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The Neolithic dualist scheme

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ABSTRACT – *The monumental twin steles of Göbekli Tepe are one in a long series of isomorphic compositions in Neolithic symbolism. Seemingly tracing back to the Palaeolithic, symmetry likely played a fundamental role for prehistoric societies. Ethnographers showed how hunter-gatherer ideology (mythology, totemism,* etc.*) is often structured around a dualistic worldview (male/female; summer/winter* etc.*) taking root in the kinship system through a division of the community into exogamic subgroups. It is this dualism that is argued to be embodied in the twin steles. The advent of autonomous agricultural lineages could explain why this timeless principle appears with such prominence in the Neolithic.*

KEY WORDS – *Neolithic symbolism; exogamy; kinship structure; hunter-gatherer ideology; incipient farmer*

Neolitski dualizem

IZVLEČEK – *Monumentalna kamnita dvojčka na najdišču Göbekli Tepe predstavljata eno od izomorfnih kompozicij neolitske simbolike. Simetrija je, domnevno že vse od paleolitika, igrala ključno vlogo v prazgodovinskih družbah. Etnografi so pokazali, kako je lovsko-nabiralniška ideologija (mitologija, totemizem itd.) strukturirana na osnovi dualističnega svetovnega nazora (moški/ženska, poletje/zima itd.), ki temelji na sistemu delitve družbe v eksogamne sorodstvene podskupine. Prav ta dualizem naj bi poosebljala kamnita dvojčka. S pomočjo pojava avtonomnih rodov poljedelcev morda lahko razložimo, zakaj je bil ta brezčasni princip tako pomemben v neolitiku.*

KLJUČNE BESEDE – *simbolika v neolitiku; eksogamija; sorodstvena struktura; lovsko-nabiralniška ideologija; prvi poljedelci*

Introduction

The Neolithic site of Göbekli Tepe in Northern Mesopotamia has raised much interest, but the most relevant questions have mostly remained unanswered. One reason is that the field of prehistory alone is rather ill-adjusted to properly address matters of ideology. The ethnology of comparable extant societies offers an alternative means of exploration (*Forest 1992.28–31; Yakar 2005.111–112*), as it can reveal the concepts conveyed through the symbolism.

The present discussion concentrates on the most imposing feature of the Southwest Asian Neolithic symbolic world, that is, the monumental pairs of twin steles standing in the centre of the PPNA stone enclosures (A to H) of Göbekli Tepe III (Fig. 1). However, these must be conceived just as one particular case among the numerous contemporary isomorphic (architectural, geometric and iconographic) representations identified throughout (Fig. 2) the Neolithic period (*Peters* et al. *2005.31–32; Stordeur 2003*): symmetric clay poles, parallel lines painted on floor, geometric figures on walls, antithetic or converging animals, twin figurines, couple of human skulls, symmetrical partition of communal buildings or of entire sites. A non-exhaustive list of such items

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is presented elsewhere (*Bodet 2021; forthcoming*). The current paper concentrates on the likely meaning enclosed in these isomorphic symbols, or rather, on the ideology and the social structure they reflect.

Ethnoarchaeological analogy presents various problems (*David, Kramer 2001.51–54*), but the symbol in question here appears remarkably central to both archaeological and ethnographic societies. If the analogy proves appropriate enough, the analysis may somehow make the archaeological data 'speak' (*Gould 1978.250*), thereby unlocking some of the meaning enclosed in the symbolism (*Wilson 2020.6*).

Problematic and methodology

The fact that the Neolithic symbolic material possesses such a meaning is made explicit by the planned and recurrent arrangement in which its various elements are invariably found. The symmetrical so-called 'pillars' systematically hold a central position in the communal buildings of a large number of spatially and chronologically separated sites in Northern Mesopotamia, the Levant and all the way to Late Neolithic Central Anatolia[1]. Moreover, this element often appears in association with the same set of figurative elements of strong symbolic connotation

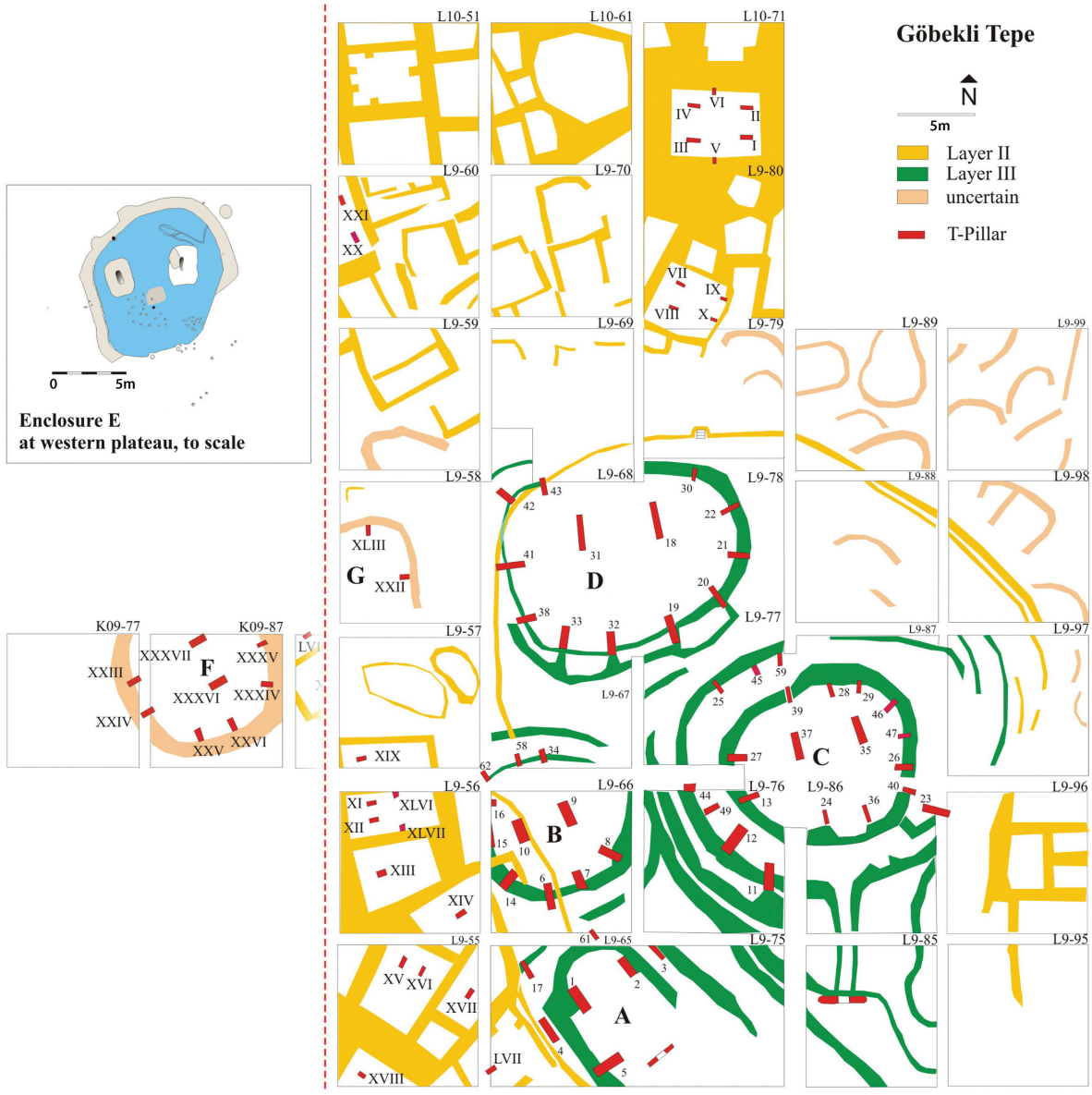

Fig. 1. Ground plan of Göbekli Tepe. GT_Gesamtplan_2014 (central area truncated), by Klaus Schmidt and Jens Notroff. © Deutsches Archäologisches Institut, Göbekli Tepe Projekt.

1 Little noticed, the female figure in Çatalhöyük gives birth by unifying two parallel pillars (*Forest 1993.7*), while (symbolically significant) parallel lines are recurrent in wall paintings. Again, see Cédric Bodet (*2021; forthcoming*) for a more detailed presentation.

(*Henderson 1964.154*), in particular predators, snakes, birds (probably with a psychopomp function), bucrania, anthropomorphic statues or smaller side-steles. The ordering and redundancy of these symbolic compositions are doubtlessly not arbitrary and must correspond to a predefined logical system, conveying a particular message left to be deciphered (*Stordeur 2003.32; Testart 1987a.171*).

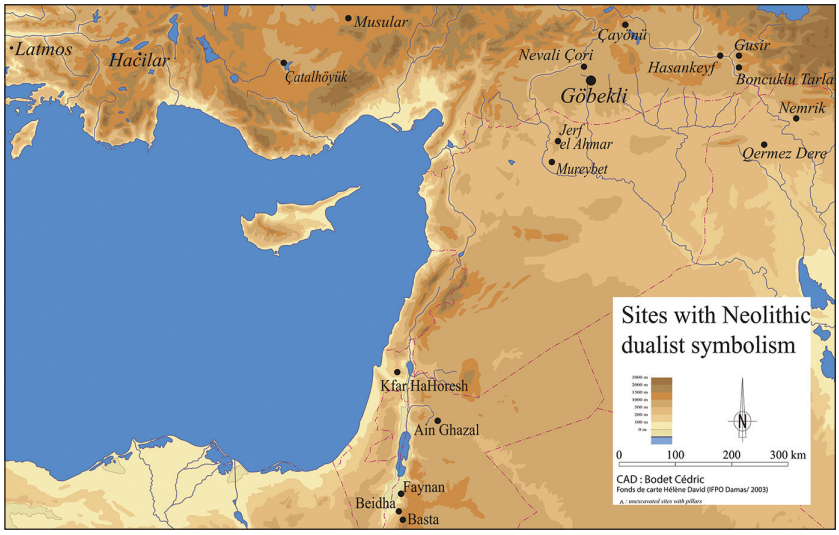

Fig. 2. Distribution of Neolithic sites with identified dualist symbolism (see Bodet (2021 forthcoming)).

This message carried by such structures, together with the fact that nothing indicates that they supported anything (*Jeunesse 2020*), is, in passing, the reason why the word 'stele' is preferred here to that of 'pillar' generally used in the literature. In the same trend of thought, the term 'temple' is ill-fated to designate these enclosures, as these ceremonies probably do not imply a 'cult of deities' (*Testart 2006a*), which only arises when required for the ideological unification of large urban congregations during the much later Obeid/ Uruk horizons (*Forest 1996a*).

Though rarely or too briefly (*Voigt 2002.254*) mentioned (*Roger Matthews 2003.37* is a significant exception), the decipherment of this symbolic message was successfully initiated nearly three decades ago by Jean-Daniel Forest (*1993*), providing a solid foundation on which further elaboration ought now to proceed.

Always placed in the centre, the twin composition is suspected to symbolize the highest sphere of Neolithic ideology. It is a simple symbol with which researchers are doomed to start with in order to patiently reconstruct the meaning it may hold in the social structure (*Durkheim 1937.42–45*). One precondition is not to underestimate the capacity of early communities to express abstract themes through corresponding symbols.

A symbol is a signifier standing for a signified. Repeated over and over again in places dedicated to communal matters, the *signified* in question must indeed be very *significant* for the community. This element can only be described, for now, as a symbol of symmetry, but it makes sense within a system of thought (ideology) deriving from a corresponding social context (*Yakar 2005.111*). Disconnected from this context, the symbol loses its meaning. This implies that in order to decipher this symmetrical symbol, the social context first ought to be reconstructed, at least in broad strokes.

This social coherence is an indispensable basis to start with, but without an intermediary reference, without a Rosetta Stone infusing the structure with meaning, the decipherment will be left to hollow speculations (*Schmandt-Besserat 2013.xxv*). It happens that, for the present concern, a reference exists. The latter is not a similar iconographic element but an abstract concept, and the correspondence appears too striking and the analogy too compatible not to be considered.

Dualism as a prehistoric principle

This investigation was originally inspired by Alain Testart's (*1985*) meticulous analysis of what he calls the 'primeval communist' societies. These are a pristine form of hunter-gatherers, prior to the advent of bows and arrows. This long Palaeolithic dawn of humanity appears, though with much caution, accessible through the abundant ethnographic documentation of Australian Aboriginal societies (*Testart 1988.12*). Any analogy led through the spectrum of a narrow technological comparison is doomed to failure, and absolutely no cultural comparison is attempted here; the social *structure*, because of its theoretical and universal nature, is the only element considered. 'Universal' is here to be understood in the sense that every human community necessarily has an economy, a kinship system, rules, customs and an ideology: these are the main structures that concern us here.

Australian Aborigines are the only living mirror of Pre-Mesolithic-type of societies. A coherent and all-encompassing theoretical reconstitution of their social structure was achieved by Testart, as stable and lengthy as the Palaeolithic period itself, as it is known from archaeology at least. But the ultimate reason why Aborigines are of interest to us here is that, together with Neolithic societies, they clearly appear to hold dualism as a keystone of their ideological construction and that only a living society can reveal its meaning.

A word of warning, however. This is not simply about making "*connection between two entirely different societies on the basis that they use symmetrical symbols in their ideology*", as one reviewer of an earlier version of this paper suspected. There could be a slight chance that isomorphism may relate to something utterly different in the two societies although as dualism and exogamy are extremely widespread (near universal) in the ethnographic record, there is a much higher chance that the Neolithic isomorphism is a delayed expression of the Palaeolithic dualism. Moreover, the modern understanding of dualism, "*two irreducible, heterogeneous principles*" (Britannica.com) must be here understood as being thoroughly complementary in their opposition, which is what we will try to report.

Ethnographers have been struck by the extreme attention given to kinship by all traditional societies, and in particular to one critical point (*Spencer, Gillen 1899; Frazer 1910; Howitt 1905*): such societies are always divided into several subgroups, at least two, exchanging sexual mates every generation for the sake of procreation. This 'artificial' social division is at the root of exogamy ('marrying outside'), an absolutely fundamental principle from which later social and kinship systems evolved (*Freud 2010[1913].39–53, 255–256; Lévi-Strauss 1967.80–97; Testart 1985; 1988*). One direct consequence of this law is that, as Robert S. Walker *et al.* (*2011.1*) say, "*arranged marriages [necessarily among relatives] are inferred to go back at least to first modern human migrations out of Africa*".

The archaeological data offers *monumental* evidence to support the idea that this arrangement perpetuated at least until the Neolithic.

It is certainly biased and erroneous to designate a society by what it does not have (bows and arrows). What Palaeolithic-type societies do have, and even more so than later hunter-gatherers, are relations of production entirely based on and shaped by an elaborate kinship system. In these small communities turned inward, 'elementary' to use Claude Lévi-Strauss' (*1967*) term or 'universal' to use Alan Barnard's (*1978.69–71; 2020.50–53*), everyone is somehow related to everyone else, and this kinship or marital relation dictates the modalities of their social interaction in every way. The way individuals respect, joke, avoid, command/obey, punish, teach/learn, give/receive, conduct ceremonials (initiation and funeral rites), and, most importantly, the way they marry, are thus prescribed primarily by the subgroup the people in interaction belong to (*Malinowski 1926; Radcliffe-Brown 1952.90–104; Woodburn 1982; Ghasarian 1996.152–159,185–197; Walker* et al. *2011.2; Bird-David 2019.15–16*).

"*The fundamental feature in the organisation of (...) Australian tribes, is the division of the tribe into two exogamous inter-marrying groups. These two divisions may become further broken up, but even when more than two are now present we can still recognise their former existence*" (*Spencer, Gillen 1899.55*). Even though odd numbers may also be found (as a result of historically induced disparities), 'primeval communist' societies are often separated into parallel subgroups or phratries: eight subsections, four sections, or, for the most genuine case, two moieties (halves) (*Barnard 2020.52*). Dualism is thus generally considered to be the most original and purest form of this form of social organization (*Cook 2003.65; Freud 2010[2013].50–51; Testart 1978.15–22; 1985.478–479*). But whatever the number of subgroups, this plurality is necessarily reduced in conceptual terms to the number two, because it is the number *par excellence* that embodies the concept of 'differentiation' (*Girard 1972.87–92*), making (equal) exchange possible.

Dualism is much more than a marital arrangement. Organically articulated to the economic system, it reflects on the symbolic sphere: totemism, mythology, rituals, *etc.* (*Testart 1985.451–489*). It finds in nature an obvious mode of expression, through fixed oppositions such as day (sun) and night (moon), winter (cold, wet) and summer (hot, dry), and, more particularly, males and females, the interdependence of which is naturally indispensable for the perpetuation of the cycle of life and death, oppositions themselves seen through their own interdependence.

This fecund sexual opposition was suspected by André Leroi-Gourhan (*1964.108*), among others (*Testart 2006b.26*), for Upper Palaeolithic societies, and

by James Mellaart (*1967.48, note 27–28*), Ian Hodder or Forest (*Matthews 2003.46*) for Neolithic ones. Dualism is also the principle behind the famous Yin (female/earth/moon/water) and Yang (male/sky/sun/fire) of the Chinese tradition (*Granet 1929. 225*). A similar symbolic partition of fundamental opposite elements is still present today, for example, in the arrangement of the Berber house in northern Africa (*Bourdieu 1980*). The philosopher Volkert Haas likewise refers to the concept of separation of the 'undifferentiated' cosmos in primeval times into two sets of opposite but mutually interdependent elements, in particular above-heaven-male and below-earth-female (*Becker* et al. *2012. 30*). This widespread differentiation is personified in the antithetic heroes, twins or brothers/sisters in many founding myths all over the world (*Girard 1972.247–248*).

Among Australian Aborigines, this binary interdependence becomes a ubiquitous principle encompassing inorganic elements like mountains, water holes, stars or meteorological events (storms, rainbows). The entire world is thus systematically divided into separated but interdependent halves, a reflection of the society itself, as ideology generally does (*Testart 1985.467–489*). Dualism thus does not appear as a cultural but as a structural element deeply wired in the constitution of (all?) early human societies.

Barnard (pers. com.) tells me that this dualist division of the society "*is true for Aboriginal Australia, but not necessarily for hunter-gatherers in general*". This is a crucial point because it shows the chronological and structural evolution from 'primeval communists', for which Australian Aborigines are the sole ethnographic representatives, towards 'later' hunter-gatherers like the !Kung San, in which relations of production seem to have been altered by a certain spur of individualization (see below; *Testart 1985.56–60; 1987b*). This evolution would explain the distinction between the 'socio-centric system' and the 'ego-centric system' made by Alan Barnard (*1978.77*), as well as, the full "*correlation between the system of kin categorization as a whole and the rules of marriage*" (*ibid. 75*) that characterizes the Australians but is not found among the San. All this tends to show how 'primeval communism' could represent the genuine social background, characterized by "*a lack of ambiguity of categorization*" (*ibid.*) and from which later developments are likely to have derived.

Among these later developments there is the Neolithic period. Right in the centre of the *a priori* mysterious symbolic repertoire on display at Göbekli Tepe, there is a pair of huge parallel stone slabs standing majestically, seemingly conveying an abstract statement (*Becker* et al. *2012.14*). They appear as nothing but a material representation of this universal dualist scheme. This is the hypothesis that will presently be explored by trying to understand what this dualism is really about.

It goes without saying that Australian Aborigines have absolutely nothing to do with Göbekli Tepe, it is just that they seem to share a similar social *structure*, thus opening the door to a possible analogy, which now needs to be questioned. A major obstacle first ought to be removed: if the aspect and centrality of the 'primeval communist' principle and the Mesopotamian Neolithic symbol present a striking similarity, these societies must be somehow structurally compatible for this analogy to function.

The analogy

Ideology is a central social organ in close interaction with the relations of production (*Giddens 1971. 42*), which implies that, for the analogy to be acceptable, the mode of production of the societies in question ought to be comparable[2]. From this point of view, primeval hunter-gatherers appear starkly different from Neolithic proto-farmers (*Willcox, Stordeur 2012.112; Asouti, Fuller 2013.308*). However, a sociological rule needs to be considered here: if technical and economic changes can diffuse rapidly, their repercussions for ideology (and, subsequently, for symbolism) are always very much delayed. This fact has been well attested by anthropologists studying the appearance of agriculture. "*People can hold on to ideologies (mode of thought) reflecting foraging for generations, even when their systems of production have undergone transition*"; "*relations of production among proto-agriculturalists (...) tend to retain the structures of a hunter-gatherer habitus*" (*Barnard 2007.8,14*, quoted by *Asouti, Fuller 2013.300*).

An ideological structure should not be seen here as a conscious and planned construction, but, indeed, somehow like Pierre Bourdieu's (*1980*) *habitus*, that is, continuously shaped by an everlasting accumulation of practice and experience. The ideology of the earliest farmers is thus likely to be largely inherited from a Palaeolithic background, built over hun-

2 In Marxian terminology, "*the gathering of food (hunting included) is a form of economic production*" (*Ingold 1980.83*).

dreds of thousands of years: Forest (*2006.126*) thus states without hesitation that "*in the case of the Pre-pottery Neolithic, the analogical basis to take into consideration is of course the 'primeval communism'*". This implies that Neolithic people are likely to have possessed a cosmogony organized around some form of totemism, animism or shamanism (*Lewis-Williams 2002.132; Bischoff 2002.237; Yakar 2005.112*).

From there, it is difficult to support the idea that Neolithic people started to cultivate grains because they would have begun (why?) to conceive differently (how?) their relation to deities (are there any?). This is where Jacques Cauvin's (*1997*) famous model is problematic, and why the chain of causal effects may benefit if reversed (*Testart 1998.27*).

The Palaeolithic 'middle range'

The idea that the dualist ideology could be present in Neolithic symbolism as a continuum of a much older tradition would certainly gain some weight if found directly in the Palaeolithic period proper. As mentioned above, Leroi-Gourhan (*1964*) pointed out such reciprocal dichotomy in the Franco-Cantabrian cave paintings, Lascaux in particular. Horned animals (placed on protruding parts of the cave wall) are supposed to represent a male abstraction (horns being an obvious phallomorphic symbol, see *Hansen 2017*), while hornless animals (horses, in concave spaces) a female one, their interaction leading to fertility. These images are moreover painted in the very depth of caves, an obvious symbol of Mother Earth's vagina and womb, where not only humans but all organic forms come to life. "*The earth would have been considered the source of all life's elements*" writes Yak Yakar (*2005.111–112*), specifying that such "*communal fertility-related rituals may have originated in the period before farming became the principal subsistence economy*". Dimitrij Mlekuž Vrhovnik (*2021.3*) further says that a cave is "*a womb and a tomb at the same time*", which would fit well with the above-mentioned idea that life is conceived as taking place in an eternal cycle where death is its inevitable opposite (*Gibson 2009[2010.23]*). Jean-Loïc Le Quellec (*2015.259–260*) comes to the same conclusion after his comprehensive studies of ancient myths from around the world, where humans and animals emerge from a hole in the ground, making the underground at the same time the place where life originates and where the deceased return. The cave paintings thus seem to have put into action symbolically the "*structuring principle (of) vitality (fecundity, life-force)*" (*Verhoeven 2002.244*), astonishingly resembling the 'tao' of the Chinese (*Granet 1929.293*).

But if all forms of life are concerned, it is certainly the community that is primarily envisaged by the principle of fertility.

The dualist principle seems to have been known by the Neanderthals as well (Fig. 3): the symbolic composition found at the bottom of the Bruniquel cave (*Jaubert* et al. *2016*) represents two piles of stalagmites (another phallomorphic symbol) in one circle (a shape often connected with maternal womb and fertility, see *Haland 2017.166*), making the composition strikingly similar to the circle surrounding the twin steles of Göbekli Tepe III (Figs. 2, 3). Since absolutely no cultural connection can be established between these cultures, such similarity can, here again, only make sense if dualism and exogamy are understood as extremely widespread *principles* among early humans (*Freud 2010*).

Because the animal species painted in the Palaeolithic caves are represented as isolated groups, Testart (*1985.276–290; 2012.254–267*) sees them as totems. His analysis is based on the identification, mostly by James George Frazer (*1910*) and Alfred William Howitt (*1905*) (who were also Sigmund Freud's main anthropological sources when he wrote his famous *Totem and Taboo*), of a strong correlation between totemism and exogamy. Totems are natural species (animals, sometimes plants) representing a specific social subgroup, as if the natural world, classified into species, was called in to *naturally* classify the community among separate groups. Both Leroi-Gourhan and Testart thus consider that Palaeolithic societies likely knew some form of 'classification', in Lewis Henry Morgan's (*1871*) use of the term (see also *Radcliffe-Brown 1972.98–103; Bloch 1983.8–13*), so as to ensure the practice of exogamy. And we saw that every classification ultimately and theoretically resumes as a two-fold division, that is, dualism.

In the absence of writing, how are people to express what matters most to them, that is, the (male) society, the (female) engendering principle and exogamy, if not by using elements with readily identifiable characteristics, such as, respectively, the horn, the circle and isomorphic forms?

