimens, namely dense thickets of *Quercus coccifera*, *Olea europaea var sylvestris*, *Rubus ulmifolius*, and *Pinus pinaster*, with occasional *Eucalyptus globulus*.

Fig. 2. Ota's vegetation cover and implantation. Left, view from the west towards Ota; right, aerial view.

Historically speaking, Ota archaeological site was discovered and excavated in 1932 by a local archaeology enthusiast, Hipólito Cabaço. At the time, the vegetation that covered the archaeological site was less dense due to the community grazing practices. While Cabaço's excavation efforts remain largely undocumented, later references by archaeologist Ernâni Barbosa (*1956*) provided some insights into the site's material culture, structures and possible context, yet without specific geographical details.

Post-1956, Ota has been intermittently referenced in academic discussions concerning specific artefacts, with comprehensive studies focusing exclusively on the site architectures and social dynamics. The recent re-engagement with Ota, initiated through Alenquer Municipality's Participatory Budget, aimed to fill the gaps in this knowledge by focusing on its Chalcolithic context, thought to be linked to the broader walled enclosure phenomenon (*Texugo, Basílio 2018*).

The results confirmed the existence of several occupation phases, with the most visible period corresponding to the 3rd millennium BC, alongside Roman Imperial materials. Sporadic occupations can be traced to Bronze and Iron Age, with some Medieval artefacts (*Texugo 2016*). New field surveys have managed to relocate eight structures and georeference 150 classifiable materials, with the findings still falling short when compared to the descriptions reported by Barbosa (*1956*).

Methodology

Aerial photography

Given the limited visibility due to dense vegetation at Ota, historical aerial photographs from the 1956-1958 USA Army Map Services Flight B were analysed. These photographs, taken at a 1:10500 scale from an altitude of 5000 to 9000 metres, have been digitized in TIFF format with a resolution of 21 microns. This dataset, along with open-access historical and current aerial images and topographic maps, allowed for the collection of detailed historical, landscape, and cultural data about the site. This proven methodology (*Ortega* et al. *2013*; *Pérez* et al. *2014*) was applied on an intra-site scale to identify preserved architectures at Ota.

Field surveys

Field surveys were conducted following the identification of potential archaeological anomalies. A 50x50m grid was established over areas of highest potential, with selective and systematic surveys conducted only in areas where anomalies were identified (*Foard 1980*). Surveyors maintained a parallel spacing of 5m, moving in a south-north orientation. Despite potential occurrences of anomalies, visibility was significantly hindered by dense vegetation.

Aerial surveys

The use of Unmanned Aircraft System (UAS) platforms facilitated the development of a Digital Surface Model (DSM) for the site. A DJI Phantom 4 Pro captured images, which were processed in DroneDeploy to standardize photograph settings. The 3D model generated via photogrammetry provided centimetric resolution, allowing detailed analysis of the site's surface features.

LiDAR (Light Detection And Ranging) technology was also employed using a DJI Matrice 600 Pro equipped with a Phoenix LiDAR Scout-8. This system scanned the site, producing a detailed digital terrain model (DTM) from which 201 495 048 data points were generated across three returns, with a point density of 367 points per square metre. Post-processing involved classifying points using SpatialExplorer 5.0.2, with additional steps to refine the data (*Zhang* et al. *2016*).

Field confirmation
Field confirmation of LiDAR interpretations involved targeted archaeological surveys and excavations at detected anomalies, following methodologies established by Barker and Harris (*Harris 1989; Barker 1993*). These excavations aimed to understand the architectural and chronological context of the anomalies, with each area being meticulously recorded and described.

Fig. 3. LiDAR data acquisition system:* a, b *in-site base station;* c *Data acquisition with a DJI Matrice 600 Pro.

Mission	Total points ($x10^6$)	Ground points ($x10^6$)	Ground Points %	Area (km^2)	Ground Points/m^2
Ota	201	35	17.4	0.1	64

Tab. 1. File statistics from the UAV LiDAR mission.

Results

Integrating various remote detection products provided a solution to the dense vegetation at the Ota archaeological site, essential for selecting excavation areas in 2019 and 2020. By leveraging traditional and innovative technological approaches and methodologies, this approach made it possible to overcome the challenges posed by Ota's dense vegetation and complex terrain, simultaneously bringing to light new data concerning the presence and preservation rate of hidden prehistoric features. With this method, 21 anomalies with high archaeological potential were identified. Three of them correlate with earlier 20th century excavations, one might correspond to a wall-like structure, and the remaining 18 correspond to so far unknown archaeological features with different typologies. Initial field campaigns attested the archaeological significance of five of these anomalies:

Structures 1 and 2 (Anomalies 1 and 2)
The first field campaigns began with the site's most prominent and visible feature: the large encircling wall, crucial for understanding the site's role during the 3rd millennium BC. With two distinct survey areas, spaced 150 metres apart and covering a total area of $38m^2$, the wall's external face was revealed, alongside construction solutions with regard to bedrock manipulations to achieve greater structural stability. Other modifications included possible efforts to redesign the structure, or even abandonment phases.

The wall's architecture, as detected at Survey 1, involved a gently sloping limestone layer topped by a five-metre wide wall of large limestone blocks on its exterior face, filled with smaller stones, replicating regional construction methods. This setup suggested multiple construction phases, akin to the findings at Zambujal. More than just walls, the findings at Ota include embankments that, while linking it to other walled enclosures, also set it apart due to their unique implementation and functionality.

Survey 2 aimed to clarify the relationship between the wall (Structure 1) and a potential tower (Structure 2). The complex dynamics where these structures met also highlighted the different construction techniques: Structure 1 was made almost exclusively out of stones, while Structure 2 was made from a combination of limestone and clay levels. The excavation area also showed unstructured stone clusters, suggesting that there might be an extended façade beyond the survey limits. Like Survey 1, the second survey confirmed anthropic modifications to the bedrock.

Structure 3 (Anomaly 20)
Structure 3, identified as a negative structure via field surveys and LiDAR, corresponds to a feature already examined by Hipólito Cabaço, though records of its original discovery remain elusive. This circular structure incorporates both natural limestone and constructed elements, using techniques already seen in

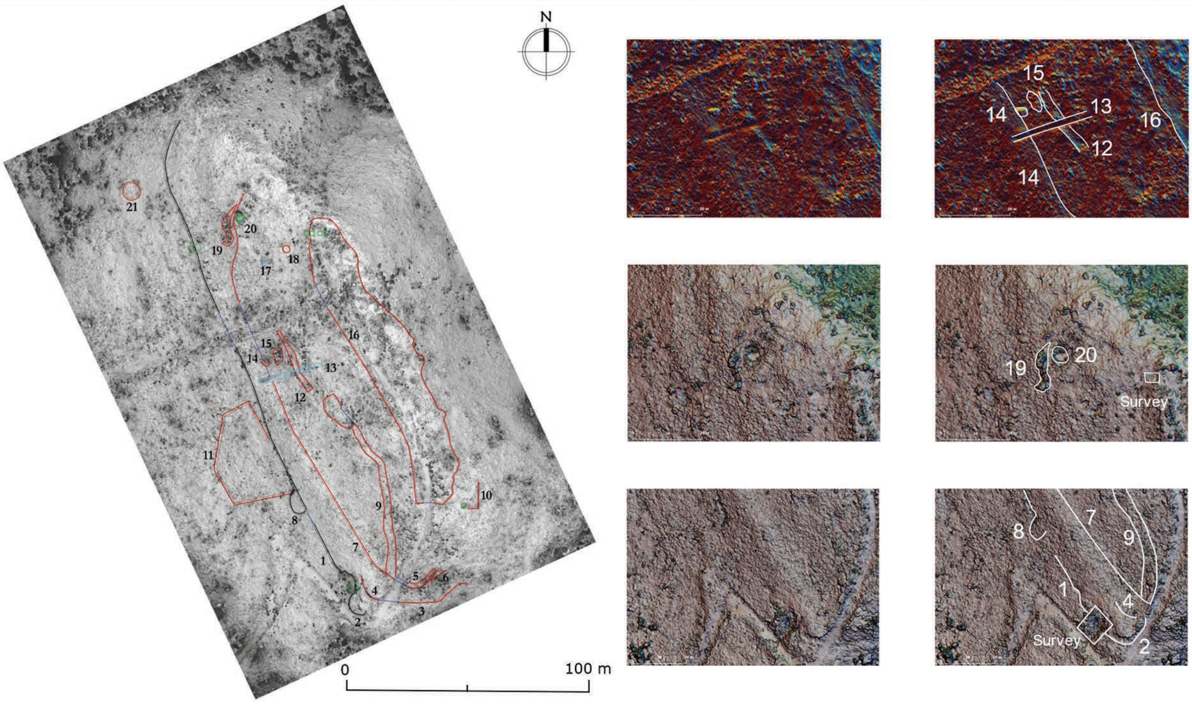

Fig. 4. LiDAR anomalies at Ota, mentioned in the text, with three close-up examples. **a** *Cabaço's intervention;* **b** *possible negative structures;* **c** *anomalies detected in the site's access area.*

Structure 1. Its excavation aimed to clarify the earlier dig processes and gather any remaining data, revealing a still well-preserved clay level that had shielded the base and parts of the structure's walls.

The analysis of surrounding detritus confirmed the selective past excavation practices: undecorated sherds and unidentified faunal remains. This artefactual set deeply contrasts with Cabaço's collection, composed

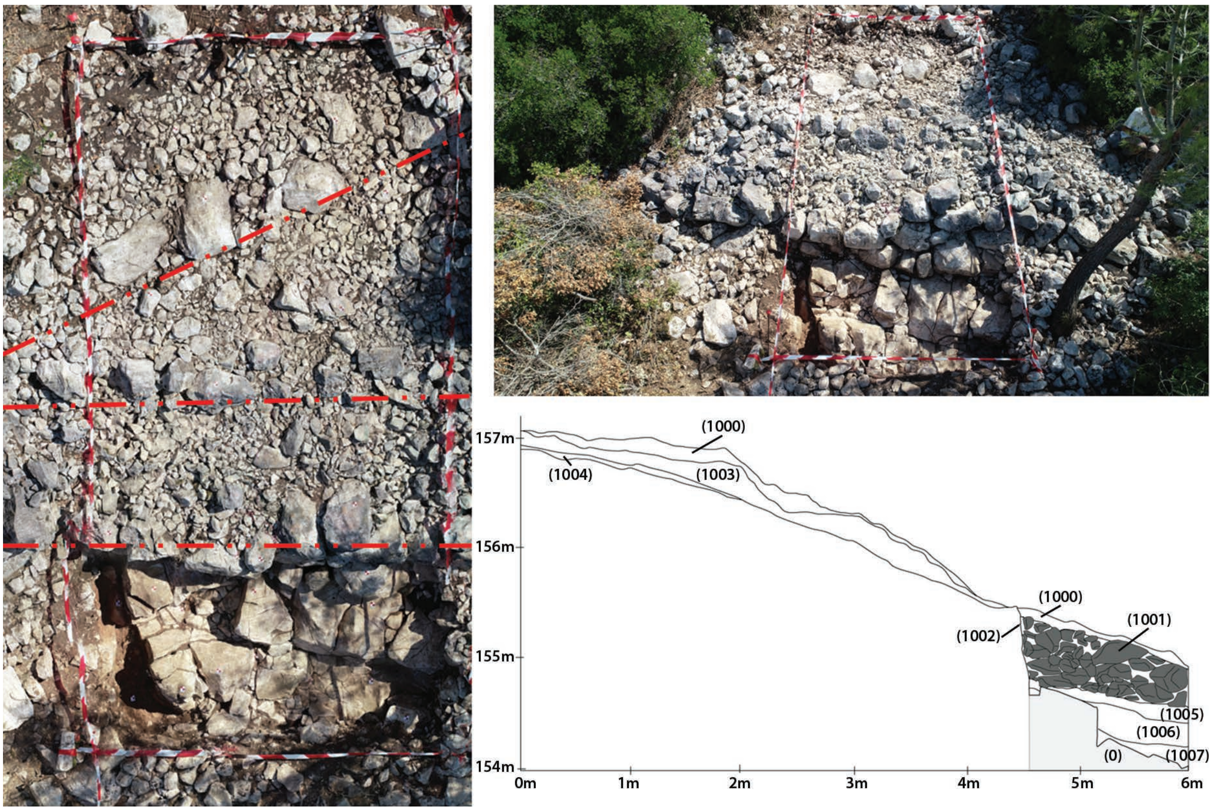

Fig. 5. Possible wall alignments and final records of Structure 1 (Survey 1) (photo/section).

by exceptional artefacts, highlighting a disconnection between field findings and archived pieces.