It is remarkable how early anthropologists from all corners of the world like Morgan in North America, Marce Granet in China, Spencer and Gillen in Australia, Marshall Sahlins in Oceania, Claude Meillassoux

in Africa or Marcel Mauss and Bronisław Malinowski in Melanesia recognized related practices of inter-clan exogamy, cross-cousin marriage or 'classificatory' structures to describe the internal organization of pre-state societies, an organization so different from their own Western 'complex' type of kinship (where marriage is practiced with the outside world, as opposed to closed-in and 'elementary', systems to use Lévi-Strauss terminology). This all-encompassing dualist classification appears as the principle according to which early human society coped with the distribution of sexual mates in order to ensure its own perpetuation. There is thus nothing surprising in finding it all the way to the Neolithic, before the Agricultural Domestic system altered it profoundly (*infra*).

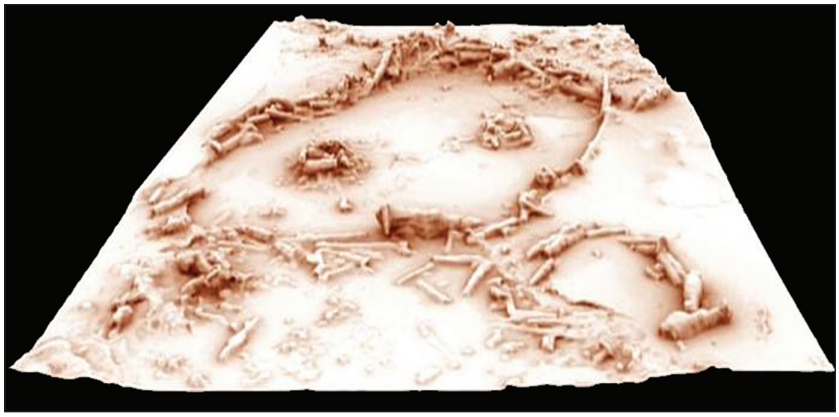

Fig. 3. A likely dualist composition in the Neanderthal cave of Bruniquel. © Xavier MUTH – Get in Situ, Archéotransfert – SHS-3D, base photogrammétrique 3D Pascal Mora Courtesy of J. Jaubert (*Jaubert *et al.* 2016*).

There seems to linger in Western thought an ethnocentric reflex to consider pre-state societies as unfamiliar with elaborate forms of conceptualization (*Asouzu 2007.192*). The ethnography of hunter-gatherer societies largely suggests the contrary (*Barnard 2020*). It is much beyond the scope of this paper to develop the Palaeolithic symbolic world, but it was essential to show that the Neolithic dualist system is a natural offspring of a much more ancient and complex ideological background (*Verhoeven 2001.84*). We are now ready to investigate more precisely what this 'dualist scheme' is all about.

The 'primeval communist' social structure and its persistence in the Early Neolithic

The relations of production

According to the analysis that Testart (*1985*) proposed of at least certain genuine (*i.e.* matrilineal) Australian tribes (in the southeast, especially), the hunter is not supposed to eat the prey he has killed, but to give it away to the community. "*For example, in south-west Victoria, the hunter is said to receive nothing, and his brothers are treated in the same way (*Howitt 1904.765*)*" (*Testart 1987b.296*). This is the basic opposition this author makes between 'primeval communists' and later hunters who usually distribute their prey according to a pattern which "*leaves no doubt about the sharer's close kinship ties*" (*Bird-David 2019.17–19*). Indeed, "*possession of a kill in a hunting society confers not the right to its consumption but the privilege of performing its distribution*" (*Ingold 1980.158, citing Dowling 1968.505*). Who, then, appropriates the prey among 'primeval communists'? It is often individuals belonging to the social group opposite to that of the hunter (*Testart 1988.10*). According to Morgan's (*1871*) 'classificatory system', these groups are defined by filiation and generation, thus grouping all siblings in the same class (*Radcliffe-Brown 1952*). Because of exogamy, the opposite moiety is the one where the hunter finds his spouse. His prey may then go to his spouse's parents. "*Among the Ngatatjara, the parents-in-law take first and the brothers last. (...) Among the Maljangaba of New South Wales, the tribe is divided into matrilineal moieties and a man gets very little meat from his maternal kin because they belong to the same kinship group as he does. He receives much more from his father, since he is not maternal kin (*Beckett I967. 459*)*" (*Testart 1987b.296*). There may be as many rules as there are societies, but it is significant that if the exchange of meat proceeds according to the kinship system among hunter-gatherers, it is in particular the non-producers who generally appropriate the product among 'primeval communists'. Generally speaking, the producer is never the consumer and the consumer never the producer (*Testart 1987b. 294*). Because the rule applies to every hunter, the latter eventually always gets his share, and, if the production is denied to the producer, it is, in the end, to the benefit of the society as a whole. Reciprocity as a rule of traditional economies is also well known in the ethnography of Melanesia (*Malinowski 1926. 33; Mauss 1924*) and elsewhere (*Barnard 2020. 31*), but it is in Australia that this form of exchange appears the most equalitarian. Comprehensive and equal internal cooperation has thus been identified

as the dominant mode of production (*Testart 1985. 115,169*).

The universality of this rule can be questioned for the early stages of humanity, but the general paradigm seems to be that sharing follows the division traced by the kinship pattern in the social body (*Speth 2010.xiiiv*). This could help shed light on specific archaeological traces. For example, food exchange can be inferred from such data in the PPNA sites of the Northern Levant, where harvested grains are assumed to have been stored in communal buildings (*Stordeur 2000.3; 2003.20; 2012*), more or less symmetrically divided into two equal parts along the axis of the building (*Stordeur* et al. *2001.32–33, Fig. 5/1*). Though this is nothing but the author's speculation, it could be that this symmetrical division of the village granary was made according to the kinship division within the community for matters of exchange (each subgroup producing and storing for the other). This division goes much beyond economic matters. At Faynan, in the southern Levant, the communal buildings are characterized by "*general symmetry to the structure along an axis formed by a deep trough*" (*Mithen* et al. *2011.354*). Sometimes, such complementary division has been identified at the level of the entire site: "*the small settlement at Qermez Dere had been laid out in two contrasting halves that performed complementary functions. Part way through its life, the village was re-formed, but once again in two complementary halves*" (*Watkins 2006.16*). Leaving aside the case of Aşıklı, which has a street dividing the village (*Özbaşaran* et al. *2012. 140*) but in less clearly symmetrical parts, Hodder (*2012.304*) identified such an arrangement at Çatalhöyük, with "*a large dip or trough across the middle, dividing it into two hills. The mound does seem to have developed in two halves (north and south). (...) In addition we have found some differences in the genetic make-up of the humans buried in the two halves*". Finally, in the late Neolithic (but in fact, contemporary with the local emergence of the farming system), Ulf-Dietrich Schoop (*2005.49*), concerning the "*lines of parallel houses facing one another*" in Hacılar and several other western Anatolian Late Neolithic sites, writes that "*this brings to mind the social organization known in the ethnographic record as the 'moiety system', in which a community views itself consisting as two competitive*[3] *halves. I do not wish to elaborate on this, for at the present state of investigation it would only be grasping at straws*"[4]. This precaution appears academically wise, but the straws grasped here are arguably nothing but the very root of prehistoric ideology.

A slow change can be detected in the following PPNB period at Çayönü, with granaries attached to every house from the Grill Building phase onward indicating "*that economic emphasis may have been shifted from community to family based production and consumption*" (*Yakar 2003.442*). This reorganization indeed seems to reflect a slow trend towards an economic (and marital) autonomy of lineages, following a "*segmentation and separation of balanced components arranged in relation to each other*" (*Hodder 2020.49–51*), and possibly leading in late Neolithic Çatalhöyük to "*the House as a historical and genealogical social unit*" (*Kuijt 2018. 584; infra*) based on a line of ancestors. This late Neolithic fission into autonomous families apparently emphasizes, by contrast, the closed-in reciprocal pattern that was arguably still strong in the earliest Neolithic.

This economic evolution also seems supported by the genetics of wild food. The PPNA plant material, though anthropologically managed, is not morphologically domestic yet. The subsequent physical domestication, eventually including animals, implies that the originally loose farming mode of production is, relatively speaking, gaining in intensity during the PPNB (*Zeder 2011.230; Willcox, Stordeur 2012.112; Asouti, Fuller 2013.329*). This trend goes well with the idea of weak communal production (PPNA) gradually intensifying (PPNB) towards the specific interests of each lineage (PN), in particular for the constitution of bride-prices (herd animals), suspected elsewhere (*Bodet 2019b*) to have begun in these latter periods. This morphological evolution of resources emphasizes, by contrast again, the economically loose, reciprocal and equal form of food exchange expected to characterize the earliest Neolithic groups.

The relations of reproduction

Economic reciprocity appears to reflect marital patterns. Among hunter-gatherers "*marriage prescriptions commonly involve real or classificatory cross-cousins and (...) exchange between two kin lineages*" (*Walker* et al. *2011.4*). The parents of 'cross-

3 We will see that the division is, at this stage at least, not about competition at all, and in fact quite the contrary (*infra*).
4 I am thankful to Çiler Çilingiroğlu (pers. com.) for bringing this reference to my attention.

cousins' are the children of a brother and sister; because the social affiliation comes from either the father or the mother, cross-cousins necessarily belong to a different 'class' and are expected to marry. This is just one straightforward example; there are many possible types of marital alliance, with many more subgroups but the founding exogamic principle remains everywhere the same: the hunter does not 'consume' his sister but the sister of a hunter from the opposite moiety (hence the famous 'exchange of sisters').

Close-kin mating is often thought to have been prohibited to lessen biological complications coming from consanguine mating, but there is no genetic difference between a cross- (prescribed mate) and a parallel-cousin (proscribed). The key point is that healthy mate circulation in the long term implies not only separate groups (at least two), but reciprocity among them. It is obvious that this social division is not prompted by emulation or rivalry but, quite on the contrary, by the welfare of the entire society. "*A social benefit results from an exogamic marriage (...), the law of exogamy is omnipresent (...). It is the archetype of all other manifestations at the basis of reciprocity, it provides the fundamental and immutable rule ensuring the existence of the group as group*" (*Lévi-Strauss 1967.551*). Exchange and the social classification permitting it thus appear again ultimately as modes of (re)production. The tight infrastructural correspondence between the kinship system and the economy seems to strengthen the fundamental role played by reciprocity and dualism in the ideology (*Lévi-Strauss 1967.48–170; Bloch 1983.9–10*).

As for the reflection of these principles in archaeology, the internal subdivision of the PPNA communities suspected above may be continuing in PPNB Çayönü, where the two large buildings just north of the Plaza could house the elder(s) of each moiety. Another contemporary hint is found in Nevalı Çori with "*two groups of houses with different orientation (...) that could have belonged to two groups of families with different lineage*" (*Yakar 2003.443*), two groups expectedly related through permanent intermarriages. Whatever the case, all hunter-gatherer societies seem to know one form or another of kinship classification (*Ghasarian 1996.31; Walker* et al. *2011.1*): there seems to be no viable reason not to expect a similar system of reciprocal mate exchange among Neolithic communities. And this could be what the twin steles state out-loud.

Totemism

Some form of totemism seems rather common among hunter-gatherer communities, though its absence among the San shows it is not universal (*Testart 2006c.149; Barnard 2020.46*). It is nevertheless thought by a number of specialists cited by Freud (*2010.42, note 2*), in particular Frazer (*1910*), to have been very widespread at an original stage which would correspond to 'primeval communism'. There is, again, no *a priori* reason to exclude its presence in the Neolithic, as strongly suggested by the twin stele arrangement. The totem consist of natural species, usually an animal, considered to be the ancestor of a clan or tribe. Individuals maintain a very specific relationship with it, being strictly forbidden to consume it, except once a year during the ritual known as 'Intichiuma', aimed at magically increasing the totemic resource for the opposite moiety to consume (*Spencer, Gillen 1899.169*). This is the symbolic projection of the rule of reciprocity reviewed for production (the hunter not eating his prey but hunting it for the other moiety to consume) and for reproduction (individuals not marrying within their own subgroup, but 'producing' children to be 'consumed' by the opposite one). By way of animal species, totemism can be conceived as a symbolic representation of the dualistic kinship system ongoing in the community (*Freud 2010.203–204, 255–256*).

Göbekli Tepe, sometimes seen as a place of interclanic reunions for very extended kinship groups (*Schmidt 2001.52–53; Belfer-Cohen, Goring-Morris 2002; Peters, Schmidt 2004.210–212*), would fit well as a place where Intichiuma-type ceremonies were taking place. In fact, if contemporary levels are to be found, the high number of large early Neolithic sites, like Karahantepe, recovered within a radius of about 20km all around Göbekli Tepe (see below), may have composed this population (*Bodet 2019a*).

For Hans Georg K. Gebel (pers. com.), "*the ideology of the early Göbekli Tepe Culture represents a symbolically sustained system needed to serve the integration of growing group numbers (...). Mutual understanding and conflict management of groups not knowing each other were reached by commonly accepted strong and binding ideologies and conventions. One may speak of ideocratic territories mediated through the fixed image programs*". A common ideological background indeed certainly played an important binding role among all these communities, and, looking at the homoge-

nous symbolic program on the entire site, this binding element must have been related to an isomorphic, *i.e.* dualist conception, shared long before the construction of Göbekli Tepe.

The Neolithic iconography could fit neatly with the totemic analogy, by supposing, like the excavators of Göbekli Tepe and other specialists (*Peters, Schmidt 2004.209–212; Kornienko 2018.17–18*), that the animals carved on the steles represented totems. However, for Forest (*2006.134*) this is probably not the case, because these elements interfere with each other, being complementary or synonymous, so as to convey a message, while totemism simply classifies in purely equal terms. Totemism and message/law indeed stand at different levels in the ideological structure, but are not at all incompatible (*Testart 1985.510*). The numerous animals represented on the side steles could fall under Forest's warning (*Bodet 2021*), while the few ones on the central steles, absolutely alone, may be more in tune with a totemic classification. Though intrinsically related in form and signification, we will see that side and central steles may hold a different symbolic value.

The rich animal repertoire represented on the side steles is very similar to that deciphered by Forest (*1993; 2003*) at Çatalhöyük: bulls, predators, psychopomp birds, found to symbolize the society, death of the body and transportation of the soul, respectively. Göbekli also has many snakes, understood as lineages (*Forest 2006*). The same geometric elements, thought to symbolize the two moieties or the sexual mates they exchange, are also found on both sites (and many others): parallel lines, zigzags, triangles, and chevrons. The several side steles could then represent the subgroups the community is composed of, linked to each other by the circular stone wall, forming a large matrimonial self-sufficient unit. The non-totemic (message-delivering) symbolic animals carved on them would suggest the endless (feminine) cycle of life (snakes) and death (birds, predators) in which these groups were involved (*Bodet 2021*). On the other hand, if the central parallel steles stand for the dualist subparts of the (masculine) society (product of the feminine principle), the isolated animals carved on them may indeed be totemic. For example, the reflecting foxes on the twin steles of enclosure B (*Peters, Schmidt 2004.184*) would represent the two inseparable but distinct subparts of the same totemic clan (see *Malinowski 1926* for compatible ethnographic examples).

A look at a tightly interwoven subject – mythology – will allow a more comprehensive understanding of the dualistic nature of totemism.

The mythology

The species included in the totemic partition have a correspondence in the mythology. The main characters of the Australian Aboriginal myths of the Dream Time (*Testart 1978; 1985.390–395*), with a correspondence worldwide (*Girard 1972*), are generally divided in two types: the violator and the counter-violator. For anything to happen in the founding myths, the fundamental rule (exogamy) must be violated, which invariably entails a counter-violation. The widespread myth of the eagle (the hunter, the creator, the counter-violator) and the crow (the scavenger, the trickster, the violator) illustrates this point. The crow steals the fire from the eagle (violation), and, as he escapes, he drops the fire, allowing humans to capture it and cook food. The eagle avenges himself by causing a huge fire that threatens humans (counter-violation). Some variants of this myth are about stealing water (violation) and so permitting life but provoking floods when uncontrolled (counter-violation). Myths thus explain the origin of the society as an interaction between two opposite but interdependent poles (*Testart 1978.95, 118–125; 1985.384–387,432–444*). Just like later religions, mythology aims in the end at securing the social order through ideology.

Forest (*1993.17–21; 2006.134*) reads the elements in the iconography of Çatalhöyük as principles conveying a message: life and death on a vertical line, two exogamic moieties on a horizontal one, all intersecting in a cross pattern to permit the existence of the community, thus recalling its fundamental rule (exogamy). This message is essentially the same as the one present in myths. It is open to question whether the animals in the iconography, strikingly similar in Göbekli Tepe and Çayönü despite a wide chronological and spatial gaps, directly represent mythical characters. But in the end it matters little, since they are likely to stand for the same opposition among interdependent elements (as an image, again, of the subgroups of the society). Just like in many myths of the primeval world, a dualistic opposition can be suspected with a certain degree of confidence among the antithetic heroes of Neolithic mythology, symbols of a fertile opposition.

René Girard (*1972.88–95*) presents a somewhat different interpretation of early myths and rituals, focusing on sacrifice as catharsis, expelling the tensions

accumulated within the community on an innocent victim, but the ultimate goal remains to prevent the 'divided' community from the risk of becoming "*undifferentiated*". Jungian psychology also notes the case of twin snakes in mythology. "*These are the famous Naga serpents of ancient India; and we find them in Greece as the entwined serpents on the end of the staff belonging to the god Hermes*[5]*. An early Grecian herm is a stone pillar (...). On one side, are the intertwined serpents (in the act of sexual union) and on the other an erect phallus: we can draw certain conclusions about the function of the herm as a symbol of fertility. (...) But Hermes is (also) Trickster (...) the leader of souls to and from the underworld*" (*Henderson 1964.155*). The two snakes appear as the dualist lineages whose union alone can engender society.

The blood ideology

Based on ethnographic data, Chris Knight *et al.* (*1995.89,93–97*) have proposed a Palaeolithic "*symbolically structured sexual division of labour*" where, notably, the recurrent use of red ochre would be utilized in menarchal rituals to symbolize fertility. This interpretation could fit well with Testart's (*1985.345–475*) reconstitution of the primeval mind, according to which the female compensation for the masculine blood-soiled meat brought by the hunter is the feminine blood-soiled newborn child.

The widespread presence of red paint on the floor of special buildings all through the Neolithic of southwestern Asia (*Gökce 2021*) supports the idea that blood played a fundamental symbolic role. At Çayönü, actual traces of human (and animal) blood have been detected on a one-ton slab in the courtyard of the so-called 'Skull-building' (*Özbek 2004.20*). Given what is known about these societies, notably the classification according to generations, it seemed likely to Forest (*1996b*) that this blood was that of initiation rites. The blood of circumcision (symbolizing the first hunt?), equivalent to that of the (first) menstruations (*Doyle 2005.280; Knight* et al. *1995. 95*), can be understood as a separation between two crucial statuses: not simply synchronically between male and female (or between their respective moieties), but diachronically between consumers (children) and (re)producers (adults).

Through its intimacy with both life and death, blood is thus considered by Testart to have played a synthetic role in the primeval communist ideology. A symbol of order and life when running in the closed system of the veins (=exogamic rule respected), blood represents chaos and death when running out of a disrupted vein system (=exogamic rule violated). Just like for the mythical figures (divided into violators and counter-violators), for the natural species in totemism (divided among social subgroups) and for society (divided into parallel moieties), blood, the one and same blood, is artificially divided and separated into distinct but mutually interdependent classes so as to promote their mutual interdependence and strengthen the unity of the whole.

Synthesis: the dualist scheme

Because the data mobilized here is not archaeological in nature, it is perhaps not superfluous at this point to synthesize what we have proposed. The kinship dual classification of the society is reflected in the economy and ideological structures, such as totemism, mythology and blood ideology. Beyond a mechanical Marxist view that would present the social superstructure as invariably determined by the economic infrastructure, kinship thus appears to dominate the primeval communist relations of production, making the reproductive infrastructure the very root of dualism. Yet, as Alan Barnard (*1978.78–79*) writes, "*Australian systems differ from other universal systems in that Australian universality is not confined to kinship*", it is "*closely connected with totemism and with other aspects of cosmology*" (which) "*divide the universe -nature and culture alike- into named categories [which] represent a concept of world order in which kinship is only a part*". It thus seems that what determines kinship and all other structures is, in fact, the exogamic principle which must be conceived as an overarching pattern imposed on the entire social fabric. Opposing sets of the natural world like male/female, sun/moon, winter/summer, water/fire, dry/wet or life/death are 'given' to humans, who use them as symbols to express and justify the only opposition on which they have a hold, the division of society itself into exogamic lineages or moieties. In other words, just as in later religious systems (*Forest 1996a*), the cosmos is mobilized to promote, through its own perpetual and fecund oppositions, the perpetuation of the fragile opposition between lineages or sub-clans in order for the society as a whole to reproduce. It is this all-encompassing exogamic division that is termed the 'dualist scheme' by Testart (*1985.207–218, 477–515*), and which, as we intend to show, was still very vivid in the Neolithic.

5 This is the caeduces, still symbol of modern medicine.

The Neolithic dualistic symbolism

Two parallel steles seem to be the symbol chosen by Neolithic people to represent the concept of exogamy/dualism. Given the pervasive twin steles present in a large number of sites (*Bodet forthcoming*), it appears that early Neolithic communities felt the urge, maybe more than Palaeolithic ones, to recall and impose this principle. Is it possible to be more precise as to the message conveyed and to the cause of the monumentality given at this precise moment to an immemorial principle?

The stele as a symbol of the lineage

In the communal building of Nevalı Çori (devoted to reunions, given the bench running at the base of the surrounding wall), Alexis McBride (*2013.54*) proposed that the anthropomorphic steles inserted in the bench are 'participants' along with the real humans seating there. This makes sense indeed, but the verticality of the stele must be meaningful. According to several researchers, like Forest (*1993.7*), Tatiana V. Kornienko (*2018.17*) or Christian Jeunesse (*2020.54*), the stele stands for a genealogical line of ancestors related over time, that is, a lineage, built up generation after generation. This interpretation is well supported by ethnographic observations: in the American North-West coast, the "*totem poles, house posts, memorial posts (...) record the household's lineage*" (*Banning 2011.626*). The endless continuity in time of the lineage could be the reason why certain Neolithic steles are reused at the same location phase after phase (*Watkins 1996*), while others are buried or ritually broken.

Seeing side steles as lineages implies that each circle could represent a larger social group, like a tribe or clan, divided into a number of subsections, an idea already alluded to, in one way or another, by several authors (*Belfer-Cohen, Goring-Morris 2002; Yakar 2013.438; Hodder 2020.50*). Beyond the representation of the cycle of life and death as suggested above, the surrounding wall of the Göbekli Tepe enclosures could bind the lineages in an endless circle of marital exchange, a stone materialization of a closed-in 'generalized-type' of kinship pattern[6] (*Lévi-Strauss 1967*), where lineage A gives a mate to lineage B, B to C... back to A (*Bodet 2012*). There would then be between four and twelve subsections for each tribe; interestingly, twelve is also the number of subgroups chosen by Freud (*2010[1915].51*) to present a typical totemic society. The interconnected side steles would then stand, like a temenos wall, as a transition between the real world and the sphere of pure abstraction, which, we will now see, seems to take stage at the centre of the circle.

The reciprocal relationship

Central and side steles have the same monolithic structure and same morphology, the latter being simply smaller and less well executed. For the symbolic program in question, they are likely to be a related signifier standing for a related signified, but on a different scale. If side steles may represent the actual lineages making up the community, the central twin steles would then represent two parallel lineages, but on a purely conceptual level. They seem to stand for an abstract idea, an allegory of the exogamic rule, the active (feminine) *principle* of fertility. Parallel, isomorphic and face-to-face, the twin steles seem to express a bilateral relation of strong symmetry, where each subgroup is at the same time the donor and recipient of a (marital) transaction. Behind the exogamic rule (*Forest 1996b.29*), the composition seems to express the type of social relation that exogamy entails, one of pure reciprocity. As Lévi-Strauss (*1967.97*) puts it, the dualist principle is itself only a modality of the principle of reciprocity.

This emphasis on the relation itself appears hindered precisely by the fact that the twin steles do not generally enter in relation with each other, just like parallel lines painted on floors (also recalling lineages). The relation between the steles is suggested elsewhere: a low bench, a slight clay lip or a slab set on edge at Qermez Dere, Beidha, Çayönü (Skull Building), Musular and at late Göbekli Enclosure A (E PPNB) (*Watkins 1996; Makarewicz, Finlayson 2018; Erim-Özdoğan 2001.208; Özbaşaran* et al. *2012; Schmidt 2001.50* respectively). In the enclosures of Göbekli III, twin steles can be said to be connected by the ground, Mother Earth, of which we saw the importance for the concept of fertility. But there is more. The lack itself of any obvious connection between the parallel steles implies exactly the contrary: perpetually reflecting each other (as well as the – totemic? – decorations carved on them), one is nothing but the permanent counterpart of the other, each stele fundamentally dependent on the other to exist. The intrinsic relation between the two steles is conspicuous by its absence.

6 https://www.britannica.com/topic/kinship/Alliance-theory – for an introduction in English to the work of Lévi-Strauss. An inspired interpretation of his work has also been proposed by Barnard (*1978*).

The composition seems to be bluntly saying: a moiety is the mirror of its counterpart, and only the two together, as equal partners in the (marital) exchange, can engender the society altogether, which, in turn, can only exist divided into equal subparts intrinsically bound to each other. But if twin steles represent an abstract sphere of symbolization with such majesty, it is exactly because this notion is not simply an allegory: reciprocity must be conceived as a law governing social conduct. In other words, the full message conveyed by the twin composition appears as such: 'marital reciprocity must be respected for the sake of the whole society'. We will later see why this antediluvian rule took such a 'monumental' urgency in the Neolithic.

The twin steles as a symbol of fertile regeneration

Let us first complete our reflection on the striking fact that the most central place of the entire composition at Göbekli Tepe (see also Jerf el-Ahmar) is the space left 'religiously' empty between the twin steles (Fig. 4). This vacant space must have been filled with meaning in the eyes of the audience. We saw that at Çatalhöyük two symbolic pillars are connected by the limbs of a feminine figure giving birth to a bull (which is a good enough reason to see this representation as a metaphor and not as a realistic scene). Again, according to Forest (see English summaries in *Bodet 2012.7* and *2021.149–151*), this is not a woman, but the personification of the principle of regeneration, engendering the society. On the same line of thought, the space between the twin steles at Göbekli can be understood as a threshold to life (a symbolic vulva?) and death (a symbolic 'swallowing' mouth), because it is a representation of the *vagina dentalia*, the 'toothed vagina', a widespread mythological female principle of both regeneration and destruction among traditional societies (*Forest 1993.22; Ross 2021*).

This invisible principle of the regeneration of society and all life forms would then be put into action by the mutual interaction existing between the exogamic moieties represented by the two monoliths. This is a practical illustration of Trevor Watkins' (*2006.21–22*) statement that "*architecture is a specially powerful mode of external symbolic storage*". And these symbols convey a specific meaning. The Neolithic twin steles seem to state: 'the eternal cycle of life and death can only be put into action by the principle of pure reciprocity'. Such prehistoric capacity of abstraction can only be a surprise to ethnocentric prejudices.

McBride (*2013.59*) further suggests that the participants in a ritual or ceremony may have been asked to walk through the central steles at Göbekli Tepe. The idea deserves attention. This particular space, here putatively interpreted as the principle of regeneration of both life and death, would indeed be the ideal place to have adolescents pass through during their initiation ceremony, initiation being conceived in many societies as the death of the child and rebirth as an adult (*Weiss 1966.72; Henderson 1964.120–121; Forest 1996b.28*). According to Max Weber (*1920[1996.184]*), initiated aristocrats in China or India call themselves 'the twice-born'. The link between dualism, totemism and initiation is further supported by the fact that in order to become hunters, young Aborigines are systematically initiated by the opposite moiety. The same holds true for funerals and Intichiuma ceremonies (*Testart 1987b.299*).

Regeneration may also be the main principle displayed in the Franco-Cantabrian caves (also an ideal place for ceremonies of initiation). In that case, the cave paintings would 'magically' assist these principles by being represented in the 'womb of Mother Earth' (*Henderson 1964.146–153*), the latter also being a recurrent theme in Carl Jung's 'collective unconscious'. An analogy can also be made with the Turkish custom of Hıdırellez, still performed today,



Fig. 4. Empty space between the twin steles of enclosure D. © Deutsches Archäologisches Institut, Göbekli Tepe Projekt. Picture No. GT10_AnlD_ 5807, by Nico Becker. Courtesy of the DAI.

where the drawing of babies and cradles on the sand or earth in springtime (when nature comes back to life) is believed to enhance fertility[7]. The belief that the mere representation of symbols has a 'magical' active power is universal: it is the same when Christians hang a cross in their homes or Muslims a picture of the Mecca. This (and probably not a belief in a deity) would also explain why so many crude female figurines (representing the same allegory of fertility) were so common in domestic contexts in the Levant or Central Anatolia (*Cauvin 1997.46–49*), as well as many hand-size T-shaped figurines in the Urfa area (*Hodder 2020*). This same belief could finally explain why symbolic enclosures in sites like Göbekli Tepe, Nevalı Çori, Sefertepe, Karahantepe (*Moetz-Çelik 2012.699*) and as far away as Çayönü, Qermez Dere (Upper/Middle Tigris basin), Jerf el Ahmar (Middle Euphrates) and Beidha (Jordan), were carefully buried upon abandonment[8], arguably so as to preserve the active principle of fertility they enclosed.

Epilogue: a likely cause for the monumentality

This investigation must now be placed in its socio-economic context, thereby answering a last important question: why such monumentality, especially if, as discussed above, the displayed concept had been a basic one for tens of millennia?

We must come back to the idea that in spite of its 'universality' (*Malinowski 1926; Lévi-Strauss 1967. 3–29,49*), the division of society into subgroups is not founded in nature, it is a social product; this implies that nothing can physically guarantee the respect of exogamy, and that its importance must be permanently reinforced in the community, in particular to the newly initiated generations.

In hunter-gatherer societies marriage is not left to the free-will of individuals; it is codified by tradition and contracted among more or less closely related individuals, like cross-cousins (*Lévi-Strauss 1967; Walker* et al. *2011; Barnard 1978; Ghasarian 1996. 147–174; Bird-David 2011*). The distribution of sexual mates is thus regulated so as to avoid a dangerous anarchy for the entire community. Once settled, communities naturally continued this immemorial tradition of 'prescriptive' (or pre-arranged) mating, every new generation being bound to stay within the village so as to comply with this systematic exchange. Coupled with the fact that settled life and farming naturally lead to a strong demographic growth (*Bellwood 2005.61–64*), the consequence of this alliance system is that this growth is largely local. This age-old inward-looking 'elementary-type' (whether 'restricted' or 'generalized') of marital alliance rule (*i.e.* among the subgroups of the tribe) is most likely the ultimate cause for the appearance of Late Neolithic mega-sites like Çatalhöyük, Halula, Ain Ghazal, Shu'eib or Basta (*Forest 1993; Bodet 2019a*; this probably goes also for Neolithic mega-sites elsewhere like the Trypillian sites). Thus, if at Göbekli the symbolic emphasis is monumentally placed on the community altogether, in the much later Çatalhöyük horizon the same concern gradually shifts towards the intimacy of the (autonomous) lineage itself, or "*multiple single-family households*", to use Kuijt's (*2018.565,584*) words.

Such evolution did not go without problems. In farming families the elder son traditionally inherits from his father not only the estate, land and animals, but also a decisional power over his younger brothers and sisters, especially in terms of alliances. This leads to a growing internal stress with younger individuals searching to withdraw from the domination of their elders by splitting from the group, a situation well described in comparable ethnographic cases (*Sahlins 1961.324–327; Meillassoux 1991.51–52, 122–124*). For Çatalhöyük, Forest (*1996b.5*) devised a similar incongruous situation, all the more so that farming allows for (and is much more efficient with) small producing units (nuclear families) spread over the landscape, each family/farm on a separate piece of land. The resolution of this inextricable situation had to wait for the abandonment of the prescribed 'elementary-type' alliance system (among related individuals). This is indeed what seems to have happened nearly everywhere by 6500/6000 BCE at the latest, as suggested by the (gradual, then total) desertion of all mega-sites, followed by the establishment of gradually smaller farmsteads spread around, wherever land allowed for farming and herding. Huge Çatalhöyük East thus gives way to relatively smaller Çatalhöyük West (though this site still remains rather large); relatively small Musular, founded towards the end of large Aşıklı, may represent an earlier (Late Neolithic), because eastern, example of the same process of site segmentation. This trend will continue throughout the early Chalcolithic, reaching its apex with the Halaf culture (*Forest 1996a. 27–35*).

7 See ethnographical support for this idea in the authors' video (in Turkish): https://youtu.be/hTl3eG6wTqM

8 This could still hold true even if the burying of Göbekli Tepe was initiated by slope-sliding and inundation (*Kinzel, Clare 2020. 33*).

The expected tense social context just referred to is crucial to understand the monumentality of the steles of Göbekli Tepe. In charge of maintaining the moral conduct of the society, the elders are constantly recalling, imposing and teaching the new (initiated) generations about the old traditions, in particular the reciprocal exchange of mates. They would have been particularly anxious and careful to avoid any disruption in the smooth circulation of women, and therefore, to counter, with the help of symbolism, the splitting of younger people from the larger kin-group. Indeed, the elders of each social subgroup, responsible for giving mates to the other subgroup(s), could not fulfil their duties if these younger individuals had left. From their point of view, such a fission would invariably lead to an outbreak of the inextricable internal violence that is known to have scared these societies so much (*Girard 1972*).

The fear of the loss of reciprocal exchange and of the cohesion of the community is hypothesized to have pushed the elders to express the old rule of (exogamic) alliances with much force and prominence by ordering the erection of the monumental twin steles. It is in this sense that we propose to illustrate Thomas Zimmerman's (*2020.14–15*) intuition that the symbolic program of Göbekli Tepe reflects much more a Palaeolithic cultural collapse than the advent of a new one, the way Cauvin (*1997.50–55*) sees it. "*It is doubtful that the supernatural world-order envisaged by earlier hunter-gatherers would have been entirely altered by new spiritual concepts*"; (the Neolithic) "*repertories of symbols (...) seem to have their origins in earlier periods*" (*Yakar 2005.111*).

"*The establishment of such symbolic systems, or the externalisation and canonisation of symbols, is not the result of a cognitive process but rather the result of a basic need, the need to sustain a current life mode by coping with newly arising social and ideological challenges of fast growing social aggregates in the Upper Mesopotamian grasslands*": this statement of Gebel (*2013.40*) applies very well to our views, provided that the "*basic need*" in question is first and foremost that of a sustained marital alliance system.

The monumental isomorphic steles understood as an enforcement of respect for the old reciprocal alliance rule, can thus be seen as a form of propaganda, erected in the face of the threat of being abandoned at a time when Agricultural Domestic lineages were gaining economic and marital autonomy. These 'monumental' fears were indeed justified as, in spite of all these efforts, elementary alliances will prove obsolete by the Chalcolithic. This necessarily implies that nuclear families (a married couple and children), breaking free from their larger family groups, proceeded to 'complex' types of marriages taking the form of 'contracts' (hence called 'alliances') among unrelated larger families, probably secured by material transactions like the bride-price (herd animals) (*Bodet 2019b*). In such a context, exogamy became reduced to the prohibition of incest (*Ghasarian 1996; Forest 1996a*) and dualism naturally lost its ground as a principle of alliance together with its ideological relevance. In Gebel's words (pers. com.), "*dualist schemes may even become extinct in early productive environments when strong relational ordering principles help or suffice to organize lineages and the societies they are part of*".

Synthesis: Dualism as a Neolithic scheme

By shedding light on the archaeological data using ethnographic social structures, we have here attempted to review how the Neolithic revolution transformed the Palaeolithic society into an Agricultural Domestic one. We were greatly helped in this task by the Neolithic symbolism on which social changes were invariably projected. This structural evolution is synthesized in Table 1 and Figure 5.

We started our investigation on the premise that hunter-gatherer societies do not marry with outsiders and are, as a rule, divided into (at least two) subgroups (moieties or lineages) as a direct outcome of the universal rule of exogamy so as to secure the distribution of mates and reproduction of closed societies: the hundreds of early societies reviewed in *The Elementary Structures of Kinship* by Lévi-Strauss (*1967*) as well as general handbooks (*Ghasarian 1996*) or articles (*Barnard 1971; Walker* et al. *2011*) on early kinship make this point clear. This seems to apply during much of the prehistoric period, as symbolic representations in the depths of Middle and Upper Palaeolithic caves seem to suggest. Throughout the Mesopotamian and Anatolian Neolithic, this tradition continues with an impressive series of isomorphic representations, in particular twin steles. The message seemingly conveyed by this dualist symbolism can be read as follows: 'only the reciprocal (marital) relationship ongoing between the moieties (lineages) composing the society can allow for the society to reproduce safely'. Beyond the kinship pattern, reciprocity encompasses all other as-

Period	Economic structure	Social st. Kinship	Relations of production	Dualist symbolism	Compatible Ethnog.
Paleolithic communism	Nomadic Hunter-gather	Closed-in Moiety sys	Primitive communism	Neandertal Bruniquel	Aust. Abori Spencer&Gill.
Late Up. Pal. Meso-Epip.	Hunter-gath. w/ bows/arrows	Classificat. Morgan	Egalitarian (Woodburn)	Franco-Cantabrian	!Kung, Inuit Barnard
PPNA (N. Mesop)	Pre-dom. Agric. (Willcox)	Lineage formation	Communal reciprocity	Monumental Göbekli	Trobriand Malinowski
PPNB/PN (C. Anat)	Domestic Agric. (Peters, Zeder)	Segment. lineage	Lineage based	Domestic Çatal	Baruya Godelier
Chalco (Halaf)	'Agricultural Domestic' (Sahlins)	'Complex' (open)	Domestic hierarchy	Lineage-base Latmos	Gouro Meillassoux

Tab. 1. (Very) rough evolution of prehistoric social structures (a preliminary attempt).

pects of the hunter-gatherer social structure, first and foremost its economy. Testart has therein come to the conclusion that dualism generally represents a fundamental scheme determining the structural and ideological composition of pre-state communities. It is suggested here that this dualistic ideology finds its most phenomenal transcription in the monumental central twin steles of Göbekli Tepe, at a time when it was in danger of being supplanted by the advent of a whole new social and ideological order, the Agricultural Domestic System, founded on autonomous (unrelated) agricultural lineages organizing marital alliances (with bride-prices) freely among themselves. As agriculture diffuses towards the west, and is appropriated by local hunter-gatherers, the same emphasis on dualism appears, this time on a more modest scale but widespread in every domestic context, as in Çatalhöyük. This latter social system (lineages, autonomous in marital terms) was destined, a few millennia later, to aggregate hierarchically into city-states on the pattern of the status differentiation between elder males and women/youngsters in the agricultural family itself (*Forest 1996a; Meillassoux 1991*).

According to the dictionary, a scheme is "*a large-scale systematic arrangement for attaining some particular object or putting a particular idea into effect*"[9]. For hunter-gatherers, the 'arrangement' is the reciprocal partition, and the 'object put into effect' the regeneration of the community. The symbolic repertoire of Göbekli Tepe and of a large number of sites up until Çatalhöyük could show that this scheme may apply all the way to incipient farmers.

It is now possible to clarify a theoretical problematic raised above, and state that there is no coincidence in recognizing dualism in the ideology of societies as geographically, chronologically and culturally distinct as the Neanderthals, Australian Aborigines, Magdalenians, Ancient Chinese, SW Asian Neolithic or early historical Mesopotamians. This convergence becomes structurally logical when the ideology of these societies is ultimately determined by

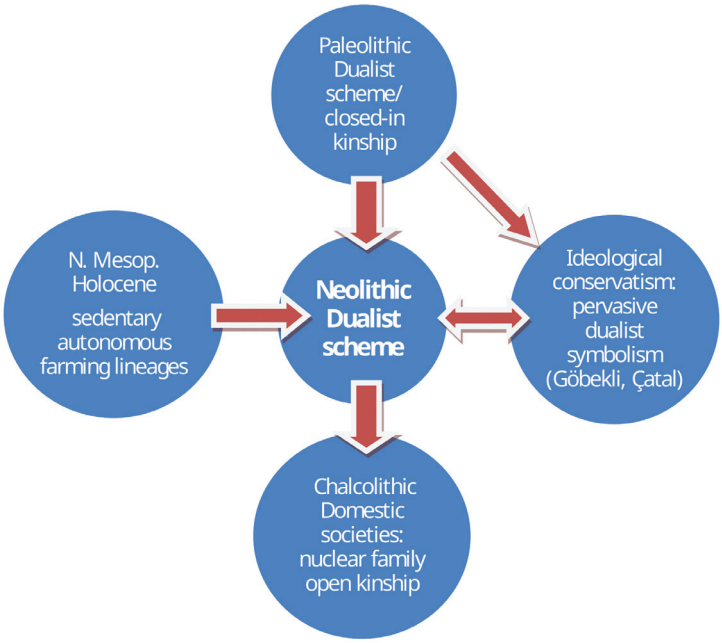

Fig. 5. The Neolithic Dualist scheme seen as an evolution of social structures (synthesizing graphic). Dualist and closed-in ('elementary') Palaeolithic societies confronted with growing autonomous Neolithic farming lineages trigger an ideological conservative reaction (monumental: Göbekli III, omnipresent: Çatalhöyük), but finally evolve towards open ('complex') Chalcolithic Domestic lineages.

9 https://www.encyclopedia.com/science-and-technology/computers-and-electrical-engineering/computers-and-computing/scheme

strictly equal relations of (re)production (compensating for low productive forces). The human constitution, physically weak but with a very high potential for intra-specific communication, is such that the survival of the species is mostly dependent on the process of exchange between individuals. This perpetual need to distribute food and especially mates within the subgroups of the community and across generations required the adoption of a form of social conduct based on pure reciprocity. Dualism appears as the ideological result (and not the cause *ex-nihilo*) of this chain of causal factors. This is the reason why dualism should not be seen as a mere cultural tradition which, among others, would have been miraculously preserved until the Neolithic. It can be presumed to have been 'socially selected' in the Darwinian sense of the expression, that is, unconsciously over countless generations, for having provided humanity with the highest, maybe the only, probability of survival.

Evaluation

It should be noted here that Testart is suspected of having somehow distorted the ethnographical facts, although this is certainly due to the goal he set himself: not that of describing specific communities, but instead uncovering the purely theoretical structure that binds them all. He was thus able to reconstruct a coherent social system where every structure (production, reproduction, ideology) is absolutely in tune with all the others. The best clue to support the coherence of this reconstitution is that everywhere societies reproduced successfully the hunting-gathering way of life throughout the entire Palaeolithic period (one to two million years?). We saw how this success was achieved through the total annihilation of individual interests to the benefit of the whole, and that dualism has been identified as the keystone of this remarkably stable social construction. But the ultimate illustration for the central position held by dualism in prehistory, and without which dualism would have never occurred to the author's mind as a way to enlighten the Neolithic ideology, is the set of central monumental twin steles of Göbekli Tepe.

Conclusion

The following quote on the Australian Aboriginal social and ideological structure seems appropriate to conclude this paper: "*to affirm that appropriation is the fact of the community as a whole only, to affirm that the latter is an inseparable totality, it was first necessary to break it into two, into two parts each closely dependent on the other. Each part was conceived from the start as part of the whole*" (*Testart 1985.478*). It is remarkable and fortunate that these lines were written about a decade before the excavation of Göbekli Tepe. Today, the twin steles stand as a monumental confirmation of Testart's (*1988*) audacious intuition that Australian Aborigines likely reflect an extended Palaeolithic ideological background.

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Different manifestations of Neolithization in Northwest Anatolia? An archaeobotanical review from Barcın Höyük and Bahçelievler, Turkey

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ABSTRACT – *The Neolithic way of life was first established in Northwest Anatolia before the middle of the 7th millennium BC. The recently excavated sites of Barcın Höyük and Bahçelievler have yielded archaeological evidence for the earliest Neolithic levels in the region and provide new archaeobotanical datasets. To compare different adaptations to the changes brought on by the Neolithization processes, we studied 348 archaeobotanical samples from Phases VIe and VId1 at Barcın and 63 samples from the contemporaneous levels, Phase 6 and Phase 5, at Bahçelievler. The economic plants include hulled and naked six-row barley, einkorn, emmer, bread/hard wheat, small-sized naked wheat, lentil, bitter vetch, pea, chickpea, flax, hazelnut, bramble, and pistacia. Our analyses show small but significant differences between the sites in the selected economic plant ranges, among the cereals, pulses as well as gathered plants.*

KEY WORDS – *archaeobotany; Neolithization; Northwest Anatolia; Barcın Höyük; Bahçelievler*

Različne oblike neolitizacije v severozahodni Anatoliji? Arheobotanični pregled v Barcın Höyüku in Bahçelievlerju v Turčiji

IZVLEČEK – *Neolitski način življenja se je v severozahodni Anatoliji uveljavil pred sredino 7. tisočletja pr. n. št. Nedavno raziskani najdišči Barcın Höyük in Bahçelievler sta prinesli arheološke dokaze in arheobotanične zbirke podatkov o najzgodnejšem neolitiku v regiji. Primerjavo različnih prilagoditev spremembam, ki so jih prinesli procesi neolitizacije, smo opravili s pomočjo analiz 348 arheobotaničnih vzorcev iz naselbinskih faz VIe in VId1 v Barcınu in 63 vzorcev iz sočasnih faz 6 in 5 v Bahçelievlerju. Gospodarske rastline so oluščeni in goli šestvrstni ječmen, enozrnica, dvozrnica, krušna žita, drobnozrnata pšenica golica, leča, grenka grašica, grah, čičerika, lan, lešnik, robida in pistacija. Naše analize kažejo na majhne, a pomembne razlike med najdišči v izboru gospodarskih rastlin, tako med žiti in stročnicami kot tudi nedomesticiranimi rastlinami.*

KLJUČNE BESEDE – *arheobotanika; neolitizacija; severozahodna Anatolija; Barcın Höyük; Bahçelievler*

Introduction

Archaeological evidence indicates that sedentism, domesticated plants, and herded animals made their way from the Fertile Crescent and Central Anatolia towards the Aegean and the Marmara Region in the first half of the seventh millennium BC. How this spread occurred and how societies adapted to Neolithic lifestyles exhibit great variability. Studies on the Neolithization processes suggest that while some

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communities established Neolithic habits from the outset, others fused two diverse ways of life; a hunter-gatherer lifestyle with agriculture (for Europe see *Robb 2013; Zvelebil 2001*). Recent studies on modes of subsistence illustrate heterogeneous and complex processes and a mosaic of adaptations (*Ivanova* et al. *2018; Jovanović* et al. *2021; Kotzamani, Livarda 2018; Zeder 2011*). These data challenge the idea of the spread of a uniform 'Neolithic Package', but much remains to be done to understand how the processes took place from region to region. Macro-botanical and micro-botanical analyses can be important to understand the variability of Neolithic adaptations and subsistence strategies during this process of expansion and colonization.

How processes of expansion took place in Northwest Anatolia remains an important question given that this region was among the first territories that Neolithic pioneers coming from the core regions of Neolithization encountered (Fig. 1a). While all early settlements in the region display an established Neolithic way of life, it is still unclear whether these Neolithic societies incorporated Mesolithic foragers present in the region. Hypotheses have been formulated about a merging of forager and farmer groups in Northwest Anatolia (*M. Özdoğan 2013; 2014*), but the supporting evidence at hand is far from concrete. Differences in architectural styles and material culture have led to theories regarding the presence and continuity of local pre-Neolithic communities at some sites (*Düring 2013; Özbal, Gerritsen 2019; E. Özdoğan 2016*). While such a mosaic model in the Neolithization process is well-documented for Europe (*Zvelebil 2001*), Northwest Anatolia faces a general lack of data with regard to Mesolithic lifeways, except, potentially, Ağaçlı to the north of Istanbul (*Gatsov 2001; Gatsov, Özdoğan 1994; Özdoğan, Gatsov 1998*). Recent aDNA studies have shown that early Neolithic populations in West Anatolia and the first farmers in Europe belong to the same gene pool (*Hofmanova* et al. *2016; Lazaridis* et al. *2016; Mathieson* et al. *2015; 2018*). Much less clear at present is the genetic history of Anatolia before and during the period of initial Neolithization, but there are indications for complex processes during and after the Late Glacial that include genetic bottlenecks, admixture from outside the region and regional heterogenization (*Kılınç* et al. *2016; Marchi* et al. *2022; Yaka* et al. *2021*).

Botanical remains provide an important dataset through which the process of Neolithization can be studied. After all, what people cultivated and gathered must be viewed as a reflection of their lifestyle choices and could provide important insights on the Neolithization process. Botanical remains can act as a proxy, not only for the reconstruction of the local environmental or ecological situation but also for the incorporation and transmission of cultivated plants (*Balcı 2018; Gaastra* et al. *2019; Kotzamani, Livarda 2018; Krauß* et al. *2017; Marinova, Krauß 2014; Popova, Marinova 2007*). How much did people engage in and exploit their local environments, especially in the incipient phases of occupation? Is there a predominant dependence on farmed Neolithic founder crops or do we find evidence for the persistent utilization of local gathered resources? In what ways could the ratio between the wild and domesticated correlate with the habits of migrant farmers and local hunter-gatherers?