Structure 8

On the hilltop, Structure 8 was part of a cluster identified in the lower part of the elevation, notable for its stone agglomerations forming circular patterns. The excavation faced challenges, due to altered contexts and soil compositions caused by a recent fire. This hampered analysis of the structure's function and dating, but the lack of prehistoric materials suggests a more recent origin.

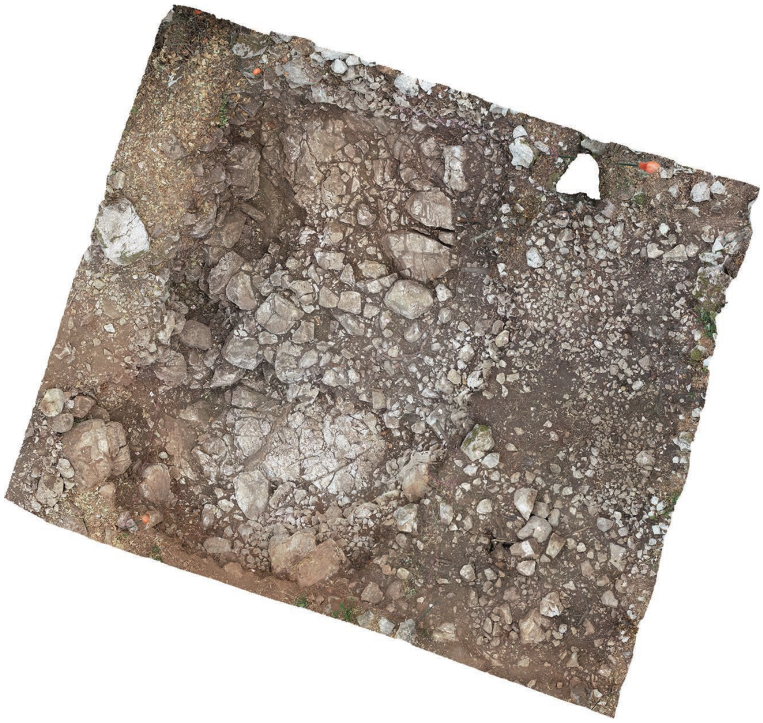

Fig. 6. 3D model of Ota's Structure 1, from Survey 2, with the beginning of Structure 2 in the bottom section of the image.

Structure 9 (Anomaly 16)

LiDAR data prompted the Structure 9 survey, to attest the existence of preserved stratified deposits and confirm the relationship between natural and constructed features. Situated between two terraced levels, the excavation did not reveal significant deposits but highlighted the adaptive reuse of natural limestone formations for structural purposes, indicative of sophisticated prehistoric architectural strategies.

Remaining LiDAR anomalies

Further LiDAR analysis revealed roads cutting through the site, one possibly dating back a century and another serving as a historical access route. These features, along with detected negative reliefs, suggest more complex site dynamics than previously understood, potentially linked with unrecognized structural elements or past interventions. These structures are currently being studied on an ongoing research project.

Fig. 7. 3D model of Ota's Structure 3.

Discussion

Cabaço's archaeological campaigns at Ota made it possible to build an extensive material collection, which lacks contextual information (*Barbosa 1956; Álvarez, Pérez 2013; Basílio, Texugo 2017*). Still, and only based on the materialities of the site, it is possible to comprehend that Ota has:

- A wide material diachrony, from the Chalcolithic to the Medieval period;
- A Chalcolithic human occupation that develops at the top and west side of the hill with;
- The exclusive presence of decorated materials;
- Specialized production of flint tools;
- Habitat materials and possible funerary elements;
- Presence of metallic tools;

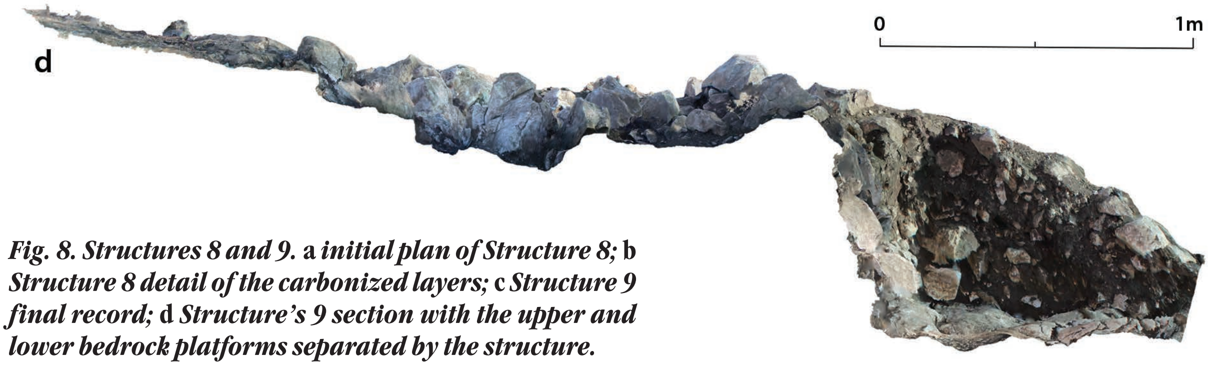

Fig. 8. Structures 8 and 9. a ***initial plan of Structure 8;*** b ***Structure 8 detail of the carbonized layers;*** c ***Structure 9 final record;*** d ***Structure's 9 section with the upper and lower bedrock platforms separated by the structure.***

• A Late Bronze Age presence (five axes and two spearheads);
• A Roman occupation, as the second most significant presence on the site, with Republican and Imperial materials and imported ceramics and metallic elements.

This interpretive framework has undergone profound changes, with new fieldwork and LiDAR results, which complexify the image of the Chalcolithic communities of Ota's archaeological site. Adding to it, it was possible to access and confirm the suitability of the methods applied here. By combining traditional archaeological techniques and geotechnologies, different architectures were unveiled under the vegetation, enlarging the number of possible archaeological anomalies and the existing knowledge of past communities. As such, and since this methodology has proven its value in the Ota case study, it is currently being applied in other regional walled enclosures.

Walls, terraces, and entrances

The narratives built for sites with similar architectures to Ota have historically focused on the role of walled enclosures as defensive mechanisms, reflecting the tumultuous social dynamics of the Portuguese Estremadura during the 3rd millennium BC. This perspective posits the structures as fortifications against social tensions exacerbated by demographic shifts (*Kunst 2010; Gonçalves* et al*. 2013*). However, recent findings suggest these structures could have served various functions, reflecting significant periods of construction and adaptation rather than a single period of fortification in response to warfare.

At Ota, Structure 1 was previously considered a straightforward defensive wall. Current evidence, however, indicates it underwent multiple transformations that reflect broader regional trends of architectural and social complexity (*Jorge 2003; Kunst, Arnold 2011*). This structure not only delineated space but also served as a communal focal point throughout various occupational phases, including a Roman period that repurposed materials from earlier structures.

Lab.	Sample	Context	BP date	Cal BC (2 σ)
Beta-561854	*Ovis/capra* rib	Structure 1 [1006]	3960±30	2571-2516 (32,8%) **2502-2400** (52,7%)
Beta-568786	*Capra hircus* horn	Structure 3 [1103]	3970±30	2383-2347 (10%) **2574-2444** (87,6%) 2424-2404 (3,3%)
Beta-612398	*Sus* sp. phalanx	Structure 3 (exterior) [1120]	3860±30	2379-2350 (4,6%) **2460-2276** (80.3%) 2256-2206 (15.1%)
Beta-612399	*Bos* sp. phalanx	Structure 3 [1115]	3990±30	**2577-2459** (95.4%)
Beta-612400	*Sus* sp. cranium	Structure 3 (exterior) [1120]	3980±30	**2576-2454** (93%) 2372-2356 (1.4%) 2418-2408 (1%)
Beta-612401	*Sus sp. tooth*	Structure 3 (exterior) [1120]	4000 30	**2579-2463** (95.4%)

Tab. 2. Radiocarbon dates from Ota.

The dynamic reuse and modification of Ota's structures suggest a continuous, layered history of occupation and functionality, challenging the notion that these were exclusive throughout its whole architectonical life. The complex construction patterns that have been observed – marked by different use, abandonment and repurposing phases – align Ota with other regional sites, indicating a shared architectural and cultural heritage across Estremadura. That needs to be seen through new, less warlike, lenses.

The layout of Ota, particularly Structure 1, points to a sophisticated history of use, possibly aligned with both defensive and social needs. The structure's strategic placement and construction techniques reflect a nuanced understanding of landscape and community safety. The presence of this structure at a key vantage point suggests it could have been integral not just for defensive purposes, but possibly to control local resources, routes and social practices.

Moreover, the architectural similarities between Ota and other regional sites underscore a possible shared cultural identity and unity that contradicts the hypothesis of widespread social unrest due to external threats. These enclosures likely facilitated complex social interactions, including trade and cultural exchanges, rather than merely serving as barricades against invaders.

The interpretation of Ota's embankments and terraces through LiDAR surveys reveals an adaptive approach to environmental and social challenges. These features, possibly unique to Ota, highlight an advanced capability with regard to modifying landscapes to suit agricultural and habitation needs, suggesting a socially organised community capable of significant engineering projects.

This perspective is reinforced by the discovery of multiple terraces and interconnected structures that highlight the integration of natural and anthropogenic features at Ota, with a balance between environmental adaptation and cultural development.

The reconsideration of Ota's structures, particularly the multi-functional use of what were once thought to be purely defensive walls, offers new insights into the social and architectural sophistication of Chalcolithic Estremadura. This case study not only challenges traditional interpretations of prehistoric settlements but also highlights the importance of integrating technological advances like LiDAR with archaeological methodologies to uncover deeper understandings of past societies.

Reevaluating Ota's funerary context: the case of Structure 3

If there seems to be a monothematic research interpretation for walled enclosures as defensive sites, it is also accepted that there is a clear spatial segregation between the world and structures of the living and those ascribed to the dead, like funerary sites (*Kunst 2010; Cardoso 2010; Sousa 2010; Gonçalves* et al. *2013; Texugo 2022*). This perspective reflects, once again, modern biases more than ancient realities. The recent findings in Ota challenge this dichotomy, revealing a more nuanced interplay between life and death within these ancient communities.

Structure 3, initially undistinguished in its role, has prompted a significant rethinking of the site's use. Unlike other structures within the enclosure, it uniquely combines architectural features and artefacts typically associated with funerary contexts – such as Palmela arrowheads, zoomorphic figures, and human remains – suggesting it served as a burial site (*Álvarez, Pérez 2013*). Its circular design, crafted through careful manipulation of the bedrock and enhanced with a clay covering, points to intentional construction for ritualistic purposes. This is further supported by radiocarbon dating, aligning it chronologically with other late Chalcolithic contexts within Ota, and with other funerary contexts.

The discovery of Structure 3 offers a compelling case for reconsidering other ambiguous structures throughout Estremadura. Sites like Olelas, Penha Verde, and Pedra de Ouro, previously reinterpreted as non-funerary despite early evidence of burial practices, may need revaluation considering the findings at Ota. This shift could signify a broader pattern of funerary practices within these enclosures, suggesting a complex relationship between the living and the dead that has been overlooked in previous research.

Ota's case illustrates the potential misinterpretations caused by modern assumptions and highlights the need for a more flexible agenda when studying Chalcolithic social structures. The ongoing investigations into Structure 3 and similar sites will continue to challenge and refine our understanding of these ancient communities, potentially redefining the function and significance of walled enclosures in the Chalcolithic landscape of Portuguese Estremadura.

Conclusions

The symbiosis between archaeology and geotechnologies has dramatically altered the perception of the Ota archaeological site. Even with limitations, the effectiveness of remote sensing using LiDAR technology was once again attested with this study, meaning that these methods and techniques can be used for the identification of intra-site architectures in other archaeological sites in densely vegetated Mediterranean landscapes (*Cerrillo-Cuenca, Bueno-Ramirez 2019)*.

As for the Ota archaeological site, we show that it has distinct characteristics and rhythms:

- Instead of the typical walls, Ota has at least two confirmed embankments, which increase and stabilise the usable area within the site;
- The terraces show different biographies and have undergone distinct taphonomic processes. The embankment delimited by Structure 1 seems to be dated from somewhere before the 3rd quarter of the 3rd millennium B.C.
- In Ota, human resilience over time is materialized in a symbiosis between natural realities and anthropic structures;
- Within the enclosure defined by Structure 1, a possible funerary architecture has been identified (Structure 3), reflecting a so far unknown social practice in enclosures of the same period.