To explore these questions regarding Neolithization, this article makes use of two new Neolithic archaeobotanical datasets from the contemporaneous Northwest Anatolian sites of Barcın Höyük and Bahçelievler. These sites are less than 40km apart and appear to be in the same vegetational zone, making them ideal case studies for a comparative analysis of macro-botanical data. The site of Barcın Höyük (Bursa) was excavated between 2007 and 2015 (*Gerritsen, Özbal 2019*); Bahçelievler (Bilecik) between 2019 and 2021 (*Fidan 2020; Kolankaya-Bostancı, Fidan*

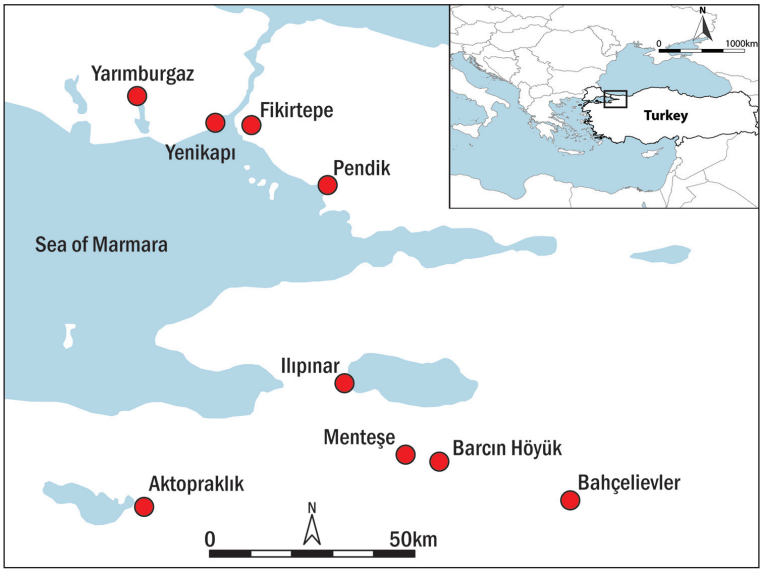

Fig. 1a. Excavated Neolithic sites in Northwest Anatolia.

2021). Both sites have levels dating to the first half of the seventh millennium BC and yield evidence for the earliest Neolithic communities in their respective sub-regions. Investigating the plant remains from the early and comparable levels of each site provides a first-hand way to observe similarities and differences in subsistence strategies. This, in turn, offers a window into their relative reliance on local resources and/or introduced founder crops. Our aim is to furnish our interpretation on the Neolithization process of Northwest Anatolia with new, first-hand data. What subsistence strategies did the inhabitants of each site adhere to, especially when it comes to plant use? When establishing Neolithic settlements where farming became the prominent form of subsistence, how much of the local flora was utilized?

Different manifestations in the same region? A case study of Barcın Höyük and Bahçelievler

Northwest Anatolia includes the region to the southeast of the Marmara Sea that extends from the Bosphorus to the Eskişehir Region. The latter provides direct access to the Anatolian Plateau. In the past, as today, this region represented a diverse vegetational, geographical, and palaeogeographical structure consisting of coasts, mountain thresholds, mountains, plains, and valleys irrigated by rivers (*Atalay, Mortan 1997; Clare, Weninger 2014; Kayan 2014; Roberts 2014*). Climatically, it has mild/Mediterranean conditions (*Clare, Weninger 2014*). Given the humid climate of Northwest Anatolia around 11 000 BC, the predominant tree species were birch, oak, pine, and juniper. These species also formed the main tree taxa during the Late Glacial period (*Roberts 2014.Fig.1a*).

A general vegetation history covering most of the Holocene indicates that the lowland hills and mountain slopes of this region were covered with woodlands dominated by deciduous oak from about 10 000 to 6500 BC (*Bottema, Woldring 1995; Bottema* et al. *2001; Kayan, Woldring 2002*). Pollen studies from a location in the Yenişehir lake basin near Barcın Höyük revealed that the vegetation was also comprised of fir (*Abies*), pine (*Pinus*), elderberry (*Sambucus*), hornbeam (*Carpinus*), hazelnut (*Corylus*), beech (*Fagus*), cedar (*Cedrus*), linden (*Tilia*), and elm (*Ulmus*) (*Bottema* et al. *2001*). A recent wood charcoal study by Schroedter and Nelle on data obtained from the Late Neolithic layers at the site of Aktopraklık – located near Lake Ulubat, fifty kilometres to the West of the Yenişehir Plain – yielded oak, pine, mock privet, and pistacia as well (*Schroedter, Nelle 2015*). Despite the geographical proximity, the latter two species are not documented in the pollen study from Lake Yenişehir (*Bottema* et al. *2001; Schroedter, Nelle 2015.92*).

Today, about a third of the region remains covered with forests (*Atalay, Mortan 2011; Roberts 2014*). Due to the felling of oak and red pine forests in historical times, dense maquis shrubland covers the landscape. Vegetation includes species such as rock rose (*Cistus creticus*), hazel (*Corylus*), tree heath (*Erica arborea*), prickly juniper (*Juniperus oxycedrus*), mock privet/green olive tree (*Phillyrea latifolia*), pistacia (*Pistacia terebinthus*), and plum (*Prunus*) (*Atalay, Mortan 2011.153*).

Archaeologically, the Istanbul region, the Yenişehir Plain, the foothills overlooking Lake Ulubat, and the Bilecik-Eskişehir region fall within what has traditionally been called the Fikirtepe Culture zone (Fig. 1a) (*Özdoğan 2014*). Evidence for agriculture and animal husbandry is most prevalent here, but minor amounts of hunting, gathering and fishing are also evident across the communities of the Neolithic and Chalcolithic in the Fikirtepe Culture zone at sites including Pendik, Fikirtepe, Yenikapı in Istanbul province, Barcın Höyük, Menteşe, Aktopraklık, Ilıpınar in Bursa province, and Bahçelievler in Bilecik and Keçiçayırı in Eskişehir provinces in Northwest Anatolia (*Arbuckle* et al. *2014; Balcı 2018; Balcı* et al. *2019; Boessneck, von den Driesch 1979; Budd* et al. *2013; 2018; 2020; Buitenhuis 2008; Cappers 2008; 2014; Çakırlar 2013; 2015; Galik 2013; Gourichon, Helmer 2008; İzdal Çaydan 2018; Karul 2011; 2017; Kızıltan, Polat 2013, Kızıltan 2013; Kolankaya-Bostancı, Fidan 2021; Özdoğan 1983; Sarı, Akyol 2019; Thissen* et al. *2010; Ulaş 2020; Würtenberger 2012*).

A noteworthy element with regard to the architecture is that we see variability across sites. While those like Barcın Höyük (*Gerritsen, Özbal 2016*), Menteşe (*Roodenberg* et al. *2003*), Ilıpınar X-IX (*Roodenberg 2008*), and Aktopraklık B (*Karul 2010*) display rectilinear architecture, others including Aktopraklık C (*Karul 2011; Karul, Avcı 2011*), and Bahçelievler (*Fidan 2020; Kolankaya-Bostancı, Fidan 2021*) yield evidence for round semi-subterranean structures. Both round and rectangular buildings have been discovered and excavated at Yenikapı (*Kızıltan, Polat 2013*) and Pendik (*Harmankaya 1983; Özdoğan 2013; Pasinli* et al. *1993*), while Yarımburgaz (*Özdoğan 2013*) stands alone as a slightly later cave settlement. If architecture is a phy-

sical manifestation of world views and lifestyles (*Lefebvre 1991*), then the variability observed across Northwest Anatolia in the seventh and sixth millennia BC may be noteworthy. The contrast that the sites of Barcın Höyük and Bahçelievler show with regard to architecture, with the former yielding rectangular and the latter round structures, juxtaposes these two pioneering Neolithic sites. This allows us to consider any notable differences in botanical remains in a larger context. We may ask whether divergences in assemblages may reflect indications of diverse representations of lifestyle preferences or whether they are, in fact, a result of micro-regional adaptations. Are there indications that we are dealing with immigrant farmers at one community and a representation of local hunting and gathering communities who adopted agriculture in another?

Barcın Höyük and Bahçelievler were inhabited partially contemporaneously, as demonstrated by both absolute dates and material assemblage comparisons (*Fidan 2020; Gerritsen, Özbal 2013a; 2013b; Özbal, Gerritsen 2019*). Bahçelievler Phase 6 is likely contemporary with Phase VIe at Barcın Höyük, while Bahçelievler Phase 5 corresponds timewise with Barcın Höyük Phase VId1. The later levels at both sites, beyond the scope of this paper, show parallelisms with the Fikirtepe culture (Fig. 1b).

Barcın Höyük general background

Barcın Höyük is located in the Yenişehir Plain, Bursa, and was excavated between 2005–2015. The Neolithic levels are separated into seven distinct phases from the uppermost VIa to the lowest VIe (*Gerritsen* et al. *2013a; Gerritsen, Özbal 2019*). The most important result of the Barcın Höyük excavations is possibly its contribution to the reconstruction of a continuous developmental sequence for the Neolithic of the Marmara Region. The stratigraphic sequence from the site, supported by 80+ radiocarbon dates, enables us to restructure the period from the first half of the seventh millennium to the beginning of the sixth millennium BC with associated material culture, architecture, and subsistence strategies (*Gerritsen, Özbal 2016; 2019; Özbal, Gerritsen 2019*).

Excavations at Barcın Höyük yielded rectangular houses. This article discusses Phases VIe and VId1, for which the botanical remains have been extensively studied (*Balcı* et al. *2019*). While two posthole structures dating to the earliest phase (VIe) were unearthed, excavations also brought to light a row of four slightly smaller structures dating to VId1, the overlying phase (*Gerritsen, Özbal 2016; Özbal, Gerritsen 2019; van den Bos 2021*). Courtyards were discovered north and south of the structures in both phases. Posthole architecture was the primary building technique in Phase VIe, but in VId1 considerably smaller posts set into foundation trenches were used instead (*van den Bos 2021.168*). Most notably, there are differences between the two phases with regards to material culture as well. The scarcity of archaeological materials in the earliest layers, including pottery, is noteworthy. By Phase VId1 the range of objects available increases both in quantity and variability (*Gerritsen, Özbal 2016; Özbal, Gerritsen 2019*).

Bahçelievler site general background

The site of Bahçelievler was discovered on an empty land parcel between apartment buildings in the city centre of Bilecik. The Neolithic settlement was located on the eastern bank of a small stream that has subsequently dried up. The Neolithic layers have been divided into seven different phases, from Phases 8 to 2. Preliminary radiocarbon dates suggest that the earliest levels of Bahçelievler correspond to the first half of the seventh millennium BC (*Fidan 2020*). The exact dates are difficult to ascertain given

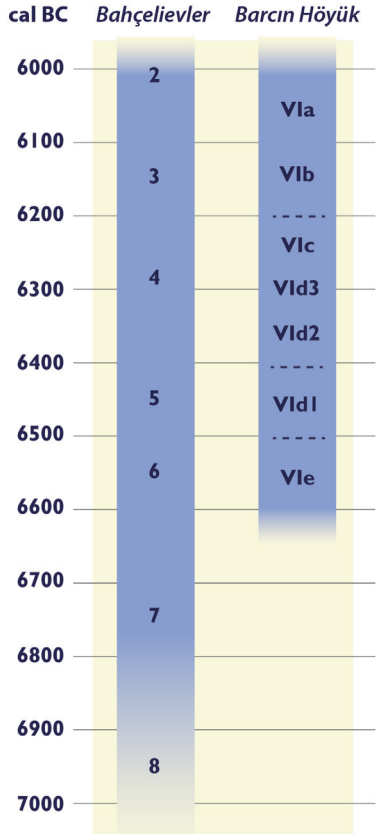

Fig. 1b. Comparative chronological table for Bahçelievler and Barcın.

the problems with the calibration curve, but the earliest dates fall between 7192–7052 BCE.[1] Excavations at Bahçelievler in Phases 3–8 yielded oval/round structures with diameters of 3–5m and walls up to 45–50cm thick in some structures. The walls were strengthened in some instances by mud or mudbrick, and post-holes traces are visible in some walls as well as clusters of small pebbles (*Fidan 2020.36*). Workshop and courtyard areas were discovered between the structures, yielding most of the artifact assemblages with the exception of stone tools, which for the large majority come from inside the buildings (*Kolankaya-Bostancı, Fidan 2021.102*).

Materials and methods

The macro-botanical samples collected at both sites were floated in water, not more than two litres at a time, by means of manual flotation in buckets. Chiffon fabric was used for drying the light material and a 1mm mesh was used for the heavy material during the flotation for collecting and drying. The dried samples were sifted through steel test sieves of 0.24<0.5<1.0<2.0<3.0mm and placed inside zipped plastic bags and centrifuge tubes for sorting. A triocular 0.6–4x stereo zoom microscope was used for identification and photography. The plant remains were compared with plant catalogues to aid with the determination of genus and species (*Bojnansky, Fargasova 2007; Cappers* et al. *2012; Cappers, Bekker 2013; Cappers* et al. *2016; Neef* et al. *2012*).

For Barcın Höyük, a systematic sampling strategy was applied to the site during the excavations. A total of 163 samples corresponding to 480 litres of soil from Phase VIe and 185 samples corresponding to 580 litres of soil from Phase VId1, all collected during the 2013–2015 seasons, have been analysed within the scope of this study. The samples represent different contexts including layers, surfaces, platforms, pits, foundation trenches, pyrotechnic features, postholes, and burials. The frequent burned contexts at Barcın Höyük facilitated excellent preservation of plant remains as well as substantial amounts of wood charcoal. There is no particular context in which we find a high percentage of plant remains in Barcın Höyük except a single burned store of lentils from structure 2a in level VId1 that yielded around 28 000 seeds. However, no special wild plant group was found among the samples (*e.g., Fairbairn* et al. *2007*). A large proportion of the wild plants consists of field grass/weeds. The wild plant group is part of another study (in prep.). The archaeobotanical samples were studied by the first author in several places including the Barcın Höyük Excavation House in Yenişehir, Bursa, the Netherlands Institute in Turkey in Istanbul, and the Koç University Archaeology Laboratory in Istanbul under the supervision of René Cappers of the University of Groningen.

For Bahçelievler, a total of 134 archaeobotanical samples corresponding to 650 litres of soil sampled from the Neolithic phases during the 2019, 2020, and 2021 seasons were analysed. Included here in this study are 40 samples (248 litres) from Phase 6 and 23 samples (108 litres) from Phase 5. The samples were taken from surfaces, courtyards, hearths, and burials, yielding great variability in the number of archaeobotanical samples for each phase. The preservation of the plant remains was notably poorer than at Barcın Höyük, probably due to the lack of burned deposits, but it may also reflect the circumstances of plant use at the site. Most of the cereal remains were fragmented, making species identification difficult and wood charcoal remains remain limited. The archaeobotanical samples have been studied in the Bilecik Museum by the first author.

Archaeobotanical results from Barcın Höyük and Bahçelievler

Overall, the crop range between the two sites is similar. Both sites display an increase in quantity and variety of plant remains from the earliest phases Barcın VIe and Bahçelievler 6 to the subsequent phases Barcın VId1 and Bahçelievler 5 (Fig. 2). This may be to some extent a result of factors like preservation and sample numbers, but despite these issues a remarkable increase in the variety of cereals and pulses at both sites is noted over time.

At Barcın Höyük Phase VIe, investigations yielded economic plants from the grass (Poaceae) family which constitute the main cereal group. This includes six-row barley – hulled and naked (*Hordeum vulgare* ssp. *vulgare* L.), einkorn wheat (*Triticum monococcum* ssp. *monococcum* L.), emmer wheat (*Triticum turgidum* ssp. *dicoccon* (Schrank) Schübl.) and bread/hard wheat (*Triticum aestivum* L./*durum* Desf.). Among the pulses (Fabaceae), lentils (*Lens culinaris* Medik.), peas (*Pisum sativum* L.) and bitter vetch (*Vicia ervilia* L.) were identified.

1 The ^{14}C results of the settlement are being prepared for publication by Erkan Fidan and TÜBİTAK MAM.

In this phase, excavations yielded only fifteen pulse fragments, while flax (*Linum usitatissimum* L.) was represented by a mere seven seed fragments (Fig. 2). In summary, barley (hulled and naked), einkorn, and emmer hulled wheats, bread/hard wheat (naked), lentils, bitter vetch, peas and flax represent the main documented economic plants from VIe at Barcın Höyük.

In Phase VId1, in contrast, we find an expansion of types and a greater variety than in VIe. The main cereals remain identical with the Phase VIe but we also begin to find a small-sized naked wheat type (not exactly defined wheat species between *Triticum* ssp. *aestivum*/ssp. *durum* and *T. turgidum* ssp. *dicoccon*) added to the cereal range in this phase. Likewise, we see a real presence of pulses – especially lentils – of the pulse family. Identified species are similar to those from Phase VIe, but we find that the chickpea (*Cicer arietinum*) begins to appear among the pulses range in this Phase. Flax is also present as observed in VIe in small quantities. Phase VId1 also yields species gathered from the surroundings including 22 fruits of hazelnut (*Corylus avellana* L.) and two fruitlets of bramble (*Rubus*).

As mentioned above, the plant preservation at Bahçelievler is poor compared to at Barcın Höyük, and many samples yielded hardly any remains. Phases 8 and 7 at Bahçelievler with a total of four and 21 plant remains, respectively, are not considered in this paper because the botanical yields are too low to make meaningful interpretations (Fig. 2). The lack of botanical remains in the two lowest phases at Bahçelievler may be a result of sampling sizes, preservation and restricted exposures of the excavations, but could potentially reflect the limited use of farming plants. Instead, this paper focuses on Phases 6 and 5 where the counts are not only adequate but the dates for these levels align well with Barcın Höyük's Phases VIe and VId1. Thirty-eight of the samples, mostly coming from Trench B3 and dating to Phases 6 and 5, show somewhat higher concentrations. In Phase 6, the cereals include six-row barley – naked/hulled (*Hordeum vulgare* ssp. *vulgare*), einkorn (*Triticum monococcum* ssp. *monococcum*), emmer (*Triticum turgidum* ssp. *dicoccon*), and bread/hard wheat (*Triticum* ssp. *aestivum/durum*). However, the einkorn wheat is only represented by two fragmented grains. Likewise, two seeds of lentil (*Lens culinaris*) have been identified for Phase 6 at Bahçelievler. Though minimal, this phase also yielded evidence for gathering with two fruits of pistacia (*Pistacia* ssp.).

In the subsequent Phase 5, however, six-row barley – hulled/naked (*Hordeum vulgare* ssp. *vulgare*), emmer wheat (*Triticum turgidum* ssp. *dicoccon*), and bread/hard wheat (*Triticum* ssp. *aestivum/durum*) were identified within the grass family among the main economic plants, while this time einkorn wheat (*Triticum monococcum* ssp. *monococcum*) was represented by a single grain. Pulses remain poorly represented and lentil (*Lens culinaris*) continues to be represented by no more than two seeds. While this points to the presence of the species, it may not effectively show that this species had a significant role in the diet, at least within the excavated contexts. At the same time, however, gathered plants may suggest a different exploitation strategy of the immediate landscape in this phase. Pistacia, which was found in negligible quantities in Phase 6, becomes represented by 77 fruits from five different samples from the courtyard areas of Trench B3, suggesting a much larger emphasis on gathering by Phase 5. The gathered plant remains also include two grape seeds.

Discussion

Comparing the results for Barcın Höyük and Bahçelievler

As at Barcın Höyük, the results also show an increase in botanical remains through time at Bahçelievler as well. While by Bahçelievler Phase 5 the variety of economic plants parallels that at Barcın Höyük, there are a few elements that show dissimilarity (Figs. 3–4). Barcın Höyük yielded small-sized naked wheat and flax, both of which were lacking at Bahçelievler, and the presence of einkorn wheat, represented by only two grains at Bahçelievler Phase 6 is debatable. In addition, the cereals remain the dominant group of edible plants at both sites when compared with other plant remains, where it comprised 95% of the assemblage at Barcın Höyük (Fig. 5a) and 72% at Bahçelievler (Fig. 5b). The pulse group comes second and retains a minor place, especially at Bahçelievler.

However, the most meaningful results that differentiate the sites derive from gathered plants. Though still preliminary, the results raise the question as to whether gathering at Bahçelievler contributed to the diet in a more substantial way than at Barcın Höyük. Pistacia, a gathered resource, comes second in quantity after the cereal remains, suggesting that it played a significant role at this site (Fig. 5b). Pistacia is represented in this area within a range of trees with edible fruits including pistacia/terebinth (*Pi-*

		BARCIN		BAHÇELİEVLER				
	phases	VIe	VId1	8	7	6	5	
	dates	(6600-6500 cal.BC)	(6500-6400 cal.BC)	(7000-6800 cal.BC)	(6800-6600 cal.BC)	(6600-6500 cal.BC)	(6500-6400 cal.BC)	
	sample number	163	185	12	20	40	23	
	liters of soil	480	580	55	84	248	108	
Economic Plants								**Economic Plants**
Poaceae	**plant parts**	**1833**	**3817**	**4**	**21**	**77**	**153**	**cereal**
Hordeum vulgare ssp. *vulgare*	fruit	60	239			3	5	six-row barley hulled-naked
Hordeum vulgare ssp. *vulgare*	rachis	0	33					six-row barley - rachis
Triticum monococcum ssp. *mon* .	fruit	75	157			2	1	einkorn wheat (hulled)
Triticum turgidum ssp. *dicoccon*	fruit	97	335	2	2	9	5	emmer wheat (hulled)
Triticum dicoccon /monococcum	rachis fragments**	905	631					einkorn/emmer - rachis frag.
Triticum aestivum/durum	fruit	37	359			6	19	bread/hard wheat (naked)
Triticum aestivum/durum	rachis	0	0					bread/hard wheat - rachis
Triticum turg. ssp.	fruit	0	59					small-sized naked wheat
Triticum/Hordeum	fruit	659	2004	2	19	57	123	wheat/barley (fragmented)
Fabaceae		**15**	**28186***		**7**	**5**	**3**	**pulses**
Fabaceae	seed					2	1	pulse unknown
Vicia ervilia	seed	6	88			1		bitter vetch
Cicer arietinum	seed	0	7		1?			chickpea
Lens culinaris	seed	8	28075		6	2	2	lentil
Pisum sativum	seed	1	16					pea
Linaceae		**7**	**24**					**oil/fibre plant**
Linum usitatissimum	seed	7	24					flax
Gathered plants		**1**	**24**			**2**	**77**	**gathered plants**
Corylus avellana	fruit	1	22					hazel
Rubus	fruitlet		2					bramble
Vitis	seed						2	grape
Pistacia ssp.	fruit					2	75	pistacia

Fig. 2. The quantitative comparison of crop plants between Phases VIe and VId1 at Barcın and contemporary Phases 6 and 5 at Bahçelievler, as well as the earliest Phases 8 and 7 at Bahçelievler. * represented as two samples, this total includes a lentil storage unit (which yielded around 20 000 seeds of lentil) and an associated collapse context (which yielded around 8000 seeds of lentil). ** rachis fragments include partly glume bases, spikelet forks, rachis, and rachis internodes.

stacia terebinthus L.). At Barcın Höyük, in contrast, gathering remains almost trivial, and hazelnut and bramble fragments, especially when compared to the high quantity of samples, remain negligible (Fig. 5a). On the other hand, it may not always be consistent to emphasize the importance of a species based on the number of remains discovered, given that a range of criteria including preservation, fruit morphology,[2] food preparation, and consumption, may affect the ultimate proportions. Nonetheless, the use of economic plants remains notably important at both sites in the earliest phases.

Local adaptation: pulses

Both Barcın Höyük and Bahçelievler yielded small quantities of pulses in their earliest phases, suggesting that pulses may be rare in general in the region in the first half of the seventh millennium BC. At Barcın Höyük, only fifteen pulse seeds were found in Phase VIe (Fig. 2), strikingly low, especially given the rich array of cereal remains recovered from the same contexts. However, we do see a significant increase in pulses by VId1 when we find a store of them *in situ* clustered in a lentil storage bin as well as from several other contexts. Bahçelievler, likewise, yields a similar picture with regards to pulses where they remain conspicuously lower in quantity when compared with cereals (Fig. 6). There may be

Plants	Barcın	Bahçelievler
Small-sized naked wheat	present	not present
Flax	present	not present
Gathered plants	hazelnut, bramble	pistacia, grape

Fig. 3. The differences in plant selection between Barcın Höyük and Bahçelievler.

several reasons underlying the near lack of pulses in the earliest phases of these sites. The earliest inhabitants, whether incipient pioneer settlers or descendants of local foragers, might initially have briefly experimented with pulses but may instead have chosen to target cereal cultivation during the first occupation Phase VIe.

On the other hand, the rarity of pulse species has also been interpreted as a result of preservation-dependent factors, and the scarcity of pulses might be a result of post-depositional processes specific to the species (*Cappers 2008; Kotzamani, Livarda 2018; Marinova, Popova 2008*). If taphonomic, the challenge is to explain the significant difference in the pulse ratio between Phases VIe and Vd1 at Barcın

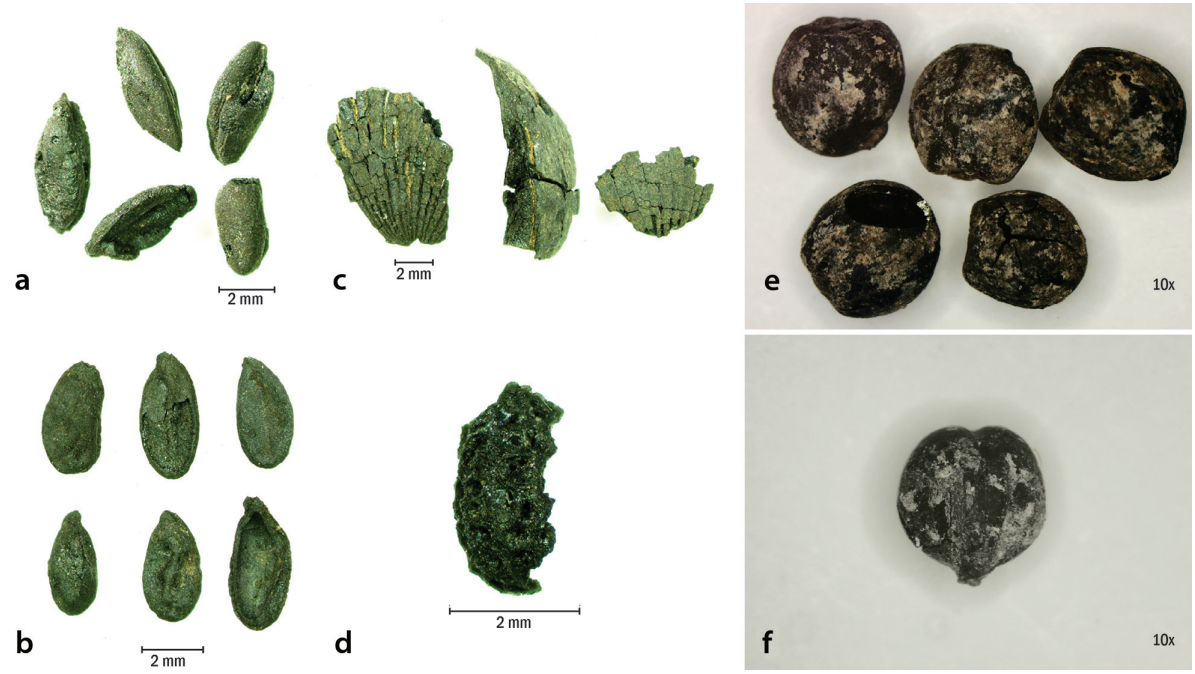

Fig. 4.* a *small-sized naked wheat;* b *flax;* c *hazelnut;* d *bramble (a, b, c, d from Phase VId1, Barcın Höyük),* e *pistacia,* f *grape (e, f from Phase 5, Bahçelievler).

2 For example, the number of fruitlet endocarps for someone who eats five brambles would be *c.* 300–350. Post-depositional dispersal might dilute the number concentrated in feces (personal communication with René Cappers).

Höyük. Except for the burned store of lentils in structure 2a in Barcın VId1, we know that there is no significant difference in terms of the preservation conditions across the site. Aside from the store, 182 pulse seeds were discovered in the 580 litres sorted for Barcın VId1 across a range of 35 different contexts. But only 14 pulse seeds were documented for the 480 litres analysed for Phase VIe. Preservation-related factors are often suggested to diminish the importance of pulses in the diet, but the discovery of a dense store of lentils in Phase VId1 questions the assumption that they were insignificant. The pulse spectrum at Barcın Höyük is paralleled at Bahçelievler, where we see an increase in quantities over time. A question that comes to mind is whether this increase is a result of the changes in social behaviour, the household structure, and/or the subsistence strategies of the inhabitants which may collectively have contributed to major shifts in the exploited species. Limited exposures and the low level of preservation of plant remains at Bahçelievler make it difficult to make a direct quantitative comparison, unlike at Barcın Höyük. However, it can be suggested that the first settlers of Barcın Höyük must have applied different strategies regarding the growing, storing and processing of pulses.

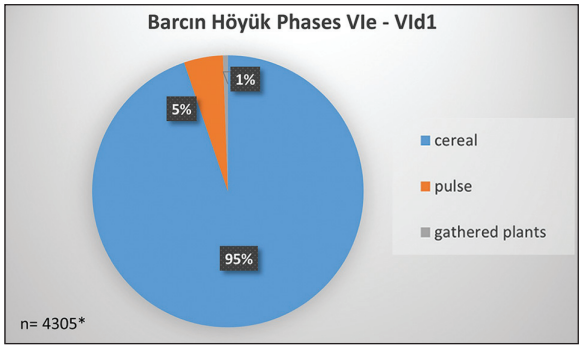

Fig. 5a. The proportions of economic plant groups in Phases VIe and VId1 at Barcın Höyük. * The 28 000 lentil seeds from Barcın Höyük are not represented in the pie chart.

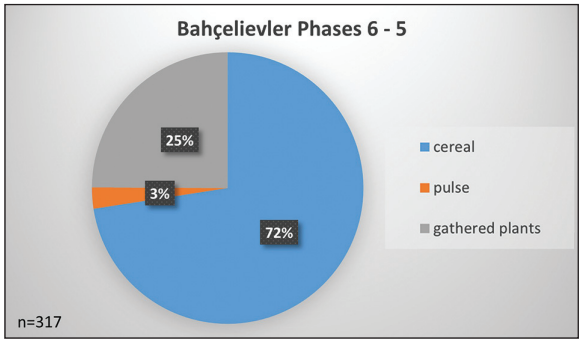

Fig. 5b. The proportions of economic plant groups in the Phases 6 and 5 at Bahçelievler.

Local adaptation: gathered plants

A major factor differentiating the sites of Barcın Höyük and Bahçelievler with regard to their subsistence strategies lies in the approaches that their inhabitants took with regard to gathered plants. Barcın Höyük lacks the general exploitation of edible fruits. Analyses only documented a single fruit of hazel in level VIe, though this number approaches 22 fruits by Phase VId1, which come from seven different contexts. The presence of hazelnut increases in the later levels of the site (*Balcı* et al. *in prep.*). This could be considered an indication of how people interacted with their immediate environment. At Barcın Höyük, the exploitation of gathered plants was quite limited, and instead, cultivated, and harvested agricultural plants were favoured. At Bahçelievler, on the other hand, as demonstrated by the courtyard area of Trench B3 in Phase 5, the gathered plant pistacia and most likely *Pistacia terebinthus* was collected, where it comprised 25% of the assemblage demonstrating definitive utilization of this species in the diet.

An interesting aspect of the gathered plant remains found at both sites is that they are typically from restricted numbers of contexts in comparison with economic plant groups such as cereals and pulses. This raises the question of full-time exploitation. Unlike cereals, which are particularly hardy and are exceptionally suited for long-term storage, gathered plants are typically seasonal, and thus collection and exploitation times must have been limited. In addition, the location of the consumption of gathered plants such as hazelnut/pistacia and bramble/grape show differences with regard to depositional processes. In this context, we can ask whether the lack of hazelnut at Bahçelievler, and, despite the large sample sizes, the complete absence of pistacia at Barcın Höyük, was a result of sub-regional vegetation boundaries. While pistacia was not documented in the pollen study from Lake Yenişehir (*Bottema* et al. *2001; Schroedter, Nelle 2015.92*), the presence of this species is well attested in the Late Neolithic layers at Aktopraklık (*Schroedter, Nelle 2015*) and in the early Chalcolithic layers from Ilıpınar X (*Cappers 2008*) which are 75 and 40km away, respectively. Tim M. Schroedter and Oliver Nelle (*2015*) suggest that pistacia is a plant that thrives in open Mediterranean type environments with shrub-like vegetation. Barcın Höyük was located in a valley bottom with ample potential for agriculture while Bahçelievler was in an upland region, so the differences in the setting may have contributed to the micro-en-

vironmental juxtaposition. On the other hand, we think that the nearby slopes along the edges of the Yenişehir plain could have been used for agriculture as well (*Balcı 2018*). Hazelnuts often thrive in open woodlands, which likely describes the situation for Barcın Höyük. We cannot rule out that the differences across the sites with regard to their reliance on gathered plants was a result of micro-climatic and vegetational aspects and hence different methods of adapting to the environment. The data from Barcın Höyük does not point to an intense reliance on other micro-climatologically suitable gathered plants. It is therefore possible that part of the divergence may be a result of the ways in which the residents of each site interacted with their immediate surroundings and exploited the local vegetation.

	Barcın		Bahçelievler				
	VIe	VId1	8	7	6	5	
sample number	163	185	12	20	15	23	sample number
Economic Plants							Economic Plants
pulse	15	28186*		6	6	3	Fabaceae
pulse unknown					3	1	Fabaceae
bitter vetch	6	88			1		*Vicia ervilia*
chickpea		7					*Cicer arietinum*
lentil	8	28075		6	2	2	*Lens culinaris*
pea	1	16					*Pisum sativum*

Fig. 6. The quantities of pulse remains from the early phases at Barcın Höyük and Bahçelievler.

A comparison of subsistence strategies in the region

Most of the Neolithic sites in Northwest Anatolia have levels dating to the end of the first half and second half of the seventh millennium, and yield evidence for what appears to be the earliest Neolithic inhabitants in their respective sub-regions, supporting our interpretation of the Neolithization process for Northwest Anatolia. Bahçelievler (*Balcı, in prep.*), Barcın Höyük (under study by Cappers, Balcı; *Balcı 2018; Balcı* et al. *2019*), Aktopraklık (*Karul 2017; Kabukçu* et al. *in prep.*), Menteşe, and Ilıpınar (*Van Zeist* et al. *1995b; Cappers 2008; 2014*), Pendik (*Ulaş 2020*), Fikirtepe, Yenikapı (*Ulaş 2020*), and Neolithic Yarımburgaz provide insights on the Neolithic way of life across the Eastern Marmara Region (Fig. 7). Even though not all excavations have yielded archaeobotanical data such as Fikirtepe, we do have ample data on their subsistence economies.

In general, a terrestrial diet, rather than an aquatic or wild game-based one, is predominant at the inland settlements of Bahçelievler, Barcın Höyük, Basal Menteşe, Aktopraklık C, and Ilıpınar X (*Arbuckle* et al. *2014; Balcı* et al. *2019; Buitenhuis 2008; Budd* et al. *2013; 2018; 2020; Cappers 2008; Galik 2013; Gourichon, Helmer 2008; İzdal-Çaydan 2018; Karul 2017; Kolankaya-Bostancı, Fidan 2021*). In addition, based on the presence of marine-based and hunted foods at coastal sites like Pendik and Fikirtepe, it is possible to interpret these subsistence practices as a continuation of Mesolithic customs (*Boessneck, von den Driesch 1979; Çilingiroğlu 2005; Düring 2011; Evershed* et al. *2008; Özdoğan 1983b; 2010; 2011; 2013; Röhrs, Herre 1961; Thissen 1999; Thissen* et al. *2010*). Burhan Ulaş' (*2020*) study on plant subsistence in Pendik also supports this suggestion. Though a coastal site, Yenikapı presents a different picture than the agricultural communities at Fikirtepe and Pendik, which also appear to have practiced fishing and hunting, probably because Yenikapı primarily represents the sixth millennium and is thus later (*Kızıltan, Polat 2013; Ulaş 2020*).

In Bursa province, archaeobotanical data has been obtained from Barcın Höyük, Aktopraklık, and Ilıpınar. At Neolithic Aktopraklık C, we know of the presence of six-row barley, emmer, lentils, bitter vetch, and flax (*Karul 2017*). At Ilıpınar, excavations yielded 24 samples from the earliest Phase X and 20 samples from the overlying Phase IX dating to just after the turn of the sixth millennium BCE. The data suggests that barley, emmer, small-sized wheat, einkorn, lentil, bitter vetch, grass peas, peas, flax, figs, and bramble were used as economic plant species in the two earliest phases. However, the earliest Phase X only yielded a single non-economic plant (*Cappers 2008*).

In Istanbul province archaeobotanical data has been obtained from both Pendik on the Asian side and Yenikapı on the European side. At Pendik, archaeobotanical analyses yielded limited results. These comprised only a few cereals including a single emmer grain, and a single barley grain as well as only a couple of pulses, including one-seed of a grass pea and one-seed of a pea. In addition, seven seeds of flax and two fruitlets of bramble were identified within the economic plant data. Other identified plant remains are included in the wild plant group (*Ulaş 2020.30–31*). At Yenikapı, there is a higher variety in the economic plant range. The cereal group includes emmer, einkorn, bread/hard wheat, and

		Northwest Anatolia										Central Anatolia	Western Anatolia	
		Bilecik		Bursa					İstanbul			Konya	İzmir	
Poaceae	**Plant Part**	**B.evler Phase 6**	**B.evler Phase 5**	**Barcın Höyük VIe**	**Barcın Höyük VId1**	**Menteşe**	**Aktopraklık C**	**Ilıpınar X-IX**	**Pendik**	**Fikirtepe**	**Yenikapı**	**Çatalhöyük VIII-VI**	**Ulucak VI-Vb-e**	**Cereal**
Hordeum vulgare ssp. *vulgare*	fruit	+	+	+	+		+	+	+			+	+	six-row barley (hulled-naked)
Hordeum v. ssp. distichon	fruit													two-row barley
Triticum monoc. ssp. monococcum	fruit	+	+	+	+			+			+	+		einkorn wheat
Triticum tur. ssp. *dicoccon*	fruit		+	+	+		+	+	+		+	+	+	emmer wheat
Triticum aestivum/durum	fruit	+	+	+	+						+	+	+	bread/hard wheat
Triticum ssp.	fruit				+			+						small-sized naked wheat
Triticum compactum	fruit										+			club wheat
Triticum spelta	fruit										+			spelt/hulled wheat
Scale cereale	fruit											+		rye
Fabaceae														**Pulses**
Lens culinaris	seed	+	+	+	+		+	+			+	+	+	lentil
Lathyrus sativus	seed							+	+		+	+		grass pea
Vicia ervilia	seed			+	+		+	+			+	+	+	bitter vetch
Pisum sativum	seed			+	+			+	+		+	+	+	pea
Cicer arietinum	seed				+						+	+		chickpea
Vicia faba	seed										+			faba bean
Linaceae														**Oil and fibre plants**
Linum usitatissimum	seed			+	+		+	+	+					flax
Gathered plants														**Gathered Plants**
Amygdalus	fruit											+		almond
Celtis	fruit/stone											+		hackberry
Prunus	fruit											+		plum/cherry
Ficus carica	fruitlet							+			+	+		fig
Rubus	fruitlet				+			+	+		+			bramble/blackberry
Vitis vinifera	seed		+?		+?						+			grape
Malus/Pyrus	seed													apple/pear
Corylus avellana	fruit		+?	+?	+									hazelnut
Quercus	fruit/seed											+		acorn
Pistacia ssp.	fruit		+					+				+		pistacia

Fig. 7. Comparative table of economic plant data in NW Anatolia and neighbouring regions.

new glume wheat, *T. spelta, T. compactum*, which is a species related to bread/hard wheat (*Ulaş 2020. 32*). Overall, this yields a different picture than the general regional crop range. The pulse group includes lentils, chickpeas, grass peas, bitter vetch, peas, and faba beans (*Vicia faba* var. *minor*, *Ulaş 2020*). In addition, a range of gathered plants including figs, grapes, and bramble have been documented (*Ulaş 2020.32–33*).

Consequently, we find notable dissimilarities in founder crops across sites. While it is possible to talk about a transition to farming and husbandry in the region, simply applying a universal 'Neolithic Package' idea does not embody the complexity that is present across different sites. From this point of view, inhabitants at most sites within the region knew and practiced agriculture, and some also seem to have had a keen understanding of the immediate environment. Overall, each settlement appears to have opted to apply individual behaviours at a small scale.

In addition, it has been shown that dairy products typically comprise a significant amount of the diet for many Marmara Region residents during the Neolithic Period (*Evershed* et al. *2008; Özbal* et al. *2013; Thissen* et al. *2010*). Meat would naturally also have contributed to the nutrition needs, but it is still generally thought that economic plants and mostly cereals formed the largest percentage of these communities' diets, because they were also intensive farmers. We know this especially from the carbon and nitrogen isotope analyses on bone collagen from individuals at Aktopraklık and Barcın Höyük from the work of Chelsea Budd *et al.* (*2013; 2018; 2020*). Fish consumption also seems to play a notable role at some sites, but it mostly appears as a supplementary food in the diet. Given this complex picture, our archaeological interpretation must, for the moment, remain incomplete and perhaps inaccurate until multi-proxy subsistence research is carried out for each settlement.

Conclusions

The main aims of this study have been to use the archaeobotanical datasets from Barcın Höyük and Bahçelievler to discern variability in Neolithization processes in Northwest Anatolia in the seventh millennium BC, and to compare local community-based adaptations with the macro-regional phenomenon of Neolithization. A careful study of the datasets from each site shows various nuances in the specific economic plant packages, which can be clustered under four groups. First, cereals such as barley, einkorn, emmer, and bread/hard wheat, are identified with certainty for Phase VIe at Barcın Höyük, but barley and einkorn are not favoured in the contemporaneous Phase 6 at Bahçelievler. Second, the data did yield some differences in the presence of flax and a small-sized naked wheat, which are both present in Phase VId1 at Barcın Höyük but have not been found at Bahçelievler. Third, the presence of pulses such as lentils, peas, chickpeas, and bitter vetch differs between phases at both sites. Although lentils, bitter vetch, and peas were identified in nearly negligible amounts in Phase VIe at Barcın Höyük, these pulses become common in the subsequent phase and chickpeas also emerge within the local inventory at this point. At Bahçelievler, on the other hand, lentils and a single seed of bitter vetch were identified in Phase 6, while lentils continue to be the only identified pulse species in the overlying Phase 5. Finally, the presence of gathered plants, conspicuously lacking from the earliest phases, appears in the subsequent levels of both Barcın Höyük and Bahçelievler. Hazelnut and bramble are found at Barcın Höyük while pistacia and grape occur at Bahçelievler. Despite the proximity of the two sites, the results show distinct local food practices and potential re-interpretations of the process of Neolithization.

Based on the current evidence, the pioneer settlers at Barcın Höyük appear to have brought their full subsistence package with them. The data from Bahçelievler also suggest a reliance on non-local economic plants. However, the inhabitants of Bahçelievler appear to show more readiness to exploit local wild resources and to integrate gathered plants into the local subsistence strategies in Phases 6 and 5. We observed that the economic plant range in both sites remains limited, especially when compared with the later levels. While some of the differences observed between Barcın Höyük and Bahçelievler may be related to sub-regional climatic variability, local geographical conditions, or vegetational differences and the particulars of the plant economies at each site were the outcome of the choices made by their respective communities, based likely on local cultural preferences and social practices.

Suggesting that this results from the divergent pathways that the inhabitants of these sites took in the process of Neolithization admittedly requires a large leap. Whether the reliance on gathering at Bahçelievler, with its semi-subterranean round houses,

was a remnant of a practice the inhabitants held onto since the pre-Neolithic periods is difficult to ascertain and cannot be addressed confidently with macro-botanical data alone. Nonetheless, we can at least propose that the behaviour that emerges from the choices that the inhabitants of each site made were due to a complex set of habits and environmental circumstances. This notion poses new questions about this region's transition to the Neolithic. Overall, though, at both sites the majority of the botanical remains, and hence the main subsistence strategy, remains one that is based on the cultivation and dominance of economic plants, yet there are clearly unique ways in which the inhabitants of each site perceived and incorporated wild resources within their diet.

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What we do for food – social strategies for overcoming food scarcity in the Neolithic of the Central Balkans[1]

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ABSTRACT – *Food is essential for survival, but how humans obtain and manage it is regulated socially. The life of Neolithic and other non-industrial communities depended on environmental variations – temperature patterns and precipitation. For farming communities, even minor changes in those patterns could have led to periods of food scarcity. In order to overcome and prepare for periods of scarcity, non-industrial communities applied different social buffering strategies. In this paper, the social buffering strategies Early/Middle Neolithic Starčevo and Late Neolithic Vinča culture communities applied in overcoming the environmental variability are tested and the most plausible ones are considered.*

KEY WORDS – *Neolithic; Balkan Neolithic; subsistence; mobility; farming*

Kaj naredimo za hrano – socialne strategije za premagovanje pomanjkanja hrane v neolitiku na srednjem Balkanu

IZVLEČEK – *Hrana je bistvena za preživetje, in družbe urejajo, kako jo ljudje pridobivamo in upravljamo. Življenje neolitskih in drugih predindustrijskih skupnosti je bilo odvisno od sprememb v okolju – temperaturnih in padavinskih vzorcev. Že manjše spremembe v teh vzorcih bi lahko povzročile pomanjkanja hrane. Da bi to preprečile in se pripravile na pomanjkanje, so predindustrijske skupnosti uporabile različne strategije socialne varnosti. V članku preverjamo in predstavljamo najbolj verjetne strategije socialne varnosti, ki sta jih uporabili kulturi Starčevo in Vinča v zgodnjem, srednjem in poznem neolitiku za premagovanje posledic spreminjanja okolja.*

KLJUČNE BESEDE – *neolitik; Balkan; strategija preživetja; mobilnost; poljedelstvo*

Introduction

The Neolithic is traditionally perceived as a time when farmers lived in permanent settlements, but this simplified generalization cannot be universally applied. By introducing the concept of the 'Neolithic package', archaeologists tried to unify cultural, economic, social and ideological innovations which occurred in the Near East during the Neolithic. These innovations spread beyond the original territory, leading to the emergence of a new lifestyle in a wider area. The Neolithic package is often described as several factors that differentiate the Neolithic from previous lifestyles and it includes agriculture (plant domestication and cultivation), domestic animal farming (animal domestication), the emergence of sedentism, pottery production, polished stone tools and an ideology compatible with the new lifestyle

1 This paper is a result of the work on the project 'Humans and Society in Times of Crisis, Archaeology of Crisis' (Faculty of Philosophy, University of Belgrade). In the first phase of the project social buffering strategies applied by Early/Middle Neolithic communities at the Central Balkans were studied (*Đuričić 2021*). This paper is a result of a second phase of the project, where this subject is further elaborated and social buffering strategies applied by Late Neolithic communities are added to the study.

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(*e.g., Çilingiroğlu 2005; Cauvin 2000; Đuričić 2021*), which led to new subsistence strategies and new risks.

At the territory of the Central Balkans, the Neolithic lifestyle arrived already formed together with a new population around 6250 cal BC. (*Borić, Dimitrijević 2007; Borić 2014; 2016; Cramp* et al. *2019; Ivanova 2020; Stojanovski* et al. *2020; Đuričić 2021*). The area these early farming communities of the Early and Middle Neolithic Starčevo culture (6250–5300 cal BC) occupied was predominantly previously non-inhabited, except from the Danube Gorges, where the local Mesolithic population was still thriving (where the local Mesolithic and new Neolithic populations came in contact) (*Borić, Dimitrijević 2007; Borić 2014; 2016; Cramp* et al. *2019; Đuričić 2021*). The arrival of the Neolithic population coincided with the 8.2-kiloyear event (*Porčić* et al. *2021*), which affected the temperature and precipitation patterns in the Central Balkan region (*Bonsall 2007; Kobashi* et al. *2007; Gronenborn 2009*). The Late Neolithic Vinča culture (5350/5300–4500 cal BC) (*Porčić 2020*), occupied similar territory as the Starčevo culture, but their settlements and material cultures differed significantly (Fig. 1).