The interpretation presented for Ota does not set it apart from the Chalcolithic walled enclosure phenomenon of the Portuguese Estremadura (*Gonçalves* et al. *2013*). On the contrary, it serves as an example of an alternative interpretation of the structures and the cultural environment when these sites appeared, were used, and collapsed (*Jorge 2003)*.

Ota's excavated area is still small. However, as with other archaeological phenomena, the inscription and belonging to the same sociocultural reality can be expressed in multiple ways, Ota being an example of this multiplicity and plurality, as well as how different sciences and methods can work together and be applied to the development of the existing knowledge about past communities.

Geolocation information

Ota is located at 39.114983, –9.000754 (datum WGS 84) at Alenquer municipality on Lisbon district – 50km to the north.

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The long and winding road: object biographies and cultural encounters in the Western Mediterranean during the Late Iron Age

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ABSTRACT - *In this paper we address the biography of a set of copper nails recovered in 1998 from a Late Iron Age structure located at the archaeological site of Puig de Sa Morisca (Mallorca, Spain). The archaeometric and typological analyses conducted on these nails allowed us to relate them to nautical technology, as well as to approach the origin of the raw materials and the production processes involved in their manufacture. The biographical information obtained from these studies has been crucial to address the extensive mobility of these copper nails through the Western Mediterranean during the Iron Age, as well as to approach their fluid nature and association with different communities of practice, assemblages and appropriation phenomena.*

KEY WORDS – *object biographies; Iron Age; cultural contact; Western Mediterranean; entanglement theory*

Dolga in vijugava pot: biografije predmetov in kulturni stiki v zahodnem Sredozemlju v mlajši železni dobi

IZVLEČEK – *V prispevku obravnavamo biografijo zbira bakrenih žebljev, ki so bili leta 1998 najdeni v strukturi iz mlajše železne dobe na arheološkem najdišču Puig de Sa Morisca (Mallorca, Španija). S pomočjo arheometričnih in tipoloških analiz jih povezujemo z navtično tehnologijo, ugotavljamo izvor surovin in postopke njihove izdelave. Biografski podatki, ki so jih pridobili s temi študijami, so ključni pri analizi njihove široke razširjenosti in raznolike možnosti uporabe v zahodnem Sredozemlju v železni dobi.*

KLJUČNE BESEDE – *biografije predmetov; železna doba; kulturni kontakti; zahodno Sredozemlje; teorija prepletenosti*

Object biographies: the flow of things in the flow of social relationships

Just like people, objects have biographies. An analysis of certain objects' biographies can lead to the development of different perspectives (*Gosden, Marshall 1999; Rainbird 1999; Joy 2009; Van Dommelen, Knapp 2010*), with the processes of transformation stemming from the movement and exchange of material culture traditionally being the most researched line. Many objects move along with people, and they tend to be as-

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sociated with certain individuals or groups over different periods of time. Such objects can change hands and be related to one community and culture or another. During this movement and transition, from the moment they are born until they die, objects are used, in their own way, as things as alive as human beings, taking on social lifecycles and biographies that link them to different contexts, situations, objects, and people. Throughout their history, and the multiple interactions they have with humans, the objects are reshaped, and they change based on how they are perceived, valued, and given meaning, sometimes even changing in appearance and function (*Hahn 2004a; 2004b*). In their transition, these objects can be linked not only to the lives of the persons involved in their way, but also to mythologies and specific stories over different spatial-temporal scales and successive social contexts *(Kopytoff 1986; Thomas 1991; Hoskins 1998; Hamilakis 1999*).

The mutation of objects can take place at the heart of one culture but be especially tangible and impactful when the object transitions to other societies *(Gosden, Marshall 1999; Seip 1999*), that is, when there is significant sociocultural distance between the contexts of production, distribution, and consumption. While there may be points of connection between the various agents involved in these steps, it is in the contexts of cultural transition, loaded with contingency, in which the metamorphosis of these objects becomes associated with significant alterations to their meaning (*Seip 1999*) and different value schemes (*Appadurai 1986*). What is important in these situations of cultural contact is not necessarily the adoption of the object itself, but the redefining of the object and giving it a new life (*Moreland 1999*), thus constructing a central element from hybrid practices and the intermediate spaces that come about as a result of the cultural contact.

The processes of hybridization that these objects undergo in these situations are related to the phenomena of appropriation, incorporation, and transformation (*Hahn 2004a; 2004b*). *Appropriation* refers to the changeover of objects or materials that end up in the possession of individuals or groups that receive them. *Incorporation* refers to the acquisition of the competencies to deal with the object in line with the new receiving context. Finally, *transformation* refers to the attribubution of new meanings to the objects, as defined by the aforementioned context. These processes of hybridization can give way to two kinds of entanglement: on the one hand, material entanglement, which takes place when objects are modified in the receiving context, and on the other hand, relational entanglement, which is associated with the new practices and social meanings into which the objects are incorporat ed within the communities that receive them (*Stockhammer 2012.51*).

As they flow through space and time the objects can mediate and lead to many social relationships (*Joy 2009*). As they move, they absorb the lives of the people who cross them, and it is there that a close bond is formed between the active agency of the material culture and the agency of the individuals (*Hoskins 2006*). In this way, the life histories of people cannot be decoupled from the histories of the objects that surround them, as these objects in some way become a metaphor for the lives of the people, their aspirations and social interactions. As for human communities, objects reshape their existence in terms of the multiple interactions that take place with people. Therefore, their role, meaning, and transcendence depend on the succession of social relationships that are created between humans and the material culture they live within *(Hoskins 1998; 2006; Gosden, Marshall 1999*). This means that when understanding these objects in one specific context, we cannot disassociate them from their past. Instead they must be considered alongside the phenomena surrounding their birth, the continuous transitions they experienced, and their final abandonment *(Gosden, Marshall 1999; Hoskins 2006; Joy 2009*).

In this way, some displaced objects become icons that can be valued from a multitude of perspectives (*Appadurai 1986*), for example, in terms of their shape, uniqueness, origin, difficulty to acquire, age, role in the past and present, associated history (accumulative, retroactive, and changing), the paths they follow throughout their lifecycles, and so on. All these object-related factors interact on many different levels with people, and are often used in defining their *personhood* or identity.

The specific active participation dynamics that work to shape personhood are those which can be linked to the circulation of objects coming from remote places, and their relationship with certain knowledge politics (*Appadurai 1986; Hoskins 2006*). In this way, the displaced objects become indispensable agents and allies to those who build their social capital, reputation and power by acquiring the objects and acting as their custodians. These objects, occasionally associated with great distances, provide the ability to create social networks, while at the same time serve as indispensable objects in the social definition of people, affecting aspects such as wealth, status, and prestige, among others (*Sherratt 1993; Kristiansen 1998; Sherratt, Sherratt 1998; Kohl 2011; Harding 2013*).

In the present study, we consider the biography of a set of nails that was discovered during a 1998 archaeological excavation at Tower 1, a Cyclopean structure at the site at Puig de sa Morisca in Mallorca, Spain (Figs. 1 and 2). Inside this structure, dated to the 6th century BC (*Guerrero* et al. *2002; García Rosselló* et al. *2022*), various metal nails have been found, some whole and others in pieces. They were discovered inside a local handmade container (Fig. 2). The discovery of an Iberian amphora and a Massiliote amphora in the same stratigraphic unit allowed us to define, using relative chronology, that the depositing of the nails in this place took place during the 4th century BC (*Guerrero* et al. *2002; García Rosselló* et al. *2022*).

Beyond analysing the context in which these materials were deposited, the main objective of the present study is to try to establish the physical and ideational metamorphosis that these nails underwent throughout their lifecycle, and with that, provide a more in-depth understanding of the different interactions that took place with human and non-human actors during each stage of their biography, putting special emphasis on the lives that they had during the Late Iron Age. The presence of the nails in a specific place at the site at Puig de sa Morisca is closely related to the cultural contact maintained between members of the indigenous community that inhabited the site and Punic agents (*Guerrero* et al. *2002*). Along this line, our article also aims to apply a perspective that focuses on the biography of the objects to address the complex relationships, connections, and contacts that existed between indigenous communities and colonial agents around the Western Mediterranean during he Late Iron Age. This perspective takes a socio-historical contextual approach to better understand how the reincarnation of an object takes place over its existence in specific cultural contexts, while delving into the biography of the object itself to better understand the complex and contingent social role of materiality and provide a more in-depth understanding of the context of cultural contact in which it existed.

The use of biographic perspectives to analyse the roles played by objects has had a limited impact on archaeological studies of prehistory, largely due to a lack of quality information, which is needed to reconstruct the various stages or lives of the objects (*Joy 2009*). We made use of a multiproxy methodology to analyse the various forms, uses, and meanings of the nails (objects of the present study), combining a study of physical characteristics with other contextual parameters. On the one hand, we performed an isotopic, technological, typological analysis of the nails to determine the origin of the raw materials used to make them and the technical decisions made in their production, aspects that provide information on the birth of the objects and their function. Furthermore, we performed an analysis of the context in which the nails were deposited to address the changes that took place during the final stage of their useful lives, as well as their relationship with certain social dynamics of the indigenous communities on Mallorca during the Late Iron Age.

Biographical unit of analysis: the Balearic Islands and the southern Iberian Peninsula during the Iron Age

The nails considered in the present study have had multiple lives – from their creation and existence in their natural state to today, when they were recovered from Tower 1 at Puig de sa Morisca by archaeologists from our team – in different assemblages and various

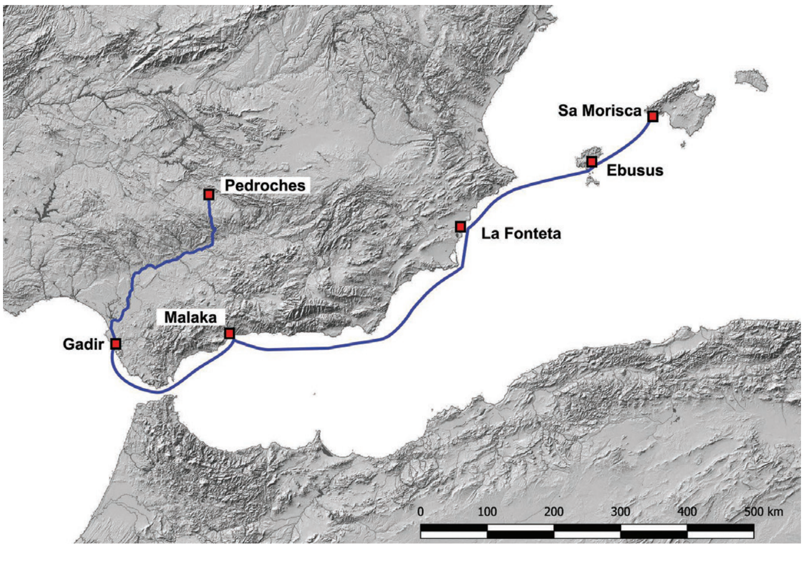

Fig. 1. Map of the Iberian Peninsula and the Balearic Islands showing the possible inland and maritime navigation routes used, from obtaining the raw materials to depositing the nails at Puig de sa Morisca.

social and historical contexts. Conducting a complete in-depth analysis of the phenomena involved in the whole biography of these objects is an extremely difficult task that requires addressing a plethora of specific spatial-temporal contexts, each of which with unique agents and relationships. This requires us to define a *biographical unit of analysis* that is coherent and focuses on episodes in the objects' lives that are interrelated and can be placed alongside similar historical phenomena and frameworks. The present work thus focuses mainly on identifying and analysing the lives that these materials could have had during the Iron Age. As such, this section deals exclusively with the historical context of this time.