Even though the process of cereal and animal domestication was a long-lasting one, fully domesticated plants and animals were documented in numerous settlements in the Near East, dating back to the Pre-Pottery Neolithic (having a dominant role in the subsistence from the Pre-Pottery Neolithic B) (*Kuijt, Goring-Morris 2002; Gibbs, Jordan 2016*). A sedentary lifestyle forms a base for the intensification of the economy, population growth and increase of social complexity (*Neil* et al. *2016.1*). However, Neolithic innovations were applied differently in different regions, resulting in a non-uniform Neolithic lifestyle with diverse sedentism and mobility patterns (see *Neil* et al. *2016*). Agriculture and husbandry usually form the base of Neolithic subsistence. The amount of food in farming communities depends on predictable seasonal changes and unpredictable weather/climate factors (temperature, amount of precipitation, type of precipitation during certain seasons, droughts, floods, climate change...). Predictable factors (seasonal changes) are something that cannot

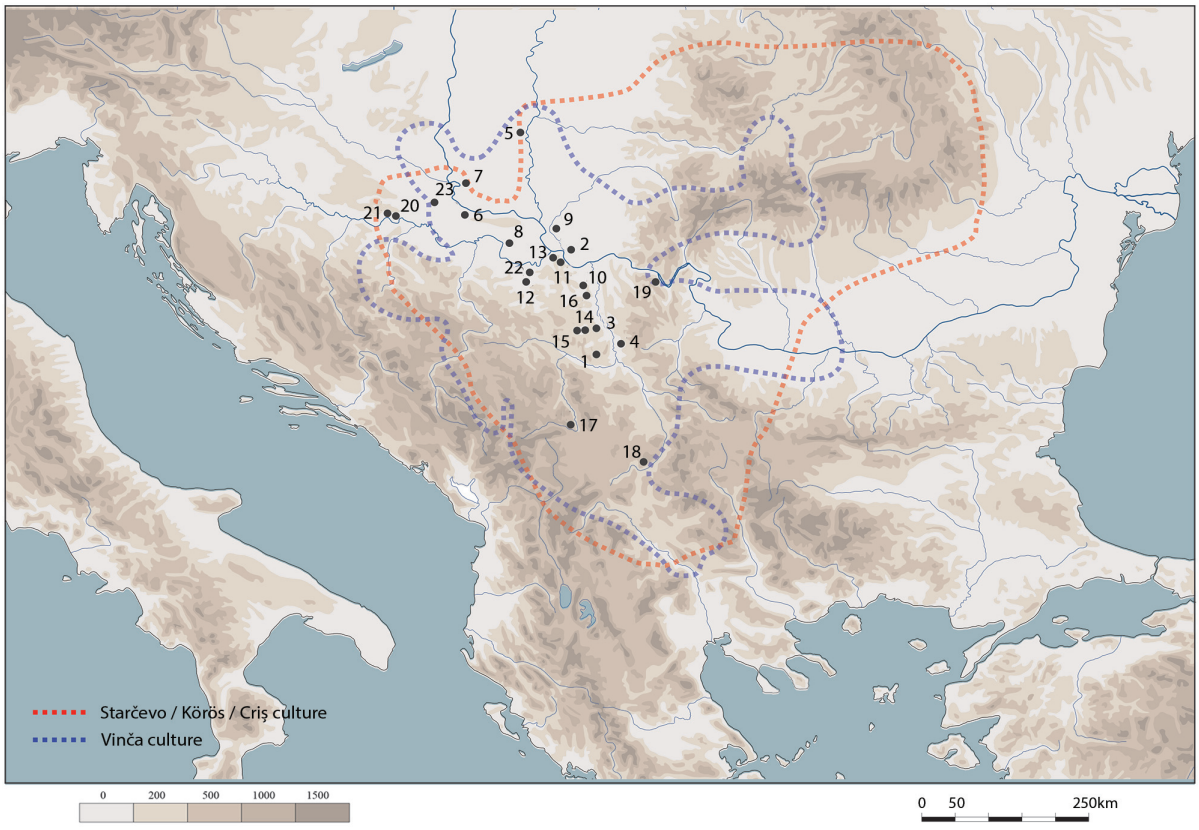

Fig. 1. Distribution of Starčevo–Körös–Criș and Vinča cultures. Sites:* 1 *Blagotin,* 2 *Starčevo,* 3 *Medjureč,* 4 *Drenovac,* 5 *Nosa – Biserna Obala,* 6 *Donja Branjevina,* 7 *Golokut – Vizić,* 8 *Gomolava,* 9 *Opovo,* 10 *Selevac,* 11 *Vinča – Belo Brdo,* 12 *Stubline – Crkvine,* 13 *Banjica – Usek,* 14 *Divostin,* 15 *Grivac,* 16 *Medvednjak,* 17 *Valač,* 18 *Pavlovac – Čukar, Gumnište,* 19 *Lepenski Vir,* 20 *Zadubravlje,* 21 *Galovo,* 22 *Zvečka,* 23 *Vinkovci (map by S. Živanović).

be avoided, so the communities apply different buffering strategies to obtain a balanced diet throughout the year. But even minor changes in temperature or precipitation patterns can sometimes endanger the existence of farming-based non-industrial communities, due to crop failure and lack of fodder for animals. Bad conditions can last one or multiple years, forcing communities to employ one or several survival strategies, based on the duration of the unfavourable period and their cultural, social, economic and ideological preferences (*Halstead, O'Shea 1989; Đuričić 2021*). The Neolithic lifestyle, being completely different from the previous ones, with the increase in population and reliance on domesticates, resulted in new survival strategies.

Four social buffering strategies for overcoming food scarcity have been proposed by Paul Halstead and John O'Shea (*1989*): (1) diversification, (2) storage, (3) exchange and (4) mobility (*Halstead, O'Shea 1989; Groot, Lentjes 2013*). These buffering strategies are not applied only when food shortages occur, but also refer to actions undertaken to prevent the lack of food and prepare for inevitable periods of the year when food is less available in nature (*Đuričić 2021*). In this paper, the social buffering strategies Early/Middle Neolithic Starčevo and Late Neolithic Vinča culture communities applied in order to prepare for, prevent and overcome periods of food scarcity caused by environmental variability are tested and the most plausible ones are considered. The similarities and differences between social buffering strategies practised during the Early/Middle and Late Neolithic of the Central Balkans will also be compared.

Overcoming the environmental variability

Food scarcity is not connected solely to natural disasters, and lack of food can occur due to different factors. Solar radiation influences ecosystem dynamics. Temperate climate zones, like the Central Balkan region, have uneven solar radiation, leading to pronounced differences between seasons (*Rowley-Conwy, Zvelebil 1989.41; Đuričić 2021*). During spring vegetation grows suddenly, giving the plants limited time for growth, development and reproduction. Summer is the season of abundance with numerous migratory animal and plant species – cereals, fruits, vegetables and berries. A decrease in resources, both local and migratory, is visible during autumn, whilst winter is the most difficult period, with the least amount of available food (*Rowley-Conwy, Zvelebil 1989.41*). These are *seasonal* fluctuations or variations, which are predictable and cannot be avoided, so people apply previously established mechanisms for overcoming periods of food scarcity, to obtain a balanced diet throughout the year (*Rowley-Conwy, Zvelebil 1989.41; O'Shea 1989.57; Halstead 1989. 71; Đuričić 2021*). *Interannual* fluctuations or variations depend upon numerous unpredictable factors. They can depend on climatological factors (droughts, frosts, storms, hail, excessive rain at the wrong time, floods, and so on), animals, insects, plague, plant and animal diseases or human activity. In farming communities, interannual variations like drought can affect crop yields or animal disease can increase domestic animal mortality rates, forcing people to compensate for the losses in alternative ways. Even though these variations are mainly unpredictable people know how to deal with them, using experience gained from previous similar situations. (*O'Shea 1989.58; Halstead 1989.72; Đuričić 2021*). *Long-term* fluctuations or variations are the results of climate or natural changes and often last for a longer period of time. To survive these, communities have to make considerable adaptations (*Rowley-Conwy, Zvelebil 1989.44–45; Đuričić 2021*). In facing these different types of variations the strategies communities apply can vary and change, but they are always in accordance with their specific natural environment, social, cultural and economic norms (*Đuričić 2021*).

Farming communities depend on plant and animal annual reproductive cycles which are controlled by regular seasonal patterns. Even minor shifts in seasonal patterns can influence the amount of food available, whether of plant, or animal origin. To overcome a lack of food, either due to predictable or unpredictable factors, communities apply one of the previously mentioned strategies: diversification, storage, exchange and mobility (*Halstead, O'Shea 1989.3; Groot, Lentjes 2013.9; Đuričić 2021*). The inclusion of a greater variety of food sources is called *diversification*. This also includes keeping certain types of food exclusively for 'rainy days' and the cultivation of different crops on different soils. For farmers, agriculture and herding are forms of diversification, but it also includes hunting, fishing and gathering. Saving food for annual periods of food scarcity is called *storage*. *Exchange* includes different social practices – trade, food sharing, obligatory reciprocity and negative reciprocity (theft). Relocation of a group of people or the whole community towards areas with available food sources is called *mobility* (*Halstead, O'Shea 1989.3–4; Groot, Lentjes 2013.9–10; Đuričić 2021*).

Communities usually mix several buffering strategies. Depending on their preferences, certain strategies can be practised as prevention, while others could be applied as a last resort. Also, different cultures can apply the same strategy differently (*Đuričić 2021*). A typical agricultural/herding community shows some degree of diversification. They cultivate multiple crop types and keep at least two types of livestock, with additional hunting, fishing and gathering that provide a balanced diet and year-round food supply. In situations when a plague or a disease attack crops or animals, diversification provides an effective fall-back strategy, ensuring that at least some food will remain for human consumption. Every society has a tendency to accumulate a surplus. Early agricultural communities accumulate a surplus as a result of seasonality, as a strategy to overcome colder periods of the year. During bad years they may have switched to hunting and gathering, which was also documented in the archaeological record (*Groot, Lentjes 2013.9*). On the other hand, hunter-gatherers rely on different wild resources, making their diversification strategy dependent on a variety of wild animal species and wild plant taxa that are available during different seasons (*Halstead, O'Shea 1989; Đuričić 2021*). According to Paul Halstead, every community generates a surplus, but they define it differently. A distinction should be made between direct and indirect storage. The accumulation of food for later consumption is direct storage, but food sharing with other members of the community, expecting reciprocity in time of need, is an example of indirect storage – social storage. With indirect storage the risk of food spoilage is reduced, as the food often cannot be stored for a long period of time (*Halstead 1989*).

Evidence for diversification in the Neolithic of the Central Balkans

Diversification is a survival strategy applied by both farming and hunting-gathering communities. Hunter-gatherers rely on different wild resources, making their diversification strategy dependent on a variety of wild animal species and wild plant taxa that are available during different seasons (*Halstead, O'Shea 1989; Đuričić 2021*), while farming communities rely primarily on agriculture and domestic animal herding with the addition of hunting and gathering, which is often accompanied by a sedentary lifestyle (*Çilingiroğlu 2005; Cauvin 2000*). Diversification is suitable for overcoming seasonal, interannual and long-term variations. It not only implies the exploitation of alternative resources, but also the cultivation of different types of cereals and pulses of different growing patterns and endurance levels on different soil types. By applying this strategy, a community can potentially reduce the possibility of crop failure (*Groot, Lentjes 2013; Đuričić 2021*). Subsistence based on domesticated plants and animals is also a form of diversification. Domestic animals can convert agricultural waste and plants unsuitable for human consumption into edible food (meat, milk and fat), further reducing the potential for food shortages (*O'Shea 1989; Đuričić 2021*).

Archaeobotanical analyses conducted on various Starčevo culture sites have revealed a broad spectrum of plant food used in the human diet, and these can be divided into cultivated crops and wild plants. However, the results of the archaeobotanical analyses were affected by the lack of systematic sampling, which was conducted only at two sites (Blagotin and Drenovac), while at other sites only contexts marked as interesting or important by archaeologists ('judgement' sampling) were sampled (*Filipović, Obradović 2013; Đuričić 2021*). The greatest plant taxa diversity was recorded at Drenovac, but it was also at this site that the most extensive sampling was conducted. Archaeobotanical remains from the sites of Blagotin, Drenovac, Medjureč, Starčevo and Nosa-Biserna Obala have confirmed the cultivation of five crops[2] (for distribution see *Filipović, Obradović 2013.41*): einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*), hulled barley (*Hordeum vulgare*, hulled), lentil (*Lens culinaris*) and pea (*Pisum sativum*) (*Filipović, Obradović 2013; Filipović 2014; Đuričić 2021*). A total of nine wild taxa has been documented so far (for distribution see *Filipović, Obradović 2013.41*): cornelian cherry (*Cornus mas*), apple (*Malus pumila*), fruit from the malus genus (*Malus* sp.), fruit from the pear genus (*Pyrus* sp.), acorn (*Quercus* sp.), beech nut (*Fagus* sp.), blackberry (*Rubus fruticosus*), unidentified berries (*Rubus* sp.) and dwarf elder (*Sambucus ebulus*) (*Filipović, Obradović 2013; Đuričić 2021*).

Over 70% of the examined faunal assemblage belonged to domestic animal taxa, indicating a reliance

2 Even though broomcorn millet (*Panicum miliaceum*) was found at Neolithic sites in the Central Balkans, recent studies have disputed its cultivation during the Neolithic in Europe, so all millet samples should be treated as an intrusion (*Filipović* et al. *2020*), which is why they were excluded from this paper.

on domesticates at the majority of Starčevo culture sites (for detailed archaeozoological analysis and distribution see *Orton 2012*) (*Greenfield 2008.108; Đuričić 2021*). Cattle is the most dominant domestic animal taxa, with the exception of Donja Branjevina, where goats/sheep dominate (*Orton 2012*), while pigs were barely represented in the faunal assemblage (*Orton 2012; Ethier* et al. *2017; Đuričić 2021*). Dogs were also present, but were probably not consumed. However, sites in the Danube Gorges, Golokut-Vizić in Southwestern Bačka and Nosa-Biserna Obala in Northern Bačka show different patterns. At these sites, a higher percentage of wild than domestic animal taxa have been documented (*Orton 2012; Đuričić 2021*). Red deer, roe deer, wild boar, fish, birds and smaller mammals, dominated amongst the wild taxa remains (*Greenfield 2008; Đuričić 2021*). The analyses of faunal assemblage from the Early/Middle Neolithic layers from the Danube Gorges sites show the significance of migratory fish for local subsistence (*Dimitrijević* et al. *2016*). Recent pottery lipid analysis has shown that the majority of vessels in the Danube Gorges settlements were used for cooking aquatic resources, contrary to the data from the sites in the rest of the Central Balkans (*Cramp* et al. *2019*), where pottery was used for processing meat, milk/dairy, plant food and storing beeswax (*Ethier* et al. *2017; Stojanovski* et al. *2020; Đuričić 2021*). Stable isotope analyses have shown almost exclusive reliance on terrestrial resources of the Starčevo culture communities with mixed terrestrial and aquatic diet in the Danube Gorges and in certain settlements located in close proximity to rivers – Vinča – Belo Brdo, Sremski Karlovci, Obrež – Baštine, and Klisa (*Jovanović* et al. *2019; 2021*). Domestic animals were not only used as a meat and fat source, as recent lipid analyses undertaken on Starčevo culture pottery confirmed milk and dairy consumption during the Early/Middle Neolithic (*Ethier* et al. *2017; Cramp* et al. *2019; Stojanovski* et al. *2020*).

Archaeobotanical analyses from Vinča culture sites have shown a greater variety of domestic crops. Archaeobotanical remains from the sites of Drenovac, Gomolava, Opovo, Selevac and Vinča – Belo Brdo, have confirmed cultivation of 11 crops (for distribution see *Filipović, Obradović 2013. 41*): einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*), hulled barley (*Hordeum vulgare*, hulled), naked barley (*Hordeum vulgare*, nudum), free-threshing wheat (*Triticum aestivum/durum*), a new type of wheat (*Triticum* sp., 'new type'), lentil (*Lens culinaris*), pea (*Pisum sativum*), bitter vetch (*Vicia ervilia*), flax/linseed (*Linum usitatissimum*), grass pea (*Lathyrus sativus/cicera*) (*Filipović, Obradović 2013; Filipović 2014*). A total of 17 wild taxa have been documented so far (for distribution see *Filipović, Obradović 2013.41*): cornelian cherry (*Cornus mas*), hazel (*Corylus avellana*), wild strawberry (*Fragaria vesca*), crab apple (*Malus sylvestris*), common reed (*Phragmites communis*), Chinese lantern (*Physalis alkekengi*), fruit from prunus genus (*Prunus* sp.), fruit from pear genus (*Pyrus* sp.), acorn (*Quercus* sp.), beech nut (*Fagus* sp.), blackberry (*Rubus fruticosus*), dewberry (*Rubus caesius*), unidentified berries (*Rubus* sp.) elderberry (*Sambucus nigra*), dwarf elder (*Sambucus ebulus*), water chestnut (*Trapa natans*), wild grape (*Vitis vinifera* (ssp. *sylvestris*)) (*Filipović, Tasić 2012; Filipović, Obradović 2013*) and sloe berry (*Prunus spinosa*) (*Filipović, Tasić 2012; Borojević* et al. *2020*).

Archaeozoological analyses have confirmed that domestic animals (cattle, sheep/goats, and pigs) played a dominant role in the subsistence strategies of Vinča culture communities. While the most significant animal was still cattle, the most dramatic shift occurred with pigs, who played an extremely important role in the diet of the Vinča culture communities. The results of organic residue analysis conducted on two Vinča culture sites so far – Drenovac and Motel-Slatina, confirmed the consumption of different types of meat, milk and dairy products (*Kruger* et al. *2019*). Two different studies have confirmed the presence of beeswax in Vinča culture pottery, confirming the exploitation of honeybees during the Late Neolithic in this region (*Roffet-Salque* et al. *2015; Kruger* et al. *2019*). The majority of the wild taxa remains still belonged to red deer, roe deer, wild boar, auroch and smaller mammals (*Orton 2012*). At the site of Vinča – Belo Brdo, apart from previously mentioned wild taxa, the remains of beaver, rabbit, otter, badger, vole, fox, wolf, brown bear, fallow deer, birds, tortoise, various Mollusca (mostly unio shells) and fish, have been identified (*Dimitrijević 2006*). Moreover, 14.5% of the dog bones found at this site between the years 1998 and 2003 showed traces of burning, and one vertebra also had butchering traces, indicating the consumption of dog meat, previously not documented in the Vinča culture (*Dimitrijević 2006.252*).

Plant food can be used in different ways during different times of the year. Cereals could have been sown in autumn, as they need a long period of vernalization to produce seed and legumes could have been sown in spring, due to their shorter growing

season (*Filipović, Tasić 2012*), securing the crop yields in case of unpredicted interannual variations. At the Late Neolithic site of Opovo, autumn/ winter sowing has been proposed for some of the identified cereals. Analysis of weed flora can help in determining crop sowing time, but those analyses have either not been conducted or the results have been inconclusive (as in the case of the Vinča – Belo Brdo site) (*Filipović, Tasić 2012*). Information about different soil types in the immediate vicinity of settlements has been provided for several Vinča culture sites. The majority of settlements in the Morava Valley are surrounded by multiple soil types, some more suitable for autumn/winter, and others for spring-sown crops (*Milanović 2019*). Cereals could have been used in several different ways – they could have been used for bread production or cooked as porridges or gruels. Porridges could have been enriched with legumes, and legumes could have been added to stews and soups. Acorn is also very versatile, and it could have been consumed roasted, dried or ground into flour. Fruit and berries could have been eaten fresh, but also dried or cooked, which prolonged their shelf life (*Atalay, Hastorf 2006; Đuričić 2021*). The consumption of milk and dairy products and their combination with other food categories further increases the variety of food sources in the Neolithic period.

During the Early/Middle Neolithic in the Central Balkans, diversification as a social buffering strategy was practised through different procurement strategies – agriculture, domestic animal herding, hunting, fishing and gathering. A broad variety of domesticated and wild plant and animal resources were used, which enabled Starčevo culture communities to obtain a year-round balanced diet and reduce the potential for food shortages. One definite model for diversification cannot be provided, however, as food procurement strategies could differ from settlement to settlement (*Greenfield 2008; Orton 2012; Filipović, Obradović 2013; Cramp* et al. *2019; Đuričić 2021*). Each settlement should be approached individually, providing opportunities for further studies on differences and similarities between communities, which surpasses the scope of this paper. Nevertheless, certain tendencies can be distinguished, such as higher dependence on domesticates in the human diet at the majority of the sites, both of plant and animal origin (*Orton 2012; Filipović, Obradović 2013; Đuričić 2021*). Archaeozoological analyses have helped in determining the seasonality of occupation of certain settlements. By analysing the seasonal availability of the represented taxa, occupation patterns have been determined for several settlements. Archaeozoological analyses of Early Neolithic sites in the Danube Gorges show patterns of seasonal habitation, based on the faunal, specifically migratory fish remains (*Dimitrijević* et al. *2016*). At the site of Golokut, analyses of faunal remains have indicated that the settlement was occupied seasonally between late autumn to late winter (*Živaljević* et al. *2017; Đuričić 2021*). Similarly, archaeozoological analyses from the site of Blagotin suggest seasonal occupation between late autumn and late spring (*Ethier* et al. *2017; Đuričić 2021*).

Vinča culture communities used even broader spectra of domesticated and wild plants and animals (*Dimitrijević 2006; Orton 2012; Filipović, Obradović 2013*). The introduction of new types of domesticated cereals (*Hordeum vulgare*, nudum, *Triticum aestivum/durum* and *Triticum* sp., 'new type') and legumes (*Vicia ervilia, Linum usitatissimum* and *Lathyrus sativus/cicera*) could further reduce the possibility of crop failure (*Filipović, Obradović 2013; Filipović 2014*). With regard to domesticated animals, while pigs had negligible significance during the Early/Middle Neolithic, they were important in the diet of the Late Neolithic communities in the Central Balkans (*Orton 2012*). Furthermore, the extreme diversity of the faunal repertoire at the site of Vinča – Belo Brdo, including previously not registered food sources, specifically in the excavated area of later occupational horizons at this site, raises a question about living conditions at this particular time. It is still not clear whether this broader spectrum of food sources reflects a period of crisis or if this inclusion of more diverse animal species represents the typical diet of Vinča settlement residents. After these occupational horizons, the habitation of the settlement continued, but archaeozoological analyses of faunal remains of the final occupational phase show typical Vinča culture dietary choices (except a smaller representation of pigs) (*Dimitrijević 2006*). It is possible that this variety of food sources represents evidence of interannual or even long-term variations leading to food scarcity and the application of diversification as a survival strategy, by the introduction of an even broader spectrum of animals. Nevertheless, one universal diversification pattern cannot be applied to every Vinča culture settlement. In some settlements, for example, hunting played a more significant role than in others (*Orton 2012*), indicating differences in procurement strategies throughout the Vinča culture. Comparison between procurement strategies during the Late Neolithic of the Central Balkans can provide important informa-

tion regarding the Vinča culture economy, but these analyses surpass the scope of this paper.

Evidence for storage in the Neolithic of the Central Balkans

Storage is a common practice, not only among farming communities but also among hunter-gatherers. Even though cereals are the most common type of stored food, fruit, meat and fish can also be stored (*Madge 1994; Đuričić 2021*). For seasonal and sometimes interannual variations storage is an extremely effective buffering strategy, but it would not be effective if long-term variations affecting the crop yield occur (*O'Shea 1989; Halstead 1989; Đuričić 2021*). In those situations, meat, fish or wild plants can still be stored.

In the archaeological record, storing features (silos, built-in storage containers, such as storage bins, storage pots or pithoi) or concentrations of carbonized plant remains are good indicators of storage. Other types of food, although stored, are less likely to be preserved in the archaeological record. The properties of the manufacturing material determine the preservation of certain objects or features in the archaeological record, so storage containers from perishable materials – wooden crates, boxes, baskets, sacks or bags made from leather, wood, plant fibres, branches and cork – would be hard or impossible to identify in the archaeological record (*Filipović* et al. *2018.34; Đuričić 2021*).

Storage containers in the Starčevo culture are rarely found, so this practice is usually determined via concentrations of carbonized grains. At the site of Nosa – Biserna Obala, more than fifty clay-lined pits, resembling silos (with a pear-shaped cross-section), were found. Inside those pits, small amounts of carbonized grains were detected, together with other fragmented material (*Garašanin 1960.229*). The fill of the pits corresponds to the fill of the refuse pits, including carbonized remains, which were charred before they were thrown away. If they were silos then those remains either would not have been carbonized or would not have been mixed with other material categories. Still, there is a possibility that those pits were primarily silos, but were secondarily used as refuse pits (*Filipović, Obradović 2013; Filipović* et al. *2018*). Pithoi, large pots that would indicate storage, are scarce at the Starčevo culture sites. A large vessel containing barley was found at the site of Bandovići (*Filipović* et al. *2018*), making it the only reported case so far (*Đuričić 2021*). Grains and other plant-based products could have been stored inside smaller vessels, but their volume does not seem sufficient for extensive storage (*Tripković 2011*). At the site of Drenovac, in the house destruction layer of burnt daub, a concentration of carbonized seeds was found (*Filipović* et al. *2018.35; Đuričić 2021*). It contained predominantly legumes (75% lentil, 20% peas, small amounts of emmer and einkorn, and several fruits remains). This concentration suggests that these different plant foodstuffs were probably stored separately in organic containers – baskets, bags, or wooden containers with several compartments (*Filipović* et al. *2018.35; Đuričić 2021*). At the Early Neolithic site of Tsangli in Greece, indications of baskets lined with clay plaster or dung were documented, showing another possible storing option, which would hardly leave any archaeological record (*Halstead 1989.71*).

At the sites of the Late Neolithic Vinča culture, substantially more evidence for storage has been found. Storage containers were predominantly found inside houses and used for short-term storage. Large storing pots (pithoi) and smaller vessels were found at the majority of the Vinča culture sites, some of which contained remains of carbonized grains, confirming their presumed role based on the pottery typology (*Jovanović, Glišić 1961; Tripković 2011; Vuković 2011; Filipović* et al. *2018*). Pithoi could be found inside separate architectural features – storage bins, made from mud plaster, usually located next to an oven (Fig. 2). The walls of those features were about 50cm high. Storage compartments, together with ovens and querns located in their proximity, form a food processing set (*Spasić, Živanović 2015*). Storage bins were found in numerous houses: house 01/06 at Vinča – Belo Brdo (*Tasić* et al. *2007; Vuković 2011; Filipović* et al. *2018; Borojević* et al. *2020*), the house at the depth of Δ 6.73m from 1912 at Vinča – Belo Brdo (Fig. 3) (*Vasić 1912.94; Đuričić 2019*), house II/1912 at Vinča – Belo Brdo (*Vasić 1912.21*), house 1 from the trench XIX at Drenovac (*Perić 2017*), house 1/2010 at Stubline – Crkvine (*Crnobrnja 2012; Spasić, Živanović 2015*), house 2/79 at Banjica – Usek (*Todorović 1981; Tripković 2013; Spasić, Živanović 2015*), house 2 at Opovo (*Tringham* et al. *1992*), and houses 13 and 17 at Divostin (*Bogdanović 1988*). One of the best examples comes from house 01/06, at the Vinča – Belo Brdo site, where two pithoi filled with carbonized (predominantly) emmer grains were found in one of three storage bins located next to an oven (*Vuković 2011; Spasić, Živanović 2015; Filipović* et al. *2018; Borojević* et al. *2020*). Next to them, without a con-

tainer, the remains of emmer, water chestnut and pears were located (*Borojević* et al. *2020*). Another type of storage bin has been found in Vinča culture houses. Although connected to the house wall, they were smaller and shallower and were not located near ovens or other architectural features. Such containers were found in house 1/2008 at Stubline (*Spasić, Živanović 2015*), house 21 at Grivac (*Bogdanović 2008*), house 1 at Jakovo (*Jovanović, Glišić 1961*), house 15 at Divostin (*Bogdanović 1988*) and house 1 from the trench XIX at Drenovac (*Perić 2017*). The number of these fixed storage bins is certainly higher, but the preservation of these features depends on multiple factors (the most significant being house destruction by fire), as they were built from mud plaster, a material which deteriorates with time (*Đuričić 2020*).



Fig. 2. Experimentally reconstructed Vinča culture oven and a storage compartment (clay bin) (photo by A. Đuričić).

In house 01/06 at Vinča – Belo Brdo, multiple caches of cereals without containers were found, but one of them was in association with carbonized wooden planks, which may imply the existence of a wooden crate. In one emmer deposit, relatively large quantities of flax/linseed and bitter vetch were documented, probably stored separately in perishable containers (wooden crates with multiple compartments, baskets or bags). Similar contexts were found at the sites of Medvednjak and Valač, suggesting the usage of containers from perishable materials throughout the Vinča culture. In house 02/06 at Vinča – Belo Brdo, a cache of well-preserved wild pears was discovered. Those pears could have been stored in bags hung on the house wall, or in pots placed on shelves (*Filipović* et al. *2018*). Pears and berries could have been dried and stored for winter consumption. Herbs, certain grass types and weeds could have been dried, stored and used as medicines or spices (*Filipović, Tasić 2012*). Storage practices in the Vinča culture are an important and interesting topic. By following changes in these, broader sets of questions about diachronic changes in social organization, architectural practices and the economy of the Vinča culture communities can be answered (see *Tripković 2013*), but detailed analyses of these issues surpass the scope of this paper.

Raw cereals are prone to spoilage and due to their exposure to insects or rodents, they cannot be stored for a long period of time. Bulgur (cooked and dried cereals) or trahanas (dried fermented cereals) are good options for prolonging their shelf life. Bulgur is prepared by first cooking, then drying and finally grinding cereals. With this process, the grain gets a hard texture, less prone to spoilage and infestation. (*Valamonti 2011; Bayram 2000; Đuričić 2021*). Indications for bulgur production were found



Fig. 3. House at the depth of Δ 6.73m from 1912 at Vinča – Belo Brdo – storage compartment (front) next to an oven (photo: Archive of the Archaeological Collection, Department of Archaeology, Faculty of Philosophy, University of Belgrade).

on emmer grains detected next to a quern in house 01/06 at Vinča (*Borojević* et al. *2020*). Trahanas is similar to bulgur, but it involves cooking either bulgur, raw grains or flour in milk or soured milk (*Valamonti 2011; Đuričić 2021*). After cooling, the mass is formed into balls or rectangles, which are dried in the sun and stored. Trahanas can be stored for up to two or three years (*Valamonti 2011*). Lactic acid fermentation from milk also preserves food, protecting it from microbes and toxins, making trahanas perfect food for prolonged storage (*Daglioğlu 2000; Đuričić 2021*).

Long-term storage is possible when a year has been particularly good, creating a considerable surplus. One part of the surplus can then be used as an investment for the future – feeding cattle that will be slaughtered during times of food scarcity. This type of storage is intended for feeding the community on an interannual level (*Halstead 1989. 73*).

Evidence for exchange in the Neolithic of the Central Balkans

Exchange is a broad term for social practices of sharing resources between communities, social groups or individuals. It does not have to be literal – goods for goods or goods for services – but also includes an exchange of goods or food between households in social settings: feasts, house hospitality and gifts/treats (*Sahlins 1965; Đuričić 2021*). These actions consolidate social bonds and obligations, forming a base for reciprocity. Food can be exchanged for labour or for tokens which symbolize the commitment of a household to return the favour, establishing the grounds of social storage. Social storage and these exchange practices are hard to detect in the archaeological record. An exchange between households within one community can be performed only on seasonal and interannual levels. By living in the same settlement, long-term bad conditions would deprive every household of food supplies, so they would have to ask for help either from neighbours or allies that live in different territories (*Halstead 1989; Đuričić 2021*). Possible ways to create alliances with outside communities are marriages or trading partnerships. These partnerships create bonds and can prevent the emergence of hostile relationships (*Sahlins 1972; Đuričić 2021*). Even though exchange and contact between close settlements is always a possibility, they are difficult to detect in the archaeological record, due to probable similarities in the material culture (*Đuričić 2021*). Two categories of exotic materials speak of contacts and long-distance trade between the Starčevo/Vinča culture communities and distant populations – *Spondylus/Glycymeris* shells and obsidian. Objects made from jadeite/nephrite can also imply contacts with distant populations, as sources of these minerals were not documented in the territory of the Central Balkans, but due to the lack of analyses the provenience of raw materials used for the production of these artefacts has never been determined (*Balaban 2013*). Even though these objects cannot provide insight into communication routes with distant communities at this moment, they should be taken into consideration for further studies, when more data is available.

The presence of thermal structures in the open spaces within a settlement is considered as an indicator of food-sharing practices between households (*Byrd 1994*). Fire installations found at Starčevo culture sites were located both inside and outside dwellings. So far, only four hearths (*Bogdanović 1988; Minichreiter 2001; Petrović 1984–1985; Đuričić 2019; 2021*) and six cooking trenches (Fig. 4) (*Đuričić 2019*), previously interpreted as tubular ovens (*Minichreiter 1992; Bànffy* et al. *2010*), have been found in open spaces within a settlement (*Đuričić 2021*). It should be noted that no cooking trenches were present inside the houses (*Đuričić 2019*). So far, all of the ovens (total of 16) and the majority of hearths (total of 11) that have been found were located inside dwellings (*Bogdanović 1988; 2008; Minichreiter 1992; 2001; 2007; Bànffy* et al. *2010; Marić 2013; Đuričić 2019; 2021*). The location of fire installations in the Starčevo culture settlements implies that at least a portion of cooking activities was conducted in a communal setting. To date, however, it cannot be concluded if these activities were performed on a daily/seasonal basis or on special occasions, nor which part of the community was involved in this process (*Đuričić 2019; 2021*). Intra-settlement food-sharing was proposed as one of the social buffering strategies practised by the Early Neolithic communities in Thessaly, Greece. Food-sharing activities were practised regularly, not only in times of need, resulting in the consolidation of neighbouring relations. Besides intra-settlement relations, they had contact with other settlements. Those contacts were documented through fine pottery, suggesting some degree of inter-settlement exchange (*Halstead 1989; Đuričić 2021*). Similar food-sharing practices could have been performed by the Starčevo culture communities (*Đuričić 2021*).

The presence of artefacts made from materials of non-local provenience suggests contacts with distant

populations. In the Early/Middle Neolithic of the Central Balkans, obsidian finds are scarce and mostly concentrated in the Danube Basin. However, the research on exchange networks has not been extensive enough, so definite distribution patterns are yet to be determined (*Tripković 2003–2004*). Ornaments from *Spondylus/Glycymeris* shells have been confirmed at only three Starčevo culture sites with a total of 11 pieces of jewellery. They were probably imported as finished products, as manufacturing debris has not been detected. Additionally, ornaments typologically correspond to the examples from the rest of Europe (*Vitezović 2012; 2016; 2019*). These sporadic finds of exotic materials in the Early/Middle Neolithic of the Central Balkans, confirm some degree of contact with distant communities, but not the nature of the contact (trade or maybe dowery upon marriage). Stable isotope analyses can offer more information about the relationships between different settlements and communities established by marriage partnerships. Strontium and oxygen stable isotopic analyses conducted on Starčevo culture individuals from several sites in the Hungarian Transdanubia have shown that there was a higher proportion of non-local and regional females than males. If these data do not point to the migration of the Starčevo culture population to the new territory, they could imply patrilocal marriage arrangements with women from different settlements, within and outside the region (*Depaermentier* et al. *2020*).

There are few indications of food-sharing practices in the Vinča culture. Two indicators for individual food preparation are household storage and indoor thermal structures (*Byrd 1994*), and both have been documented at the Vinča culture sites (*Đuričić 2019*). Contrary to ovens which were always located inside houses, hearths (hearth-pits) were only found at two sites, Pavlovac – Čukar (*Đuričić 2019*) and Pavlovac – Gumnište (eight in total) (*Perić* et al. *2016; Đuričić 2019*). These types of hearths indicate either communal (*Byrd 1994*), seasonal (*Rollings 1989*) or some specialized activity. Due to the scarcity of these finds, further studies should be conducted in order to determine their practical and social role. Still, even though cooking activities were probably conducted on the household level, this does not exclude other food-sharing practices like feasts, household hospitality or gifts.[3] Even though the inter-settlement exchange is hard to determine and identify in the archaeological record, certain products could have been used in negotiations between close settlements. For example, access to pastures in the vicinity of one settlement, by herders and cattle from other settlement, could have been compensated for with products like milk, butter, cheese, meat or some other trade goods (*Gillis* et al. *2021*). Copper can also be used in determining inter-settlement and regional contacts between Vinča culture communities and contemporary non-Vinča culture sites in modern-day Bulgaria. Copper ores used for the production of copper objects found at the Vinča culture sites of Belovode, Pločnik, Vinča – Belo Brdo, Gomolava, Selevac and Gornja Tuzla and Ruse and Durankulak in the Lower Danube region in modern-day Bulgaria came from deposits located mainly in eastern Serbia. The social dynamics of these inter-settlement and intercultural contacts have not been determined so far (*Radivojević* et al. *2021*).



Fig. 4. Experimentally reconstructed Starčevo culture cooking trench (photo by A. Đuričić).

Exotic materials are found more frequently at Vinča culture sites. A number of settlements, especially those located in the Tisa Valley, the South Banat and the Morava Valley, show a considerable amount of obsidian objects. The most abundant collection of obsidian finds comes from the site of Vinča – Belo Brdo, where this material makes up 69.5% of the chipped stone industry (*Tripković 2003–2004; Tripković, Milić 2009*). Analyses shows that the obsidian

3 Although there is no evidence of places for gathering and communal feasting in the Vinča culture settlements, one interesting context found at the Late Neolithic site of Kleitos 1 in Northern Greece can offer some insight how this practice was conducted (*Kalogiropoulou, Ziota 2021*).

came from the source in the Carpathian Basin, implying strong and long-lasting connections with Tisza culture communities (*Tripković, Milić 2009*). Connections with these communities are further documented by unique finds from the site of Vinča – Belo Brdo, with pottery and other ceramic objects of Tisza provenience (including the famous Mayres pithos) (*Ignjatović 2008*). *Spondylus/Glycymeris* shell ornaments were more common and present in more varying forms than in the previous period. Their finds were especially abundant at the site of Vinča – Belo Brdo (*Dimitrijević, Tripković 2002; Vitezović, Antonović 2020*). *Spondylus/Glycymeris* trading routes have not been determined yet, and several options are plausible. Even though it was commonly assumed that these shells came from the Aegean Sea, the lack of *Spondylus/Glycymeris* finds along the presumed trading route via the Vardar and Morava River valleys opens the door for new options. The trading network between the communities in the Central Balkans with the communities living on the coast of the Adriatic Sea was established either directly or via intermediaries in what is today central Bosnia. *Spondylus/Glycymeris* objects and raw material were found at the sites along this route, suggesting that Vinča culture communities could have been a part of this exchange network (*Dimitrijević, Tripković 2006*). The number of exotic finds at the site of Vinča – Belo Brdo distinguishes it from the rest of the Vinča culture settlements, indicating a prominent role of this community in trade and exchange, with long-lasting and well-developed connections throughout south-eastern and central Europe (*Vitezović, Antonović 2020*).

Evidence for mobility in the Neolithic of the Central Balkans

Mobility is considered the 'easiest' survival strategy, and it is undertaken when a community encounters a lack of resources. This strategy is typical for hunting-gathering and pastoral communities. Certain archaeologists consider mobility as an unfavourable option for agricultural communities, as storage (characteristic of agricultural communities) and mobility are mutually exclusive (*Halstead, O'Shea 1989.3–4; Đuričić 2021*). It is thought that forced mobility in agricultural communities occurs when long-term variations make arable land unsuitable for farming for a prolonged period of time, and thus these communities would perceive mobility as a last resort (*Rowley-Conwy, Zvelebil 1989.46; Đuričić 2021*). But mobility is not rigid and not all mobile communities have the tendency to become sedentary. Equally it does not mean that sedentary communities cannot become mobile in certain situations. Even in fully sedentary communities, there are certain social groups with a higher level of mobility (*Leary, Kador 2016*). Mobility is thus an extremely complex term that cannot can be defined just as relocation but also through *movement* (a certain period of time, season), *motion* (mobility pattern), *motivation* (resources, cultural identity, social or economic circumstances) or *segment* (parts of the population) (*Wendrich, Barnard 2008.8*). Nevertheless, as a social buffering strategy practised by communities to overcome environmental variability, mobility mostly refers to group or settlement relocation towards areas with available food resources (*Halstead, O'Shea 1989; Groot, Lentjes 2013; Đuričić 2021*).

It is considered that the level of sedentism of a certain community is most accurately determined through architecture. The model for determining mobility/sedentism came from cross-cultural studies conducted on modern non-industrial communities. Those studies have suggested that mobility is implied by settlements with pit-dwelling house types and sedentism by above-ground houses (*Greenfield, Jongsma 2006.67; Nicholas 2002.75; Đuričić 2021*). Ethnographic studies show that pit-dwellings are a preferable choice for communities with increased mobility during the colder months (*Nicholas 2002. 75*). The development of agriculture is followed by the reduction of mobility. Sedentism forms a base for economic intensification, population growth and an increase in social complexity (*Neil* et al. *2016. 1*). This approach, even though suitable for some Neolithic communities, cannot be applied universally, as a number of Neolithic agricultural communities display a certain degree of mobility (*Neil* et al. *2016; Depaermentier* et al. *2020; Đuričić 2021*). Although architecture can be a good indicator of mobility, stable isotopic analyses offer the most accurate data. Stable isotopic analyses performed on the material from the Early Neolithic sites in this region have been primarily focused on dietary practices, not mobility patterns (*Jovanović* et al. *2019; 2021; Stojanovski* et al. *2020*), so future studies can offer more clarification on this subject.

The most prominent Starčevo culture architectural features are pits, and due to the fact that above-ground structures are rare it is considered that these Early Neolithic populations lived predominantly in pit-dwellings. Although pits at Starčevo culture sites can be very large with large quantities of material, a pit cannot be determined as a dwelling purely on its

size. In order to be interpreted as a pit-dwelling, a pit should have thermal structure remains (*Garašanin 1949.52–54*). Unfortunately, Early Neolithic Central Balkans sites have not been excavated extensively, so the data we have is still fragmentary, especially when architecture is concerned. Pits that meet the criteria for being interpreted as dwellings have been identified at several sites: Divostin (*Bogdanović 1988*), Lepenski Vir (*Srejović 1969*), Donja Branjevina (*Karmanski 2005*), Drenovac (*Perić 2008*), Grivac (*Bogdanović 2008*), Zadubravlje (*Minichreiter 1992; 2001*) and Galovo (*Minichreiter 2001; 2007*). Their interiors are divided by platforms, niches or differences in floor levels (*Petrović 2001; Đuričić 2021*) and the presence of a superstructure is indicated by postholes or daub remains (*Bogdanović 2008; Đuričić 2021*). The roofs were thatched, made from straw or reed (*Bogdanović 1988.37–39; Petrović 2001*). Architectural features made from mud plaster, indicating fixed house furnishing, are not present in these dwellings (*Đuričić 2021*). Additionally, almost all of the ovens were underground, not built or modelled from mud plaster, and they were easy to make by digging niches (Fig. 5) or chimney-like features (Fig. 6) into the sides of the pit-dwelling. The walls of these ovens were made from burnt soil, due to exposure to fire. The only examples of ovens modelled from mud plaster, similar to the ones found at the Late Neolithic sites, were found at the site of Lepenski Vir, but they were also located inside pit-dwellings (*Đuričić 2019*). These types of houses and ovens, with all of their characteristics, show less investment in the living spaces, suitable for a community with increased mobility (*Đuričić 2019; 2021*).

Besides pit-dwellings, above-ground houses were also found at Starčevo culture sites, but in a significantly smaller number. They were found at: Divostin (*Bogdanović 1988*), Nosa – Biserna Obala (*Brukner 1979*), Grivac (*Bogdanović 2008*), Zvečka (*Todorović 1966*), Zadubravlje (*Minichreiter 2001*), Vinkovci (*Dizdar, Krznarić Škrtvanko 2000*) and Galovo (*Minichreiter 2007*). These houses are poorly preserved and are only detected based on the postholes, trenches and poorly preserved daub fragments (*Bogdanović 1988.34; Đuričić 2021*). Regarding fire installations, a total of four hearths and no ovens were registered inside these houses. Postholes, trenches and daub fragments indicate that they were made using the wattle and daub technique and the roof was probably thatched and made from straw or reed (*Bogdanović 1988; Đuričić 2021*). Spatial organization is unknown, and the determination of potential separate rooms has not been possible (*Đuričić 2021*), which is in complete opposition to the later Vinča culture house organization and furnishings.

Both strontium and oxygen stable isotope analyses have been conducted on several Starčevo culture sites in Transdanubia in modern-day Hungary. The



Fig. 5. Experimentally reconstructed Starčevo culture dug-in dome oven (photo by A. Đuričić).



Fig. 6. Experimentally reconstructed Starčevo culture chimney-like oven (photo by A. Đuričić).

majority of analysed individuals found at these sites were either mobile or of non-local origin (21 out of 37). However, the non-local individuals may have belonged to the first generation of settlers (12 out of 37) or could point to marriages with partners from different regions. Nonetheless, the number of individuals who led a mobile lifestyle should not be neglected (nine out of 37) (*Depaermentier* et al. *2020*). Studies like these performed on the material from other Starčevo culture sites can enable the reconstruction of mobility patterns of these Early Neolithic communities.

Vinča culture houses were rectangular in plan, with one or multiple rooms, made using the wattle and daub technique with a thatched roof (*Jovanović, Glišić 1961; Todorović 1981; Tripković 2007; 2013; Crnobrnja 2011*). Each house had at least one, but usually multiple domed ovens (Fig. 7), with rebuilt floors (up to six at the oven from house 01/2010 at Stubline) (*Crnobrnja 2012*). Sometimes an oven was inside each room (*Tripković 2013; Tasić* et al. *2007*), and on occasion, two ovens could have been located in the same room (*Vasić 1932*) (Fig. 8). Next to ovens, clay bins and composite grinding stones have have been found (*Todorović 1981; Bogdanović 1988; Tasić* et al. *2007; Tripković 2013; Spasić, Živanović 2015; Perić 2017; Borojević* et al. *2020; Đuričić 2019*). Symbolic elements, such as bucrania, when present, were fixed to a post next to an oven (*Spasić 2012*). Some furnishing regulations are observed inside Vinča culture houses, especially in the food processing area, where fixed architectural features (ovens, clay bins, composite querns and bucrania) were located. All of the fixed architectural features were built from mud plaster, implying time-consuming activities with intentional placement of furnishings (*Đuričić 2019*). Contrary to the Starčevo culture settlements, Vinča culture ones are multi-layered, with houses built one on top of the other, during multiple settlement phases (*Vasić 1932; Kraiser, Voytek 1983; Perić 2008*). Settlement duration, architecture, subsistence and extensive storage, all indicate increased sedentism of the Vinča culture communities. Nevertheless, certain social groups could have been more mobile (*Leary, Kador 2016*). Even some settlements show different occupation patterns. A good example for this is the site of Opovo. This settlement was occupied for a shorter period of time, which is implied by its stratigraphy, architecture, scarcity of storage features, pottery, tools and a lower percentage of domesticated plants and animals (*Tringham* et al. *1992*). Archaeozoological analysis has shown that 65–70% of faunal material be-

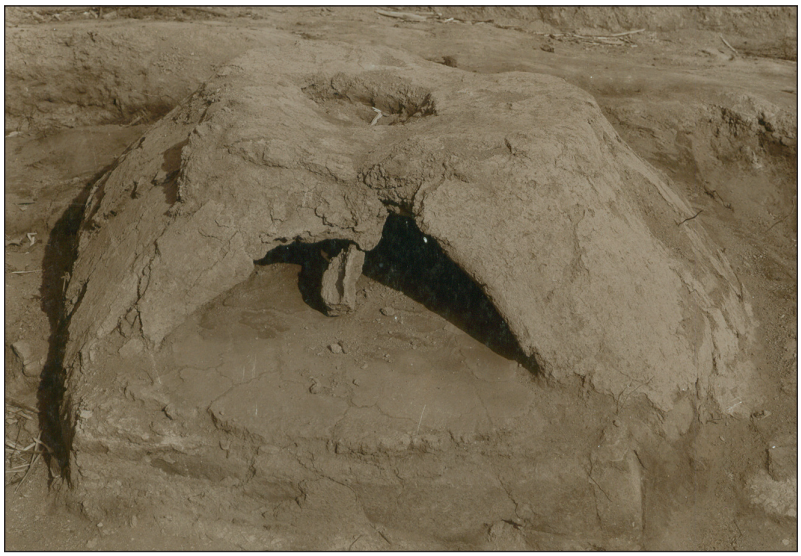

Fig. 7. Oven from the northern room of the house at the depth of Δ 3.20m from 1911 at Vinča – Belo Brdo (photo: Archive of the Archaeological Collection, Department of Archaeology, Faculty of Philosophy, University of Belgrade).



Fig. 8. 3 ovens from house at the depth of Δ 3.20m from 1911 at Vinča – Belo Brdo (one in the northern room and two in the southern room) (photo: Archive of the Archaeological Collection, Department of Archaeology, Faculty of Philosophy, University of Belgrade).

longed to wild animal taxa (*Orton 2012*), indicating that hunting was the dominant procurement strategy (*Tringham* et al. *1992*). Furthermore, cattle remains represent 22.6% of the archaeozoological assemblage, while pigs were not detected at this site (*Orton 2012*). All of these data have led archaeologists to propose an interpretation that the site had a short-term or seasonal occupation. Opovo could have been formed as a specialized settlement oriented toward the exchange and procurement of raw materials like venison or antler (*Trinhgam* et al. *1992.384*). So even within fully sedentary communities, there are examples of partial, maybe seasonal mobility of certain groups due to some specialized activity they were conducting. Recent stable carbon and oxygen isotopic analyses conducted on cattle, sheep/goats and pigs from the Vinča – Belo Brdo and Stubline settlements have revealed new herding patterns. During warmer months domestic animals spent some time away from the settlement in different natural environments (*Gillis* et al. *2021*). It is still unknown whether they were kept in the vicinity of the settlements or if Vinča culture herding strategies required seasonal mobility of animals and herders. Strontium stable isotopic analyses conducted on cattle from the Neolithic site of Arbon Bleiche 3 in Switzerland suggest three different herding styles – local herding, the seasonal movement of cattle and non-local herding (*Gerling* et al. *2017*). Similar studies could help in reconstructing the mobility patterns of one specialized social group within the Late Neolithic communities of the Central Balkans. Nevertheless, these social groups with different mobility patterns point also to diversification and exchange. With their lifestyle, they obtained and managed different resources and enabled contacts between settlements and communities.

Discussion

Each community applied one or several social buffering strategies in order to overcome environmental variability, whether it is caused by seasonal, interannual or long-term fluctuations. Most of the proposed buffering mechanisms (diversification, storage, exchange and mobility) are complementary, but the ways in which they were implemented was community specific. The difference is how dependent each community was on each of these strategies and which were applied as the last resort. By presenting the Early/Middle and Late Neolithic examples which point to each of the four social buffering strategies, we were able to examine which strategies were predominantly used during these periods in the Central Balkans. Members of both Starčevo and Vinča culture communities practised agriculture and animal herding, but it seems that they used differing buffering strategies in order to prepare for, avoid and overcome periods of food scarcity.

Early/Middle Neolithic communities of the Central Balkans practised agriculture and herding, but the evidence for storage is scarce, with caches of plant food indicating storage inside perishable containers (*Filipović* et al. *2018; Đuričić 2021*). The current data does not allow the determination of the amount of surplus they produced or the extensiveness of their storage, so it is difficult to assess how reliant they were on this buffering strategy (*Đuričić 2021*). They cultivated crops with diverse growing patterns, that could have been sown during different seasons (*Atalay, Hastorf 2006*), which could provide a balanced food supply on the seasonal level and diminish the risk of crop failure in case of unpredictable interannual variations. In addition to the cultivation of multiple crops, domestic animal herding, hunting and wild plant gathering form part of their diversification strategy. By applying these mutually complementary procurement strategies, the community can obtain a balanced diet on the seasonal and interannual levels. Even though evidence of long-distance exchange is scarce, there are elements which would point to certain food sharing practices within settlements. While exchange between neighbouring settlements is a possibility, the available data still does not allow determination and reconstruction of inter-settlement relations (*Đuričić 2021*).