Throughout this period, nails were embedded in a complex historical context, as they were related to the mobility networks (especially in maritime and inland navigation) and cultural contacts that were developing in the Western Mediterranean. During this period migration took place, and Phoenician-Punic people settled in the southern Iberian Peninsula and some of the Balearic Islands (Fig. 1). In these places, multiple areas of contact and hybrid situations arose between these external agents and preexisting local populations (*Gosden 2004; Van Dommelen 2006; 2012; Vives Ferrándiz 2008; Calvo* et al. *2014; García Rosselló, Calvo 2021*). In our case study, it is worth mentioning that many Phoenician-Punic colonial enclaves were founded along the coast of Andalusia (*e.g.,* Gadir, Malaka, Sexi, Abdera, and Baria) starting in the 9th century BC (*Aubet 1997; Bravo 2000; López Castro 2003*). In the case of the Balearic Islands, the first Phoenician-Punic inhabitants established the settlement at Sa Caleta on the island of Ibiza towards the end of the 8th century BC. The founding of the city of Ibiza (Ebusus) took place in the middle of the 7th century BC (*Costa, Fernández 1997; Ramon 2007).* The colony of Ebusus was a significant enclave in the Punic world of the Central and Western Mediterranean, serving as an important port of trade, a production centre, and an exporter of goods, like wine. These dynamics created two distinct worlds in the Balearic Islands, both culturally and geographically, characterized by, on the one hand, the Phoenician-Punic colonial settlement in Ibiza and later

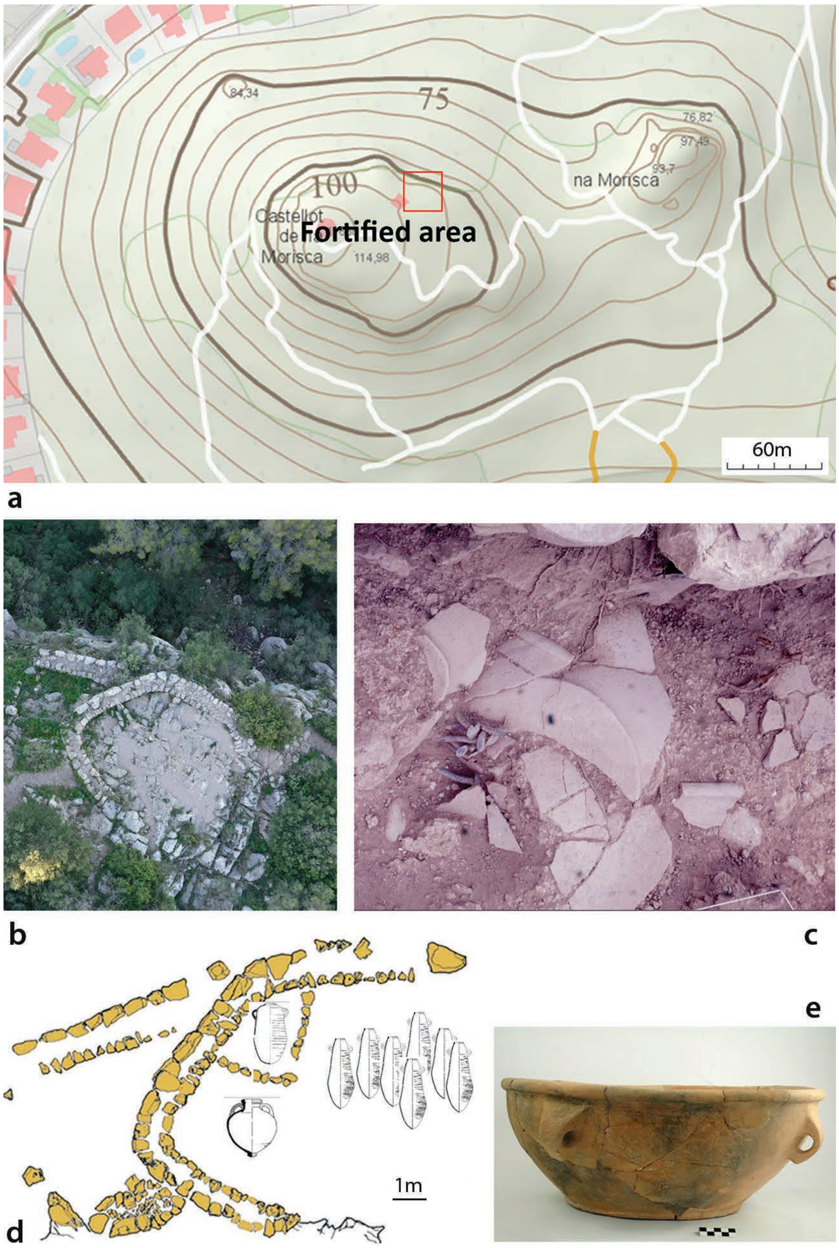

Fig. 2. **a** ***Topographical map of Puig de sa Morisca showing the elevated fortified area where Tower 1 is located;*** **b** ***arial photo of Tower 1, where the nails were discovered;*** **c** ***photograph of the nails and the ceramic container in which they were found during the excavation;*** **d** ***layout of Tower 1 showing the area delineated by walls and various amphorae found inside the structure;*** **e** ***local handmade ceramic container that housed the nails.***

in Formentera, and on the other hand, the presence of indigenous communities on the islands of Mallorca and Menorca.

The Phoenicians adapted to the various characteristics of the territories in which they settled, establishing varying levels of connection with the multiple indigenous populations that inhabited the same areas as them. These contacts were, in some cases, asymmetrical, and they were not free from the occasional conflict, as the settlers needed to occupy part of the locals' territory and make use of their resources (*Wagner 2005*). In the case of the Balearic Islands, the Phoenician-Punic communities on Ibiza maintained a significant contact with local Iberian communities on the mainland from their beginning, thus providing them with another important point of contact (especially after the 6th and 5th centuries BC) with the colonies in Andalusia and the Central Mediterranean (*Ramón 1996; 2007; Fernández, Costa 2006*). The first record of contact between these Phoenician-Punic agents and local communities in the Balearic Islands comes from the 8th century BC, the so-called Talayotic period. Nevertheless, it is not until the 5th century BC (the post-Talayotic period), that evidence of such interactions increase significantly, until eventually Mallorca and Menorca were occupied by Roman forces in 123 BC (*Guerrero* et al. *2002; Ramon 2017; Tsantini* et al. *2019*).

Coinciding with the development of contact between Phoenician-Punic communities, especially those on Ibiza, significant social and cultural changes have been documented in indigenous communities throughout the Iron Age. Manuel Calvo and Victor M. Guerrero (*2011*) described the main transformations that have been documented in the material culture on Mallorca during these periods. Among many other changes, of note are the disruption to the construction of certain types of buildings that pertain to the Talayotic period (*e.g.,* talayots and turriforms) and the appearance of new spaces for rituals. New layouts of domestic spaces (*Salvà, Hernández-Gasch 2009*) and the landscape (*Calvo 2009; Galmés 2021; Galmés, Calvo 2022*) have also been reported, in addition to new burial rituals, including the first symbolic individual burials (*Calvo* et al. *2020*). With regard to manufacturing technologies, ceramics, and metallurgy, there is also evidence of significant change, with an increased range of technical practices and strategies (*García Rosselló 2010; Albero 2011; Perelló 2017*). These changes have been associated with a progressive decoupling of social cohesion strategies that were popular on the island during the Bronze Age and the Talayotic period and an emergence of new social dynamics in a post-Talayotic period, marked by a noted difference in the presence of certain resources and shows of power by specific individuals and groups (*Lull* et al. *1999; Calvo, Guerrero 2011*). These changes have also been related to the process of power consolidation seen in some post-Talayotic groups, with the appearance of individual caches of weapons and furnishings and the emergence of a mercenary class from the 3rd century BC onwards (*Castro* et al. *1997; Guerrero* et al. *2006*).

In recent years new narratives using post-colonial perspectives have been introduced – based on a colonial understanding of the contact between Phoenician-Punic agents and indigenous communities on the Balearic Islands, which influenced hegemonic dynamics and inequality, reducing local communities to unquestionably passive entities (*e.g., Guerrero 1997; Ramon 2017*) – and these consider the active agency of indigenous communities as well as the imitation, ambivalence, and hybrid and intermediate situations that took place therein (*García Rosselló 2010; Hernández, Quintana 2013; Calvo* et al. *2014; Calvo, García Rosselló 2019; García Rosselló, Calvo 2021*). It is along these lines that the present article focuses, taking the perspective that considers the biographies of the objects as essential elements for being able to understand the social role that the objects themselves played and their involvement in phenomena of cultural contact.

Materials and methods

Materials

The set of objects whose biography we consider in the present study is made up of 13 metal nails (Fig. 3), all of them characterized by having been produced in the same way (except nail SM-98-UE17-11200, which is square). The nails have flat mushroom-shaped heads and octagonal bodies on their upper two-thirds, which slowly changes to a square or circular shape towards the objects' lower ends.

A preliminary study of the nails suggests that they were not a part of the Talayotic structures or any other furnishing or object found in Tower 1. Both Guerrero's studies *(Guerrero* et al. *2002.239; Guerrero 2006.29*) and the studies we carried out in the present work suggest that, based on their dimensions and bends, the nails were likely related to ship carpentry: specifically, elements to fasten planks to the ribs or frame of a

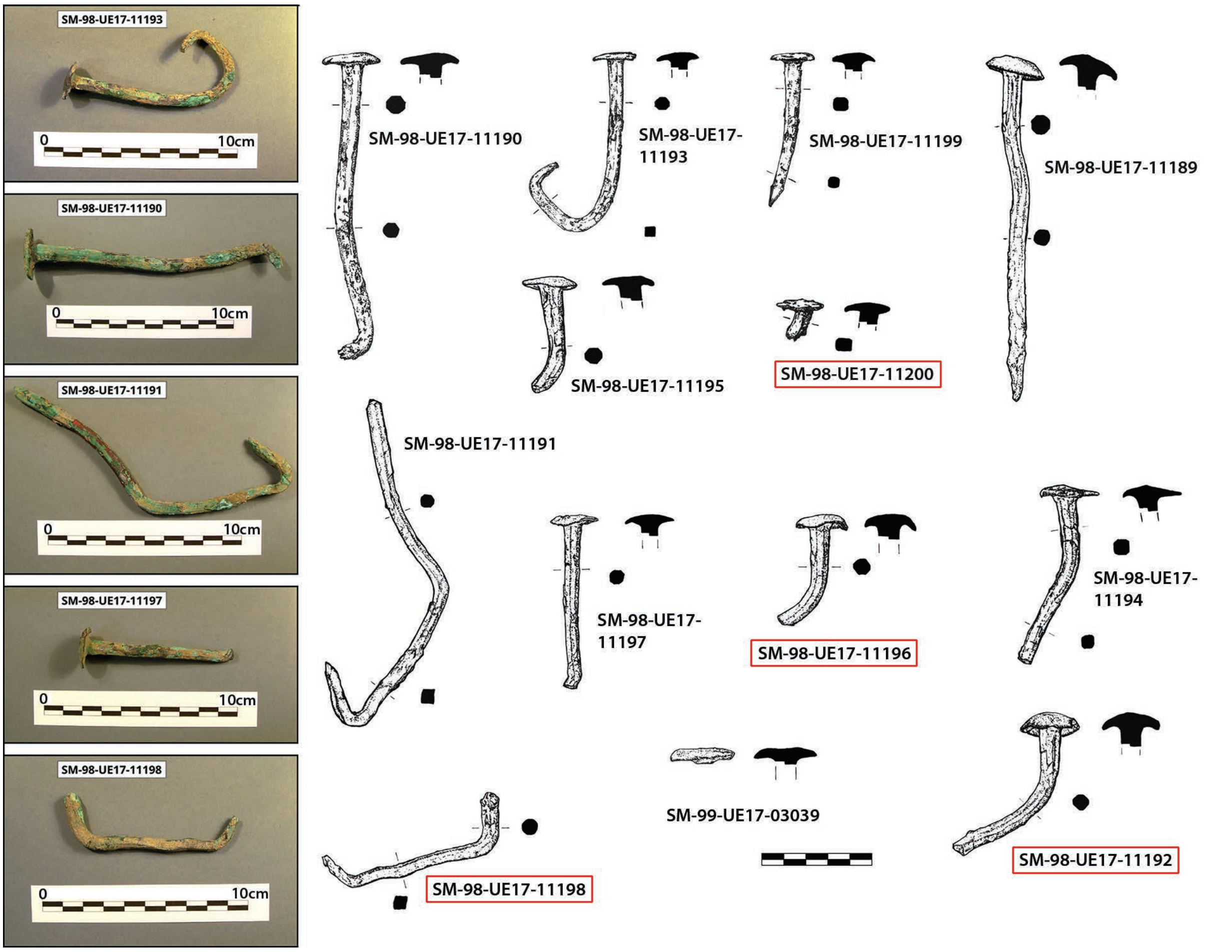

Fig. 3. Drawings of the set of nails studied and photographs of those that best preserve the shape of the ribs in their bends. The red frames indicate nails that underwent isotope analysis.

boat. Guerrero (*2006*) holds that these nails may have formed part of a Punic ship, and he speculates on the possibility that they were salvaged from a shipwreck and stored there by members of the indigenous community at Tower 1 on Puig de sa Morisca to later be recast. The effort made to recover whole nails without them losing their original shape led this author to suggest the possibility that the ship was dismantled so that the boards and metals could be used following a shipwreck (*Guerrero 2006.29*). Another plausible alternative is that these nails are evidence of a repair which was carried out on the hull of a ship.

Analysis techniques and methods

In order to provide complete and exhaustive information on the nails recovered, our analysis used different archaeometric techniques that, together, allow us to discuss the nails' biographies. On the one hand, elemental ICP-MS and lead isotope composition analyses allow us to link the nails to the raw materials used to make them, providing information on the objects' *birthplace*. Typological and metallographic studies provide us with an in-depth understanding of the processes underlying the manufacturing of the nails and their function. Finally, an analysis of the context in which they were deposited allows us to address how these nails, in the last stage of their lives, became a part of indigenous reality. All the nails were analysed using SEM-EDS. Due to the destructive nature of the analysis used, we were forced to choose from the set. Specifically, specimens SM-98-17-11192, SM-98-17-11196, SM-98-17-11198, and SM-98-17-11200 (Fig. 3) were chosen for metallographic, ICP-MS, and lead isotope analyses. Below, we explain details of the analytical process used for each one of the methods applied.

Scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM-EDS)

The identification and quantification of the major elements present in the nails was made by means of X-ray energy dispersion using a RX-EDS Bruker AXS XFlash 4010 microanalysis system at a resolution of 133eV connected to a Hitachi S-3400-N scanning electron microscope using the Quantax 400 software package (equipment from the University of the Balearic Islands' Technical-Scientific Services). We should point out that it is difficult to detect trace elements with the techniques used. The process detects elements from carbon to uranium, but if the concentration of an element is less than 0.3% by total weight then it can go unnoticed. The analysis can be performed ona very small, localized area, or on a large surface to obtain general information. In our case, general analyses were always performed in scanning windows between 100x and 200x; in addition, specific points were analysed to provide more specific information. We proceeded to remove the patina from the area to be analysed so that the tests could be performed on healthy metal. The results obtained from the SEM-EDS analysis were normalized to 100%. Whenever it was possible, we performed more than one analysis per area and object, as there was a risk of analysing heterogeneous areas of the alloys.

Inductively coupled plasma mass spectrometry (ICP-MS)

An ICP-MS analysis was performed on the same nails that were selected for isotope analysis, aiming to provide more precise information on the composition of the metal under consideration and the impurities found in its main constituents. Elemental analyses were conducted by ICP-MS at the SGIker-Geochronology and Isotope Geochemistry Facility at the University of the Basque Country (UPV/EHU), Spain. The samples were dissolved with either aqua regia (for Sn and Sb determinations) or concentrated HNO_3 (the rest of the elements) in closed Savillex PFA vessels set on a hot plate at 120°C for 24h. Dilution after dissolution was done gravimetrically using an electronic balance with a precision of 0.1 mg to prevent errors caused by volumetric dilutions. We carried out a quantitative identification of the analytes of interest using a Thermo XSeries 2 ICP-MS equipped with a collision cell (CCT), an interphase specifically for elevated total dissolved solids (Xt cones), and a shielded torch. A concentric nebulizer and a quartz expansion, Peltier-cooled chamber were employed. Rh and In solution were used as the internal standard, and multi-elemental solutions for the initial tuning and calibration of the mass spectrometer, and for quality control (QC) of the results were prepared 100 ppm high-purity standard solutions for ICP, stabilized in diluted HNO_3. The internal standard was added online with an automatic addition kit in order to prevent random errors. Further details on the instrumental method are given in García de Madinabeitia *et al.* (*2008*). In percentage terms, the recoveries for the QC solutions are given in Table 1. Error estimations for each element were established using the error propagation equation from James N. Miller and Jane C. Miller (*2010*). The uncertainty of the results corresponds to a 95% confidence level.

Lead Isotope Analysis

This type of analysis allows us to provide information on the origin of the raw materials used to produce the metal objects. This technique is based on a study of the differences and similarities in the isotope composition of the archaeological objects compared to ore deposits. This composition does not change during the processes of transforming the ore (*e.g.,* smelting, oxidation, and reduction), and therefore it is possible to identify similarities in the isotope values seen in the archaeological objects and the raw materials used.

The lead isotope analyses were performed at the Geochronology and Geochemistry-SGIker facility at the University of the Basque Country (UPV/EHU), Spain. About 0.100g of powdered sample was dissolved in HNO_3 overnight and left to evaporate until dry. The residue was taken in HBr and Pb isolated by conventional ion-exchange chromatography (AG1-X8 resin in HBr and HCl media). The recovered lead was left to evaporate until dry, dissolved in 0.32N of HNO_3, and diluted to a final concentration of 150-200ppb. The lead isotope ratios were measured with a Thermo Neptune multicollector ICP-MS, and the mass fractionation was internally corrected after the addition of thallium isotope reference material NBS-997 (*Walder 1993*). The detailed protocols were similar to those described by Igor V. Chernysev *et al.* (*2007*). The accuracy of the results was confirmed in several analyses with lead isotope reference material NBS-981.

To identify the origin of the raw material with which the archaeological objects were manufactured, we contrast the results of the isotope analysis with those of known mineral ores. First, we determine Euclidean distance to see which are the closest neighbours. To do this, we chose to use the method described by Thomas Birch *et al*. (*2020*). Additionally, the results were evaluated using the methodology described by Sarah Ceuster and Patrick Degryse (*2020*), which uses an application of kernel density calculations and relative probability percentages for the isotope ratios $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$. However, neither of the two methods described allow us to fully evaluate the results of the minerals' isotope evolution curve. For this reason, the use of bivariate graphs to visually interpret the data is essential for making distinctions.

Metallographic analysis
Our metallographic analysis centred around a study of the microstructure of the metal, which allowed us to deduce which processes were used during the manufacturing of the objects and how they might have been treated and had their microstructures altered afterwards. For this study, we used the equipment available at the University of the Balearic Islands' Technical-Scientific Services. To prepare the metallographic analyses, we packed the samples into moulds with conductive resin and cold copper polymerization bases. Then, once the moulds were removed, the samples were wet sanded with silicon carbide sandpaper at different grains. The final sanding was performed with abrasive diamond particles. Before being studied under a microscope, an iron chloride attack was performed to expose the metal's microstructure. The first part of metallographic analysis takes advantage of the fact that the constituent parts of the nails with the greatest reaction speed are attacked more quickly and are seen as darker under the microscope. Elements that are less susceptible to the attack are more reflective. Our analysis of the microstructure of the nails was performed on an optical reflection and transmission microscope, the Olympus BX60, using reflected light, as well as a scanning electron microscope and energy dispersive X-ray spectroscopy (SEM-EDS), the Hitachi S-3400N, which allowed us to take high-resolution images while performing chemical analyses to determine the elemental composition of small areas of the sample.

Results

First life: obtaining and transporting raw materials
The SEM-EDS analyses performed provide evidence that all the nails were made out of very pure copper. No other element was detected over the 0.3% by weight threshold, a finding that is also confirmed in the samples analysed by ICP-MS (Tab. 1). The only impurities detected was As (0.15-0.2%). The chemical composition of all the nails analysed using the latter technique is very similar, which might even suggest that they were produced from the same metal casting. In addition to this similarity in composition, we find that the isotopic footprint of the set of nails is also very homogeneous. The resulting dispersion diagrams provide evidence that the four nails have a high level of isotopic correlation among themselves. While the graph for SM-98-17-11196 was slightly shifted, its composition does not differ significantly from the rest of the samples (Fig. 4). These results allow us to suggest that the metal used in these nails came from the same place or their raw materials have a similar origin, as they have very similar values (Tab. 2).

A comparison between the isotopic results obtained from nails and the copper ores nearest to where the nails were discovered (Fig. 4) shows that the nails do not coincide with any of the copper outcrops on the Balearic Islands (*Llull* et al. *2021*). This suggests a foreign origin of the raw materials used to make them. An exhaustive study of the existing mineral deposits on the Iberian Peninsula allows us to confidently associate the isotope values associated with nails to the isotopic field from the mining region of Pedroches *(Santos Zalduegui* et al. *2004; Klein* et al. *2009*). There is a clear similarity between the data obtained from ores from this area, and there is no partial overlapping between isotopic fields of other regions and the nails that would give us any cause for doubt (Fig. 4). In addition to the presence of copper sulphide, we should mention that all the nails analysed were made with very pure copper. The absence of other trace elements, such as Sn and Pb, indicates that the nails were not made from recycled or scrap metal. Moreover, because As is a volatile element, such detected impurities, along with the isotopic similarities seen in the analyses, reinforce the idea that they were not recycled metals.

The area of Pedroches, the most likely origin of the copper in the nails, is located in the province of Cordoba, Spain (Fig. 1). Geologically, it belongs to the Central Iberian Zone of the Hesperian Massif. There is a geological feature that characterizes the area known as the Batholith of Pedroches, located in the centre of the Sierra Morena, a large mass of igneous rocks where mineral deposits in subvolcanic rock abound (*Hunt, Hurtado 1999.284*), and these are rich in copper. The use of copper in this region of Cordoba has been documented as far back as prehistory, and mining and metallurgical activities associated with the metal were practiced intensely during the Late Bronze Age, though with the arrival of foreign agents during the Orientalizing period this interest shifted to silver ores (*Pérez 2013*). But this does not mean that they completely abandoned copper mining. Fernandez-Ochoa *et al.* (*2002.48-49*) highlights the significant increase in settlements in the Pedroches region during the Early Iron Age/Orientalizing period, which according to Juan Francisco Murillo's (*1994*) classification were associated with the process of extracting copper ore, metallurgical activities, or the strategic control of territory. Nevertheless, the emergence of settlements in this region was short-lived, as during the Late Iron Age/Iberian period it seems that the majority of these habitats were abandoned (*Fernandez-Ochoa* et al. *2002)*, the land was reorganized, and the economy was refocused toward agriculture during the Tartessian period (Carrillo *et al.* 1999). As suggested by Fernandez-Ochoa *et al.* (*2002*), we must keep in mind that there is a significant void in the archaeological research in the area that would touch on this period, making it difficult to draw definitive conclusions as to how these changes would have actually affected the operations surrounding copper. In any case, mining activities never completely stopped in this area during the Iron Age, and there is a plethora of archaeological information to confirm that the extraction of mineral

LAB CODE	MUESTRA	Na µg/g	Mg µg /g	Al µg /g	K µg /g	Ca µg /g	Ti µg /g	V µg /g	Cr µg /g	Fe µg /g	Mn µg /g	Co µg /g	Ni µg /g
D19_09_08	SM-98-17-11192	22.2	3.71	<LMD	<LMD	<LMD	<LMD	0.022	0.09	1544	1.94	397.6	207.09
D19_09_09	SM-98-17-11196	38.0	<LMD	<LMD	<LMD	<LMD	<LMD	0.026	0.47	486	<LMD	205.3	187.58
D19_09_10	SM-98-17-11198	37.3	5.16	7.13	<LMD	<LMD	<LMD	0.095	0.15	694	0.43	217.3	195.83
D19_09_11	SM-98-17-11200	19.0	4.67	5.83	<LMD	49.6	0.40	0.081	0.07	939	0.16	146.6	238.74
LMD (ppb)		12.5	2.52	1.99	18.51	25	0.36	0.005	0.01	1.69	0.11	0.01	0.09
QCS (Recovery %)		96.0	98.2	98.0	77.5	85.9	94.1	97.4	98.5	95.0	97.7	98.9	99.8
Error %		0.06	0.07	0.07	0.23	0.17	0.07	0.07	0.07	0.11	0.08	0.07	0.07
D19_09_08	SM-98-17-11192	99.8	123.4	0.17	1537	37.2	<LMD	<LMD	<LMD	0.01	<LMD	0.008	5.49
D19_09_09	SM-98-17-11196	99.6	91.7	<LMD	1533	37.9	<LMD	<LMD	<LMD	0.02	<LMD	0.013	4.30
D19_09_10	SM-98-17-11198	97.8	94.5	0.02	1566	40.2	<LMD	<LMD	0.00	0.02	<LMD	<LMD	4.45
D19_09_11	SM-98-17-11200	98.1	212.3	0.12	2087	73.2	<LMD	0.14	0.00	0.02	<LMD	0.011	4.75
LMD (ppb)		0.90	7.60	0.01	0.04	0.61	0.09	0.08	0.001	0.005	91.43	0.00	0.00
QCS (Recovery %)		90.2	97.0	98.0	101.4	99.1	96.7	102.1	93.9	97.3	104.7	109.4	101.3
Error %		0.03	0.08	0.07	0.06	0.07	0.08	0.08	0.07	0.07	0.22	0.06	0.07
D19_09_08	SM-98-17-11192	37.5	115.63	0.031	0.12	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD
D19_09_09	SM-98-17-11196	171	231.20	0.000	0.45	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD
D19_09_10	SM-98-17-11198	95.6	117.35	0.046	0.58	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD
D19_09_11	SM-98-17-11200	13.2	89.21	0.024	0.15	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD
LMD (ppb)		4.01	0.042	0.023	0.032	0.012	0.010	0.000	0.002	0.003	0.001	0.000	0.000
QCS (Recovery %)		101.1	107.3	100.7	100.4	95.5	95.7	95.6	97.1	96.8	96.6	98.2	96.9
Error %		0.11	0.05	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.06	0.05	0.05
D19_09_08	SM-98-17-11192	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	0.10	170	17.2	0.001	<LMD
D19_09_09	SM-98-17-11196	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	0.09	162	16.4	<LMD	<LMD
D19_09_10	SM-98-17-11198	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	<LMD	0.10	169	19.7	<LMD	0.002
D19_09_11	SM-98-17-11200	0.001	<LMD	<LMD	<LMD	0.00	<LMD	<LMD	0.51	225	26.0	0.001	0.002
LMD (ppb)		0.002	0.000	0.002	0.000	0.002	0.000	3.526	0.013	0.131	0.039	0.001	0.004
QCS (Recovery %)		98.8	97.2	97.3	97.1	99.5	96.9	100.9	106.4	109.1	106.7	104.0	95.5
Error %		0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.05	0.05	0.05	0.04	0.04

Tab. 1. Chemical composition of the copper nails studied by means of ICP-MS. Results are expressed in µg/g of analyte in sample, except for Cu which is expressed in %, that is, gram of analyte in 100g of sample (<LMD =below the detection limit).

ores was intense during Roman times (*Domergue 1990; Fernandez-Ochoa* et al*. 2002; García Romero 2003*).

Beyond this, it is more interesting to discuss, in our biographical analysis of this set of nails, how materials from Pedroches and the mining areas of the Sierra Morena got to the coast.

The most logical natural route, the one with the best archaeological evidence on the movement of people and material culture between both areas, is the Guadalquivir River. Proof of this is that the Romans used routes that had existed since prehistory to connect the mining resources from the region to Corduba (*Melchor 1993*), the city governing the area and from which materials could easily be distributed on waterways.

In the same way, it is worth noting that the shores of the Guadalquivir River host many sites that related to the trafficking of such mineral ores or metal materials (*Renzi 2012.64*). A significant example is the site at Colina de los Quemados, located in the city of Cordoba itself and inhabited from the 3rd millennium BC to the 2nd century BC (*Murillo 1994; Murillo, Jiménez 2002*). The site provides a strategic position, located on the rightedge of the Guadalquivir at a point in which the river becomes unnavigable. Activities related to processing copper ore have been documented here from the 8th century BC (*Marcos 1978*), which lines up in time with when levels of materials imported from the Eastern Mediterranean began to appear (*Martín Ruiz 2012*). This, along with its location, means that the site had been associated with the distribution of mineral ores and metal materials arriving to the area since at least the Early Iron Age (*Renzi 2012.64*).

The sites at which metallurgical activities took place and ores and metals were distributed, represent intermediate spaces of interaction between indigenous communities and foreign agents. Juan Antonio Martin Ruiz (*2012*) notes that imports arrived relatively late to the area that today is the province of Cordoba, and these imports were not especially abundant compared to those found in other places. Nevertheless, the pre-

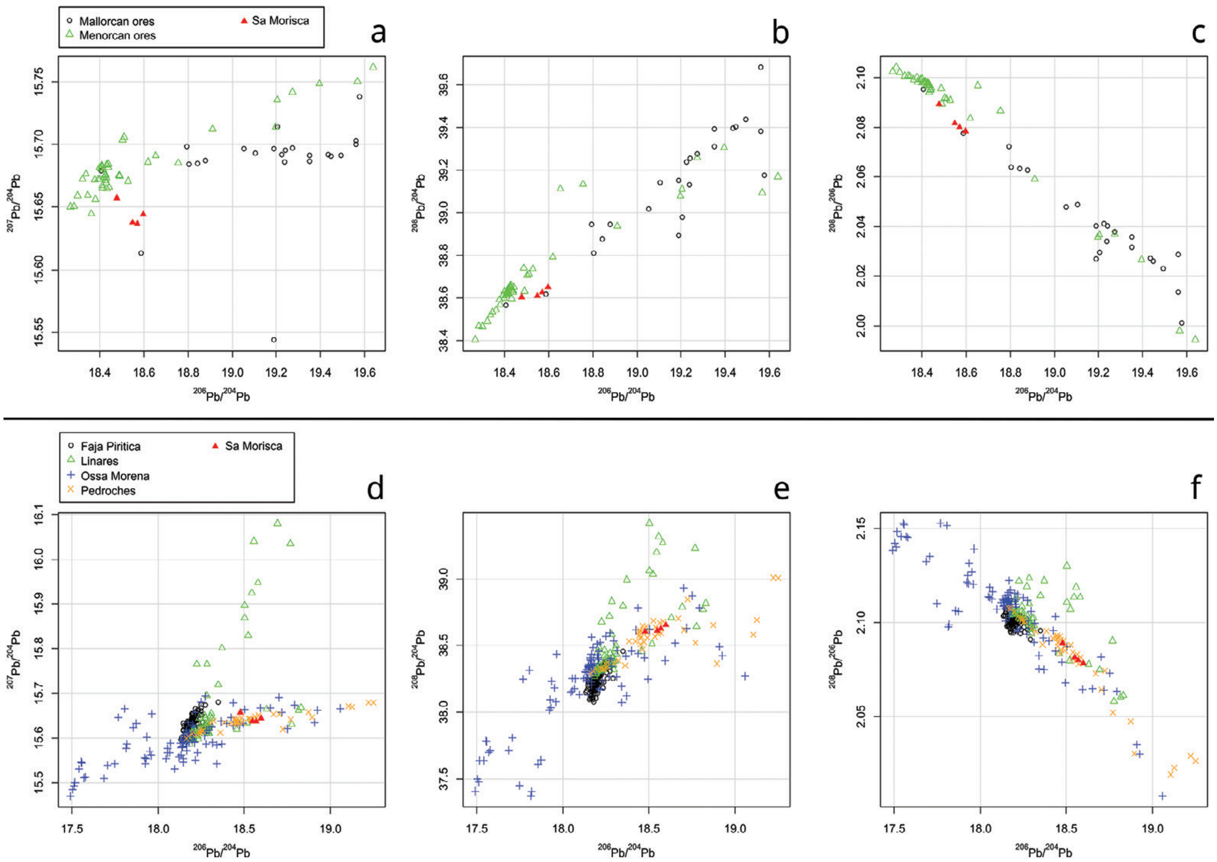

Fig. 4. Dispersion diagrams showing the isotopic values of the nails and mineral ores from various geographic regions. **a, b,** ***and*** **c** ***show the differences between the isotopic values of the nails in relation to copper outcrops on Mallorca and Menorca.*** **d, e,** ***and*** **f** ***show matches with the Pedroches region along with the isotopic fields from other regions on the Iberian Peninsula.***

ID SAMPLE	208Pb/ 206Pb	Error 208/206	207Pb/ 206Pb	Error 207/206	206Pb/ 204Pb	Error 206/204	207Pb/ 204Pb	Error 207/204	208Pb/ 204Pb	Error 208/204
SM-9817-11192	2,081573154	0,00004	0,843049529	0,00001	18,54911787	0,0009	15,63782514	0,000843649	38,61134602	0,00220538
SM-9817-11196	2,089225285	0,00004	0,847342824	0,00001	18,47814314	0,0008	15,657322	0,000714054	38,60500404	0,00195574
SM-9817-11198	2,080046546	0,00005	0,842032919	0,00001	18,57019468	0,0009	15,63671528	0,000819072	38,62686952	0,002188332
SM-9817-11200	2,078370567	0,00004	0,841199132	0,00001	18,59755216	0,0008	15,64424473	0,000704439	38,65260509	0,001841456

Tab. 2. Pb isotopic composition of the nails recovered from Tower I at the site of Puig de Sa Morisca (Balearic Islands, Spain).

sence of imported materials is well-documented at sites like Colina de los Quemados, Ategua, Santaella, La Atalayuela, and Llanete de los Moros, as well at necropolises such as Cerro del Castillo and Los Torviscales. The incorporation of new manufacturing techniques has also been documented in this area, *e.g.,* the use of a potter's wheel, the presence of grey pottery, and oriental-inspired shapes in local pottery (*Martín Ruiz 2012.159-160*). This record provides evidence of the development of a range of hybrid practices, not only in the daily lives of indigenous communities that lived along this river route, but also in the Phoenician-Punic settlements, as demonstrated in the discoveries made at Castillo de Doña Blanca in Puerto de Santa María, Cádiz (*Marín 2015*).

Second life: morpho-technological transformation and manufacturing of the nails
Up to now, we have discussed the *birth* of the copper nails in their original form (that is, as raw material) and their relationship to a Turdetani mining community in the Pedroches region. These mining groups inherited the manufacturing and distribution infrastructure native to that area during the Early Iron Age, and they would not change much over the following period, when the raw materials that made the nails found in Mallorca were extracted. We have also pointed out that the life experience of these Phoenician-Punic nails was marked by the passage of the raw materials by waterways to Cordoba, and from there to the Phoenician settlements on the coast via the Guadalquivir. This major waterway ends up in the area surrounding the Strait of Gibraltar, where notable settlements were located, such as the Phoenician colony of Gadir (Fig. 1).

The metal from Pedroches may have got to the Phoenician-Punic shipbuilders from here, perhaps in the form of a copper ingot, or in cast rods ready to be worked. Along these lines, the second life that we propose for these nails revolves around the transformation of the copper into items destined for shipbuilding, which probably took place in the aforementioned coastal settlements. During manufacturing, the nails underwent an intense, complex process of metamorphosis that changed their shape, significance, function, and (probably) value. Our metallographic study of the microstructure of the nails (Fig. 5) allows us to deduce the technique by which they were manufactured, and thus discuss the specific lives of the objects.

From the metallographic study we can work out that the manufacturing of the nails started with the smelting of copper. It was then poured into moulds to create small rods that took their final form after being cold hammered. The metallographs of nail SM-98-UE17-11196 show that the body of the nail was subjected to less stress than the head of the nail (Fig. 5.a), proof that the former was worked on less. This allows us to deduce that the nails were likely made from an element that had already been worked over, perhaps simple small rods of cast copper. Thus, the forming of the head was not performed with the same mould, and instead it was likely formed afterwards (Fig. 5.b,d).

The bodies of these rods were made thinner and thinner as the craftsman neared the point by process of cold hammering. More cold hammering took place on the more pointed end of the nail than in other areas (Fig. 5.c). The head of the nail was also formed using cold hammering (Fig. 5.b). Finally, for all the samples considered, we find that the nails were heat treated, which normalized the structure of the material and lessened the internal stresses in the metal. We also find that the operational chain used to produce the nails was the same for all specimens, though there were differences in the intensity of their cold treatment and subsequent heat treatment.

The variability observed might be due to the handcrafted work that went into each individual object.

The presence of crystal twinning in all cases indicates that the metal was cast and worked with intense cold hammering, which broke the structure of the metal, which was then normalized in an annealing process to reduce intergranular stress. There is, however, also the possibility that the nails were worked when hot, hammering the metal as it was being heated to over 200°C. There is a certain consensus among specialists that it is nearly impossible to distinguish between the two processes (*Rovira, Gómez Ramos 2003.175*). In our case, the numerous cracks that we find in the microstructure of the nails leads us to believe that they must have been worked on when cold, not hot, as working on them when they were hot would have led to the recrystallization of the metal, avoiding internal stress and reducing the appearance of cracks. In the metallographs we can see some of these cracks, and some are even visible to the naked eye, as notable corrosion has set in (Fig. 5.c,f-i).

The two metallographic analyses performed on the heads of nails SM-98-UE17-11196 and SM-98-UE17-11200 show slip lines on the upper part of the heads (Fig. 5.d), which indicates a final cold hammering over the granular microstructure. As the slip lines are not found on any other part of the head or body of the nail, we can deduce that the lines are the result of the nails being hammered into place. It does not seem to have been very intense, which may indicate that holes were drilled before the nails were inserted into the wood, and then they were fixed into place with a final hammering.

In all cases considered, the copper used to produce the nails had no other detectable metallic elements or impurities, except for specimen SM-98-UE17-11200, which had more chalcocite present than any other object studied (Fig. 5.f). This means that the metal used to make this nail was less refined than the others. Therefore, we suppose that it came from another batch. Here we should point out that this is not the nail that had slight isotopic divergence (SM-98-17-11196), so we can-

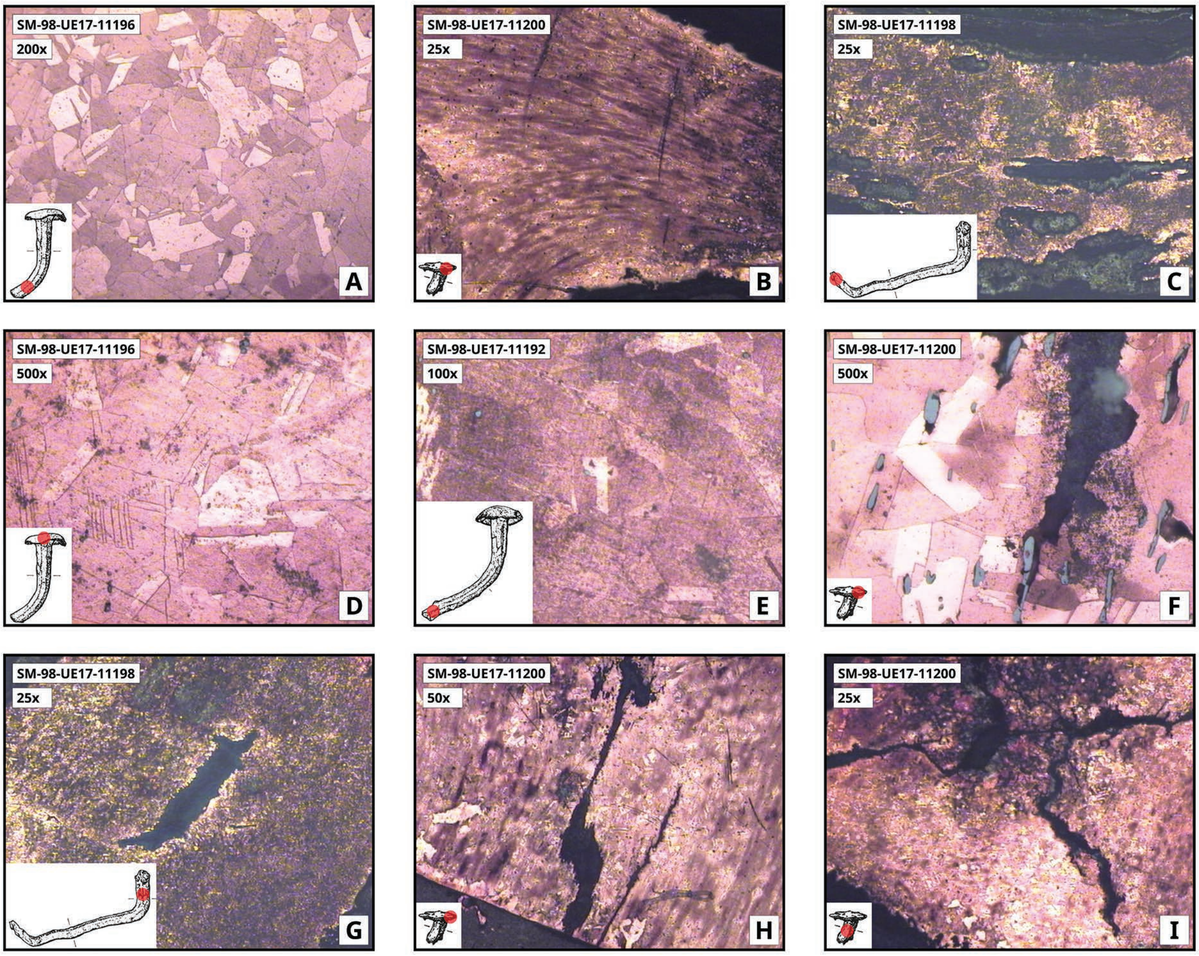

Fig. 5. Images of the microstructure of the nails obtained from the metallographic analyses. Red marks on the drawings are the specific areas that were analysed.

not relate this compositional difference to the use of raw materials with a different origin, but to the reduction process and/or possible smelting and casting that took place later. Additionally, this nail, SM-98-UE17-11200, is the only one in the set that has a square cross section, suggesting that perhaps this nail was manufactured using a different process, an aspect that is visible in the fact that it was produced more poorly and has a different shape, and thus might have been produced by a different craftsman.

The choice to use pure copper to produce these shipbuilding nails might have a logical end, as unalloyed copper nails will bend before breaking, which would support the movements of a structure that is constantly moving and is not completely rigid (in this case a ship). As such, the use of bronze alloys to produce fasteners designed to form part of the structure of a boat might be counterproductive, as they are more likely to break, and they do so more abruptly.

Ultimately, the set of activities related to the transformation of the copper metal into nails destined for shipbuilding meant the creation of a new life, one related to a new community of practice associated with the sea and maritime pursuits, thus placing them into a new social and technological context.

Third life: the nails as parts of a Phoenician-Punic ship

As opposed to the metamorphosis that took place during their second life and the creation of the nails, we shall consider how, in their third life, a profound change took place at a contextual level. The copper nails, once produced, became part of a ship, as a fastening element for the ribs of the hull. Given that these nails were left behind for good at Puig de sa Morisca around the 4th century BC, the ship that housed them would have to have existed before that, though it is difficult to know exactly when this morpho-technological transformation took place, as the lives of these ships could be very long.

The nails under consideration in this study can be divided into two groups based on their type, the size of their heads, the width of their bodies, and their length. On the one hand, we have a group of smaller nails, with octagonal bodies; they include nails SM-98-UE17-11193, SM-98-UE17-11197, and SM-98-UE17-11199. Because of their size it is unlikely that they would have been part of the hull. However, it is reasonable to infer that they would have been destined to be used on other structures on the ship. On the other hand, we also have a group of larger nails. The shape and bends seen in some of these nails (Fig. 3) offer clues to their possible role as fastening elements in the hull of a ship; they include nails SM-98-UE17-11189, SM-98-UE17-11190, SM-98-UE17-11191, and SM-98-UE17-11198, all of which are bent at the tip, exactly the part that would protrude from the pierced wood. In specimens SM-98-UE17-11191 and SM-98-UE17-11198 we can also see how the tip of the nails were bent in so that it could be hooked back into the wood of the ship. This procedure would avoid possible damage that the tip of the nail could cause, and it would favour a stronger hold at fastening points on the structure. Nails SM-99-UE17-03039 and SM-98-UE17-11200 have more ambiguous backgrounds: we know nothing about the cross-sectional shape of the former, the latter is the only one with a square cross-section, and it was manufactured differently than the other nails according to the metallographic analyses. Both of these nails were included in the second group because of their size.

As for typology, the longest specimens have an octagonal cross section that becomes square around the final one-third of the nail (Fig. 3). The square part corresponds to the part of the nail that would stick out of the wood and would later be bent. The metallographic analyses indicate that more hammering took place in this area, possibly to facilitate clamping down the ribs of the ship, as the tip of the nail that goes into the wood must be bent first, and then the part of the nail that sticks out. In this way, the square cross section would have offered a flat area to work on, preventing the nail from going in at an angle and facilitating it being inserted at a right angle to the wood. Fragment SM-98-UE17-11200 has some peculiarities that distinguish it from the others. This specimen, of which only the head and a small part of the body remain, is entirely square, and its head is much flatter than the others. Additionally, this nail does not have cut marks on its body, but it does show signs of breakage.

The technique observed has been associated with the use of hooked copper nails, traditionally employed by ancient river carpenters (*McGrail 2001.146,435; Pomey, Boetto 2019*); in fact, the practice is still used today. In the Balearic Islands, this technique is popularly known as 'doblegat' while in English the practice is widely known as 'clenching' (*McGrail 2004*). This way of fastening, using hooked copper nails to join the hull, ribs, and floor boards of a ship, has been documented on the ship Kyrenia II and the Ma'agan Mikhael Ship, for example, both of which (along with the nails in this study) have been dated to the 4th century BC (*Katzev, Katzev 1986; McGrail 2001.146-149*). Another closer example can be found in the underwater Punic site dating back to the 2nd century BC at Illa des Conills near Cabrera (Balearic Islands). In the underwater photographs that appear in Joan M. Pons Valens' paper (*2005*), we can see that nails have been hooked back into the ribs.

Regarding typology, the nails from Puig de sa Morisca are a good match with the nails used in the construction of these types of ship. Nail SM-98-UE17-11190 is the one that offers us the most clues on how the ship that it was a part of might have been. The specimen is intact along its length until its first bend, that is, the part that occupied the hull and the rib. From below the head to the bend measures about 13cm in length, lining up perfectly with the thickness of the ribs (between 8 and 10cm) and the thickness of the hull (between 3 and 5cm) of the ship found at the site at Illa des Conills, which was calculated to have had a maximum length of 15–20 meters (*Pons 2005.763*) and measurements very similar to the ship Kyrenia II. The nails found at Puig de sa Morisca show clear similarities with data obtained from the archaeometric and technological analyses of the nails from the ribs of the Ma'agan Mikhael Ship (*Kahanov* et al. *1999*). These nails were also made of pure unalloyed copper and underwent intense hammering. The cross sections of these nails also get larger as we move towards the head of the nail.

In short, we have seen how the third life of the nails considered in the present study involved a community of practice associated with the shipbuilding and riverboat masters connected to the Punic communities around the Strait of Gibraltar that built the boat that housed the nails. We suppose that, once built, the boat left the shipyard from some Punic settlement in the south of the Iberian Peninsula. The nails thus once again entered a new socio-technological context involving a community of practice associated with the field of seafaring, in this case Phoenician-Punic merchants and/or sailors who in all likelihood operated around the Strait of Gibraltar, the coast of the eastern Iberian Peninsula, and the colony of Ebusus (Ibiza) (Fig. 1). Unfortunately, as the ship associated with the nails was never found, we do not have any further information that would allow us to delve further into this nautical life of the nails.

Fourth life: disposal of the nails in the indigenous context of Mallorca

We can consider a fourth life in this set of nails to be the new context associated with them before they finally came to rest in Tower I at Puig de aa Morisca at the end of the 6th century BC (*Guerrero* et al. *2002*). This new life can be linked to the indigenous community that inhabited the site at Puig de sa Morisca and their appropriation of the nails, a significant redefinition, which can be ascribed to certain types of hybrid practices that took place here as the consequence of the contact between indigenous communities on Mallorca and Punic-Ibizan agents.

The presence of these nails at the indigenous site at Puig de sa Morisca is evidence of the interest that this community had in obtaining and possessing these objects. This *appropriation* meant a radical change in context. With regard to material entanglement, we see how, in this phase of the objects' lives, the nails underwent a physical change, becoming fractured and broken up. This is a notable aspect, as the cut marks that can be seen on the nails may indicate that they were selected to be extracted. The breaks that we have recorded are old and are not due to the wear of the metal, as under the patina there is healthy metal (Fig. 5). Some of the specimens we analysed also show signs of twisting, which can be associated with the work that was done to facilitate the cut while it was being made. The scrapes observed in the metallographic analyses are further evidence of this (Fig. 5).

The documented hybridization that took place with regard to these nails is also related to transformation and relational entanglement (*Hahn 2004a; 2004b; Stockhammer 2012*), as demonstrated by the place in which they were deposited and the new praxis with which they were associated. The set of nails was found in an indigenous, handmade ceramic container, discovered in primary position, in Area 1 of Tower 1 at Puig de sa Morisca (Fig. 2). Such specific placement, conscious and voluntary, suggests a fractal, multiscale dynamic with regard to the especially significant nature of the place where the nails were left.

It is important to note that, on Mallorca, the site at Puig de sa Morisca played a key role in the contact and interaction that took place between the island's post-Talayotic indigenous communities and Punic-Ibizan agents between the 6th and 7th centuries BC. It was at this site that the first contact between these two groups was documented, and later it became an especially significant enclave in the redistribution of imported materials to other local sites on the island (*Guerrero* et al. *2002; Quintana, Guerrero 2004; Tsantini* et al. *2018*).

Furthermore, the Cyclopean structure in which the nails were found (Tower 1) is set up as a singular place at the site for a variety of reasons: first, its location at an elevated position in the site with wide visual range of the surrounding lands, which also served as a visual point of reference for inhabitants of the town below (*Galmés 2015*). Second, it is an essential structural part of the defensive complex that the upper part of the site represents. It is one of the four towers that stand out in the larger area, which together provide visual control over the area of the village, the beach, and the nearby lagoon (Fig. 2) (*García Rosselló* et al. *2022*). Third, it served as a place to store imported materials (*i.e.* Punic, Massiliote, and Iberian amphorae were discovered in this tower) (*Quintana, Guerrero 2004*). And fourth, imported objects unique among the indigenous populations of Mallorca around the time have also been found here (Attic pottery with black glaze, a Phoenician scarab, and a Phoenician arrowhead) (*Guerrero* et al. *2002*).

On a microspatial level it is important to consider that the nails were left inside Tower 1, specifically in a small space (Area 1) delineated by stone walls (Fig. 2). That these materials were deposited in the most closed off and private space in Tower 1 (itself a unique space in the whole site) indicates that the indigenous community had an interest in keeping and spatially singling out these objects (just like other unique materials found in this structure). The interest shown in individualizing and affirming the space in which the nails were located is further shown in them being left in a large local ceramic container (Fig. 2), a piece of handmade pottery typologically unique to any others found on the islands (*García Rosselló, Quintana 2003*).

Ultimately, regarding the place where the nails were deposited, we find a split dynamic when it comes to significance, which can be defined both at a microspatial level – with the choice of the ceramic container into which the nails were deposited, which represents a unicum in the world of local ceramics of the time – and at a macrospatial level, with the role that Puig de sa Morisca played in the contact that took place between local communities on Mallorca and Phoenician-Punic agents. Between these levels we can also find intermediate levels, such as the uniqueness of Tower 1 among the buildings at the site, or the decision to choose Area 1 in the structure to be the final resting place for the nails.

In this new multiscale indigenous spatial context, the nails were given a radically new significance, losing their original function as elements for shipbuilding and being used in new ways in accordance with the logic of the local communities. In this context, it has been speculated that these nails were possibly recovered from a repair carried out on a ship or directly from a shipwreck to be recast later (*Guerrero* et al. *2002.244*). We also cannot ignore the value of copper as a metal, as it was a material that was suitable for trade, and from this point of view the interest in storing these nails (which in total represent 396.93g of copper) may just correspond to the logic of amassing things. The material value of this very pure copper should not be underestimated in this respect. The practice of recycling and the general use of scrap metal is well-documented among Mallorcan communities of the Late Iron Age (*Perelló 2017*). Moreover, to date no copper outcrops have been documented in Mallorca, and therefore any copper objects present at Mallorcan sites seem to have been fabricated with foreign raw materials (*Perelló 2017; Llull* et al. *2021; 2022; 2023*), which would have likely been highly prized. We can imagine that, in the case of these nails, the purity of the metal used to make them might have been seen in the parts of the metal that were cut, *i.e.* the characteristically reddish colour of unalloyed copper metal.

On the other hand, we cannot disregard the fact that these nails were given a radically new significance by indigenous communities, and in doing so, any associated intangible elements played a key role. The nails would have been seen as foreign, and noted for their association with an imagined past built from the objects' previous lives, their association with other material culture (*e.g.,* a Punic ship), and their link to communities of practice distinct to that of their most recent owners. Such communities of practice include mining, shipbuilding, commerce, navigation, and sailing. The past of these nails, and the path that they took, may have created interest in keeping them, as perhaps they were regarded as more than mere scrap to be recast. While an analysis of these phenomena goes beyond the objective of the present study, we imagine that these nails, because of their inherent materiality and complex biographies, were unusual in their local environment, one of a kind, and therefore, inalienable. These characteristics would have given them significant symbolic weight, making them objects that would be ideal for developing certain indigenous agencies.

In this way, the depositing of the nails into containers scaled fractally with a marked indigenous component (*i.e.* the noteworthy site, an important Cyclopean architecture, unique local pottery) and their association with new practices (*e.g.,* recasting, storing) show how, in this stage of their lives, the nails were given a radically new significance based on a hybrid logic and rationale, characterized by a profound dialectic between local and foreign objects. These types of hybrid practices have been documented before in the lands surrounding Puig de sa Morisca (*Calvo* et al. *2014; García Rosselló, Calvo 2021*), with the present case study serving as yet another indicator of the intermediate spaces that were created within indigenous post-Talayotic communities on the Balearic Islands.

Conclusions

The biographic analysis of these copper nails allows us to conceptualize the objects based on their fluid and relational nature. This perspective enables us to discuss the variety of situations that these objects experienced, as well as the metamorphosis and multiple redefinitions they underwent in the context of their cultural contact with indigenous and Phoenician-Punic agents during the Late Iron Age in the Western Mediterranean. In their interactions with humans, the nails experienced various instances of *appropriation* and *incorporation* by the different communities of practice associated with these societies (*e.g.,* mining, metallurgy, river masters, sailors, and indigenous post-Talayotic communities) that allowed them to be appreciated for more than their material nature and led to their being transported through various spaces (inland waterways, the sea, coasts, and islands) and physically transformed to varying degrees (Fig. 6). On the one hand, the nails represent a chain of various processes of metamorphosis (material entanglement) since they were harvested as raw materials, cast into ingots or bars, and made into objects for shipbuilding; they were bent when they were hammered into place and then cracked when they were recovered. On the other hand, in each one of their lives there is a new context for interaction (relational entanglement) in which various communities of practice are involved (*i.e.* the indigenous community from Pedroches, the indigenous Mallorcan community, and the Phoenician-Punic community), and they all interact in different spaces with different material culture (*e.g.,* shipyards, vessels, indigenous pottery, Tower 1).

Each one of these communities in some way appropriated these objects, starting with the appropriation from nature by the mining communities in Pedroches. What is interesting here is how these processes of appropriation, incorporation, and transformation of the material considered herein (in any of its forms), represents the materialization of certain asymmetrical power relationships in colonial contexts, but also the development of indigenous agency. We see how in each situation, though in a different way, the nails played a key role as allies to human beings when it came to defining their political agency, and thus, their social space, likely having a different narrative in each one of its lives.

On the one hand, the harvesting of the raw materials, and its acquisition by Phoenician-Punic agents in the area around the Strait of Gibraltar was made possible by the relationships that existed between these agents and the local community in the Pedroches region. Here we see a relationship in which one power obtained raw material, which by their cultural logic was very valuable (metal), but it came from an area being worked by indigenous communities of practice. Once in the hands of the Phoenician-Punic agents, the metal was incorporated and transformed into a set of nails destined for the shipyard. In this new life, the nails (as part of a ship) served the Phoenician-Punic agents, helping them develop their power in a colonial context, as the ships and their nautical expertise (*e.g.,* technology, navigation, orientation, *etc.*) were fundamental to the dominance that the Punic world held over the seafaring routes and trade in the Western Mediterranean, which (with certain particularities in each case) allowed them to interact with the other cultures that inhabited the Mediterranean during the Late Iron Age.

On the other hand, the analysis we performed allows us to see how the already fractured nails were also appropriated and re-understood in the indigenous island context of Mallorca. By identifying many phenomena of multi-level hybridization, we see the insertion of these foreign copper nails into a new context, one closely associated with the communities that inhabited Puig de sa Morisca. Thus, via their appropriation and transformation, the nails became a key ally in the development of indigenous agency itself. While an analysis of this indigenous agency is a topic that should be explored more deeply in future work, after completing the present research we can state that the reassignment of significance to the nails in a local context was associated in part with their previous lives.

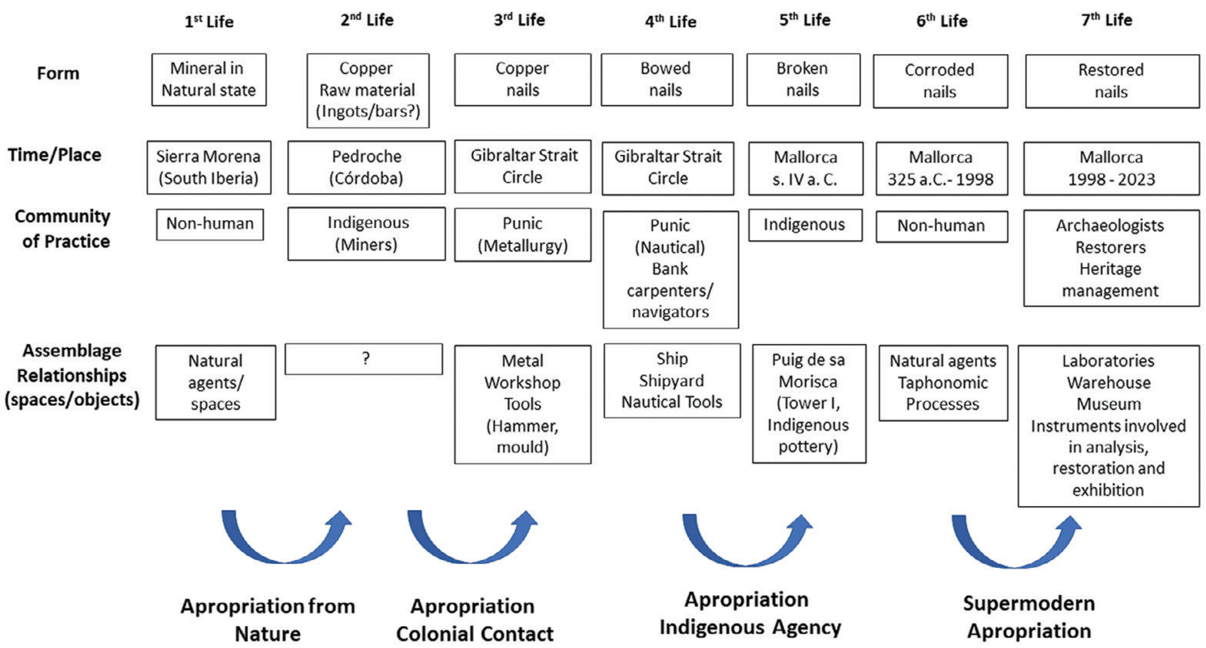

Fig. 6. Diagram of the different physical forms, spaces, communities of practice, and assemblages identified throughout the biography of the nails.

Although it is not the objective of the present work, we should mention that after being definitively discarded in the middle of the Late Iron Age these nails experienced a new stage of life that lasted nearly 2350 years, during which they interacted with multiple non-human actors and phenomena (Fig. 6). As a result, the nails established multiple relationships with certain natural elements (soil, water, air, insects, *etc.*), leading to certain taphonomic processes (whose effects were especially visible on the nails in the corrosion of the metal) until their recovery in 1998. The excavation of these nails by archaeologists at the end of the 20th century meant, once again, the beginning of a new phenomenon of appropriation, giving way to one more stage in the objects' lifecycle (Fig. 6). It is worth noting that in this most recent life the nails have taken on a new social meaning based on their insertion into new logics and narratives that are closely related to archaeological research, the management of heritage, and the appropriation of the past that takes place in modern societies (*Thomas 2004; Hamilakis 2013; Rich* et al. *2022*). This process, which involves us in the path taken by these nails, means yet another new significance and set of changes for the materials therein, affecting both their conceptual side as well as their physical form (Fig. 6). This transformation takes place, for example, in the processes of consolidating, restoring, analysing (typologically and archaeometrically), and turning the set of nails into a piece for a museum. We therefore find a process of appropriation that is not neutral, and instead it has significant implications for how we build the past today and how we construct our own identity and the power relationships that exist in this regard (*Thomas 2004; Holthorf 2005; Hernando 2006*). We should also consider the coming lives of these nails, as after being recovered, analysed, and preserved, their future will be to go on display in a museum. As such, their (currently imagined) nearest future life will correspond to a Western, colonial idea of the past, one associated with certain phenomena of appropriating, analysing, and displaying material culture (*Hamilakis 2013; Rich* et al. *2022*).

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