Nonetheless, the majority of settlements of these farming communities imply increased mobility (*Kraiser, Voytek 1983; Greenfield, Jongsma 2006.66–67; Whittle 1996.52; Đuričić 2021*). The architecture of Starčevo culture communities with pit-dwellings and above-ground houses, which a lack of thermal structures and fixed architectural features, indicate less investment in house construction and furnishing (*Đuričić 2021*). Recent studies offer some insight into potential reasons for this increased mobility of Starčevo culture communities (*Ethier* et al. *2017; Stojanovski* et al. *2020; Ivanova 2020; Đuričić 2021*). Domesticated plants and animals were brought to the Central Balkans by the new population of Early Neolithic Near Eastern migrants. These plant and animal taxa did not have wild relatives in this region, so their relocation to the temperate climate of the Balkan inland may have created problems for these Mediterranean crops and animals, accustomed to warmer and dryer climate. The climate in the Bal-

kan inland was harsher, with winter frosts and a more precipitation. Acclimatization to new conditions was certainly a long-lasting process, so communities who previously primarily relied on agriculture had to create new subsistence patterns (*Ethier* et al. *2017; Stojanovski* et al. *2020; Ivanova 2020; Đuričić 2021*). The arrival of the Neolithic population to the territory of the Central Balkans around 6250 cal BC coincided with the 8.2-kiloyear cold event (*Bonsall 2007; Kobashi* et al. *2007; Gronenborn 2009; Porčić* et al. *2021*). This event lasted for roughly 200 years (approx. 6250–6050 BC) (*Porčić* et al. *2021*), resulting in 2–3°C lower temperatures in the northern hemisphere in comparison to the previous period. In the territory of the Central Balkans this also resulted in an increase in precipitation, both in winter and summer months (*Bonsall 2007*). These conditions could have been unfavourable for the newly arrived Mediterranean plant and animal taxa, but further studies are necessary for the determination of the effects this event had on the environment. In order to compensate for losses in agriculture due to this acclimatization process, Early/Middle Neolithic communities may have relied more on cattle meat, and dairy products (*Stojanovski* et al. *2020; Đuričić 2021*). Furthermore, goats/sheep also did not have wild relatives in the Central Balkans, so they may have had problems adjusting to the new climate, resulting in changes in their reproductive patterns, which may have led to the increased role of cattle (*Ethier* et al. *2017; Ivanova 2020; Đuričić 2021*). In contrast to goats and sheep, pigs had wild relatives in the Central Balkans, and this territory is favourable for them, but their significance in the diet of the Starčevo culture population was negligible. Pigs, being less prone to transhumance, are usually a good indicator of sedentary settlements (*Ethier* et al. *2017; Đuričić 2021*). Archaeozoological analyses conducted on the material from the sites of Golokut and Blagotin provided information about the seasonality of these settlements (*Živaljević* et al. *2017; Ethier* et al. *2017; Đuričić 2021*). These analyses are crucial for the determination of the seasonal occupation of the settlements and understanding of the mobility patterns of the Starčevo culture communities. By comparing the data, it is evident that Starčevo culture communities had an increased level of mobility, but the character of their mobility is still unknown. Sites with both types of dwellings are often interpreted as multi-seasonal settlements (*Nicholas 2002.75*). Milutin Garašanin argued that Early Neolithic mobility was cyclic (*Garašanin 1979.138*), while Dragoslav Srejović noted that Starčevo culture communities inhabited a location while the soil was fertile, abandoning it afterword (*Srejović 1988.15*).

In contrast to Starčevo culture communities, Vinča culture ones show less reliance on mobility as a buffering strategy but are more dependent on storage. They cultivated an even wider range of crops with diverse growing patterns, possibly sown during different seasons (*Filipović, Tasić 2012; Filipović, Obradović 2013*). They could rely more on cereals, which enabled storage as a buffering strategy. Storage was well documented on the Vinča culture sites, with numerous pithoi, food caches and clay bins found inside houses (*Vuković 2011; Tripković 2013; Spasić, Živanović 2015; Filipović* et al. *2018; Borojević* et al. *2020; Đuričić 2019*). Even though Vinča and Starčevo culture communities based their diet on the same domestic animals, cattle and pigs had a more prominent role during the Late Neolithic (*Orton 2012*). Hunting and gathering were also practised as a form of a diversification strategy. Interestingly, a wide variety of previously undocumented animas (wild animals and dogs) was consumed during later phases of the Vinča settlement. Archaeozoological analysis conducted on the faunal material from the final occupational horizon at this site shows the typical Vinča culture diet, indicating that the inclusion of new animal species in previous phases could have represented application of diversification as a buffering strategy during periods of food scarcity. Nevertheless, final conclusion cannot be made before the material from other excavated areas is analysed (*Dimitrijević 2006.252*). The longevity of Vinča culture settlements, with numerous occupational horizons and houses built one on top of the other, rectangular buildings with fixed mud plaster architectural features and regulations in house furnishings, attest to the sedentary lifestyle of these Late Neolithic communities (*Vasić 1932; Perić 2008*). Pigs, which were well represented in the archaeozoological assemblage (*Orton 2012*), are a good indicator of a sedentary lifestyle, as well (*Ethier* et al. *2017*). Even within sedentary communities, certain social groups could have been more mobile (*Leary, Kador 2016*). Residents of Opovo, a settlement with short-term occupation, could have conducted some specialized activities – the procurement of certain raw materials or exchange (*Tringham* et al. *1992*). The mobility of these social groups could have further pointed to diversification and exchange, as they performed specialized activities and came in contact with members of different communities. For sedentary communities, storage and diversification are suitable buffering strategies, especially on the seaso-

nal and interannual level. For them relocation would be applied when no other options were available. The evidence for food sharing within a settlement is limited, but this practice should not be excluded as it is hard to confirm this in the archaeological record. Further studies could point to contacts between settlements and exchange networks within the region. Nevertheless, Vinča culture communities had established connections with communities of other contemporary cultures (*Tripković, Milić 2009*), so in times of need they could have contacted their distant 'allies'. Even though this strategy could have provided some level of security, the exchange would not be a long-time solution.

Conclusion

In order to avoid periods of food scarcity, Starčevo culture communities relied primarily on diversification and mobility. Based on the current archaeological evidence, storage seems to have been limited. Even though exchange was practised, as we have indications for food sharing activities within settlements and confirmations of contacts between communities, it is hard to assess how dependent they were on this strategy. The increased mobility of these farming communities could have been caused by long-term variations. Whether the 8.2-kiloyear event had an effect on the adaptation of the Mediterranean crops and animals (sheep/goats) in the Central Balkan region has not been established, but current data suggests that these new plant and animal taxa, accustomed to a warmer and dryer climate, had problems acclimating to the harsher conditions of the Balkan inland. Starčevo culture farmers were prevented from being fully reliant on agriculture, resulting in their increased mobility (*Đuričić 2021*). On the other hand, Vinča culture communities relied primarily on diversification and storage. Exchange within the settlement and between different Vinča culture communities was probable, but we still need more studies to determine these social practices. They had established relations with communities form other cultures, so in times of need they could have contacted 'allies' from distant territories. Vinča culture communities lived in permanent settlements, so mobility during the Late Neolithic was different from the Early/Middle Neolithic one. Specialized short-term settlements, like Opovo, could point more to the mobility of certain social groups, diversification or exchange than to settlement relocation as a buffering strategy. Vinča culture communities did not rely on mobility as a buffering strategy on a seasonal or interannual level, but they applied it as a last resort, when no other options were available.

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Late Bronze Age food storage in Lower Cerovačka Cave, Croatia: the archaeobotanical evidence

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ABSTRACT – *This paper presents new archaeobotanical data from the Lower Cerovačka Cave located in Dalmatia, Croatia. At the site a high density of carbonized plant remains was recovered, indicating the remnants of a burnt crop store dating to the Late Bronze Age. Overall, the assemblage is dominated by lentil (*Lens culinaris*) and free-threshing wheat (*Triticum aestivum/durum*), and to a lesser extent, emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), spelt (*Triticum spelta*) and broomcorn millet (*Panicum miliaceum*). In general, the large botanical collection from Lower Cerovačka Cave fits with what is already known about Bronze Age agriculture in Croatia, yet the unique nature of this site brings to the fore questions around storage practices and the use of caves in prehistory.*

KEY WORDS – *crop processing; carbonized chaff and grain; south-east Europe; cave storage*

Pozno bronastodobna shramba hrane v Spodnji Cerovački jami, Hrvaška: arheobotanični dokazi

IZVLEČEK – *V članku predstavljamo nove arheobotanične podatke iz Spodnje Cerovačke jame v Dalmaciji na Hrvaškem. V jami so odkrili mnogo karboniziranih rastlinskih ostankov, ki kažejo na ostanke požgane shrambe pridelkov iz pozne bronaste dobe. Med njimi prevladujejo leča (*Lens culinaris*) in neplevasta žita (*Triticum aestivum/durum*), manj pa je dvozrnice (*Triticum dicoccum*), enozrnice (*Triticum monococcum*), pire (*Triticum spelta*) in prosa (*Panicum miliaceum*). Na splošno se velik botanični zbir iz Spodnje Cerovačke jame ujema s tem, kar že vemo o bronastodobnem kmetijstvu na Hrvaškem, vendar izjemno mesto najdbe postavlja v ospredje vprašanja o praksah shranjevanja in uporabi jam v prazgodovini.*

KLJUČNE BESEDE – *predelava pridelkov; karbonizirano pleve in zrnje; jugovzhodna Evropa; shramba v jami*

Introduction

The seasonality of the agricultural cycle means that some degree of storage is inevitable. In prehistory, seasonal and intensive storage of major food resources for the short, medium or long-term would have been directly related to coping with seasonal variability in agricultural productivity and sedentary overwintering strategies (*e.g., Halstead, O'Shea 1989*). In addition, large-scale or centralized storage has been seen as an indication of social complexity, surplus production, and redistribution, as well as emphasizing socio-economic inequality (*e.g., Bogaard* et al. *2019; Forbes, Foxhall 1995*). Surplus

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also links to networks and trade, whereby an individual or group does not have to store everything themselves but can count on others to provide food at certain times (*Angourakis* et al. *2015; Hastorf, Foxhall 2017; Winterhalder* et al. *2015*). Subsequently, storage has been conceptualized in three different ways (*Ingold 1983; Soffer 1989*): (1) as intra-corporeal, where body fat helps survival through lean times; (2) social storage where formalized exchange systems and social obligations can be reconverted into food in times of shortage; (3) and material or practical storage that involves the processing and accumulation of food resources, and the construction of immovable storage features such as storehouses and pits that encourage permanent residence. Recognizing different modes of food storage in prehistory is therefore critical to assessing the roles that the environment, mobility, settlement size, and socioeconomic circumstances play in the development of different storage behaviours.

Interpreting the economic and/or social motives for storage facilities in prehistory is challenging. Was their use temporary, seasonal, or long-term? Were they managed by households, networks of extended kin, entire communities, or aspiring or established elites? Were they securing food resources, and/or other goods? In order to help with this interpretation scholars typically look at food storage and preparation facilities, as well as primary deposits of ecofacts, such as *in-situ* food storage (*e.g., Bogaard* et al. *2009; Sadori* et al. *2006*). Here we present unique archaeobotanical evidence of Late Bronze Age crop storage within Lower Cerovačka Cave, located in Dalmatia, Croatia. We will examine the use of caves as storage contexts and how this site can expand our understanding of Bronze Age communities in Dalmatia.

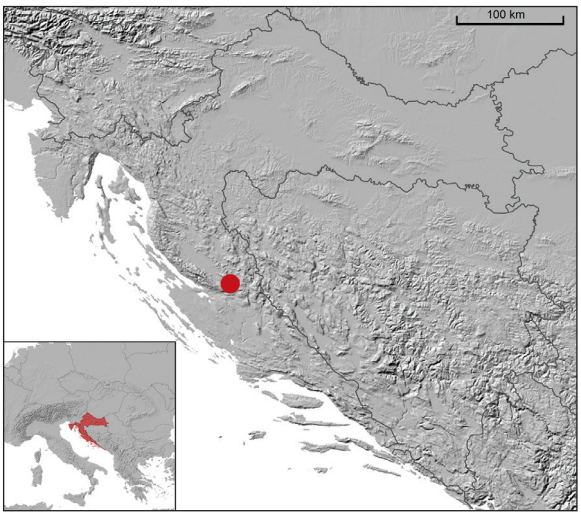

Fig. 1. Location of Cerovačke caves, Croatia.

The site

The Cerovačke caves are located on the south-eastern part of Mt. Velebit (Fig. 1), on the steep northern slopes of the massif of Crnopac, on the edge of Gračac field (elevation 550m). They are represented by three sub-horizontal cave channels, namely the Lower (Donja), Middle (Srednja) and Upper (Gornja) Cerovačka Cave. The Lower Cave was discovered in 1913 and since then the caves have been a focus for speleologists and other geoscientists (*Kurečić* et al. *2021*). The first exclusively archaeological excavations in the Lower Cave were conducted by Ružica Drechsler-Bižić in 1966 and 1967. They recovered fragments of ceramic vessels and a few metal artefacts attributed to the Late Bronze Age (*Drechsler-Bižić 1970; 1983; 1984*).

In 2019 new archaeological excavations were conducted in the Lower Cave in response to the construction of a new visitor's path running 120m from the entrance (Fig. 2). Excavations covered an area of 173m², *i.e.* 120m in length and from 0.5–6m in width. Six phases were identified; Phase 1 was the bedrock, Phase 2 the first human occupation at the beginning of the Late Bronze Age, Phase 3 a further Late Bronze Age layer, Phase 4 the end of the Late Bronze Age, Phase 5 which dated to the Middle Ages (13th century AD), and Phase 6 which dates to the modern era. The Late Bronze Age Phases 2 to 4 were thin layers that together did not exceed 10cm.

A large amount (3.5 tons) of Late Bronze Age pottery fragments were recovered, as well as several objects made of bronze, amber, bone, ceramics and stone, identified mainly as dress ornaments. Only a small number of animal bones and utilitarian objects (needles, awls, vertebrae) were found, suggesting that the cave was not used regularly. Instead, it is suggested that the cave functioned mainly as a storage location during the Late Bronze Age, with periodic episodes of temporary occupation. Three radiocarbon dates (tooth, charcoal and grain) were taken from different locations within Phase 4 and all had similar dates of *c.* 2870–2910 BP (Tab. 1). Phase 3, dated to *c.* 2950 BP, and Phase 2 to *c.* 3090 BP. It is likely that the period of use was relatively short and ended abruptly at the same time in the whole occupied area of the cave, possibly due to fire, resulting in large areas of burnt archaeological features. This was particularly evident in quadrant D21 where a large deposit of carbonized plant material was found, along with possible remains of a woven basket or other type of receptacle, as well as

ceramic fragments (Fig. 2). In the same area three postholes were discovered, which may indicate the presence of a wooden structure, possibly linked to some sort of storage shelf or structure. Clusters of carbonized plant remains were also found in other layers, but in much smaller numbers and are largely isolated cases (*Tresić Pavičić 2020*).

Materials and methods

Twenty-three samples were collected for archaeobotanical analysis during the 2019 excavation (Tab. 2). Four samples were taken from Phase 6, sixteen from Phase 4, two from Phase 3 and one from Phase 2. Soil samples and hand-picked archaeobotanical remains were collected. The samples were taken to the Division of Botany, Department of Biology, University of Zagreb. No flotation was conducted due to the high density of plant material in the soil samples, and instead the samples were dry sieved to allow easy sorting under the microscope (*Radaković 2021*). All samples were 100% sorted, except samples U-130, U-131, U-132 and U-134 (Tab. 2). Due to the high density of the remains, further subsampling was required for samples U-130, U-131, U-132, U-134 and U-135, where the >1mm fraction was fully sorted, but only 1/3 of the <1mm fraction was sorted, including only a 1/3 of the chaff remains (*Radaković 2021.15*). Subsequently, the Supplementary Data contains the multiplied estimates for the plant macroremains identified within these samples and not the actual subsampled counts.

The carbonized plant remains were sorted and identified under a zoom stereo microscope at a magnification of 7–45x with the help of reference literature/seed atlases (*Cappers, Neef 2012*), as well as the modern carpological collection (under establishment) of the Division of Botany. The nomenclature of scientific plant names follows Daniel Zohary and Maria Hopf (*2000*) for cultivars and the Flora Croatica Database (*Nikolić 2018*) for wild plants. Whole grains were counted as one, and two longitudinal fragments and embryos of grains were also counted as one. Glume bases were counted as one, while whole spikelet forks were counted as two glume bases. Cereal remains classed as fragments had to be at least 1/4 of the original grain/seed, and anything smaller was not counted. The fruit and weed seeds were counted as one, even when only a fragment was found, except where large seeds were broken and clearly represented the same parts of the same seed (*e.g., Quercus* sp.).

Results

All 23 samples contained carbonized plant macroremains, totalling approximately 1 179 000 items (see Supplementary Data). Lumps of broomcorn millet (*Panicum miliaceum*) were recovered from U-201 (20ml, Phase 3) and U-137 (20ml, Phase 4) and have been estimated to contain up to 4000 grains per sample (Fig. 3a). Overall, preservation was good, especially the plant remains recovered from quadrant D21. The bulk samples taken from Phase 4 had the highest density of remains that were dominated by lentil (*Lens culinaris*) and free-threshing wheat (*Triticum aestivum/durum*) grains, as well as emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), spelt (*Triticum spelta*) grains and chaff and broomcorn millet. The other phases have generally very low quantities of remains, since the plant remains were handpicked during the excavation. For Phase 2 a few acorn fragments (*Quercus* sp.) were picked out, while four lentil seeds were identified from Phase 3, along with a lump of broomcorn millet grains, approximately 20ml (≈4000 grains). Phase 6 contained mostly broad beans (*Vicia faba*) and a few cereal grains and acorn fragments, totalling no more than 76 items.

The largest quantity of plant remains were from the burnt area identified in quadrant D21 (Fig. 4). Samples U-130, U-131, U-132, U-134 and U-135, in particular, contained a large quantity of cereal grain and chaff (Fig. 3b), as well as pulses, but only a small proportion of wild/weed type taxa (Fig. 5a). The composition of these samples is relatively similar except for U-134, a posthole, which has a higher proportion of broomcorn millet grains and less glume wheat chaff. The proportion of crops within Phase 4 is dominated by lentil and free-threshing wheat, while the remaining crops only represent up to 5% of the assemblage (not including the cereal chaff, Fig. 5b). The diversity of wild/weed type taxa identified is extremely low,

Sample no.	Laboratory number	Type	Phase	Conventional ±30 BP	Calibrated age (cal BC, 95.4% / 2σ hpd range)
7	Beta-533949	Tooth	4	2890	1133–978
140	Beta-533951	Grain	4	2870	1127–931
152	Beta-533952	Charcoal	4	2910	1209–1011
185	Beta-533953	Charcoal	3	2950	1236–1051
228	Beta-533954	Charcoal	2	3090	1427–1277

Tab. 1. Radiocarbon dates from Lower Cerovačka Cave.

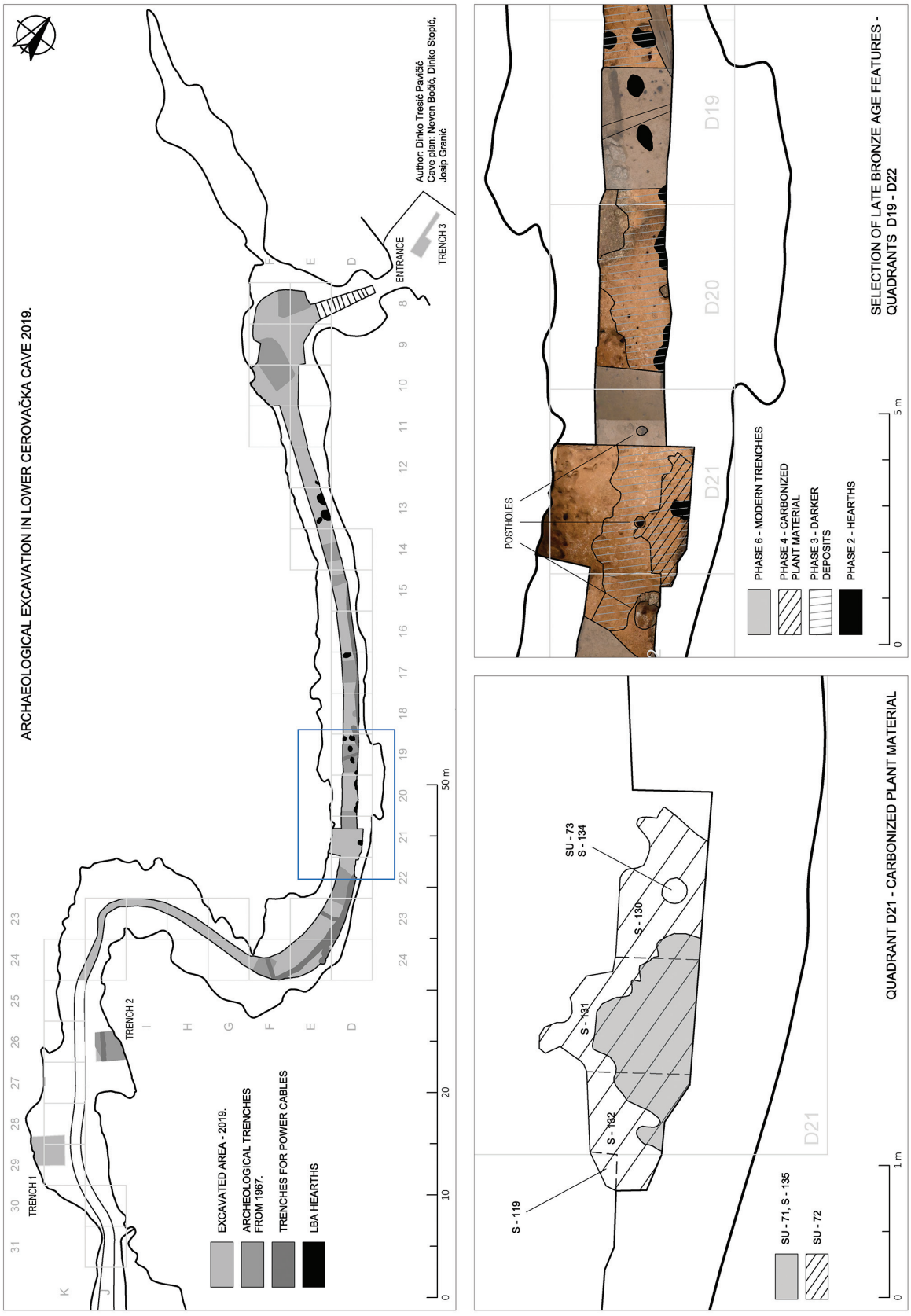

Fig. 2. Plan of the 2019 excavation in Lower Cerovačka Cave, focusing on area D21.

Sample (U)	Stratigraphic unit (SJ)	Quadrant	Phase	Archaeological context	Litres (L)	Litres analysed
192	87	D21	2	Fill	0.01	0.01
201	109	D19	3	Deposit	0.02	0.02
216	132	E13	3	Deposit	0.01	0.01
119	72	D22	4	Deposit	0.01	0.01
130	72	D21	4	Deposit - North	28.7	2
131	72	D21	4	Deposit - Centre	34	2
132	72	D21	4	Deposit - South	19.4	2
134	73	D21	4	Fill - Posthole	1	0.33
135	71	D21	4	Deposit	3.5	3.5
137	72	D21	4	Deposit	0.02	0.02
139	72	D21	4	Deposit	0.01	0.01
148	95	D20	4	Deposit	0.01	0.01
153	97	D20	4	Deposit	0.01	0.01
156	98	D20	4	Deposit	0.01	0.01
159	93	D20	4	Deposit	0.01	0.01
172	104	D21	4	Deposit	0.01	0.01
211	168	E13	4	Hearth	0.07	0.07
246	69	E14	4	Deposit	0.01	0.01
252	200	D16	4	Deposit	0.01	0.01
116	42	D22	6	Fill from 1967 trench	0.01	0.01
117	42	D22	6	Fill from 1967 trench	0.01	0.01
118	42	D22	6	Fill from 1967 trench	0.01	0.01
233	194	D17	6	Fill from 1967 trench	0.01	0.01

Tab. 2. List of archaeobotanical samples from the Lower Cerovačka Cave.

consisting of grasses, mainly *Bromus arvensis* and *B. secalinus*, and cleavers (*Galium aparine* and *G. spurium*), which can all be found as weeds in cereal crops.

Measurements were also taken of emmer, einkorn, spelt and free-threshing wheat, lentil, and broad beans recovered from quadrant D21 (Tab. 3). The size of the wheat and pulses correspond with measurements taken from Late Bronze Age Kalnik-Igrišče; a site located to the north-east of Lower Cerovačka Cave in continental Croatia (*Radaković 2021*).

Discussion

Crop processing

The high density of plant remains in the five samples from quadrant D21 and the clear evidence of burning in and around the deposit indicate that the plant remains were burnt *in-situ*. Unfortunately, the similarities in composition of the plant remains recovered from the different areas in D21 prevent any assumptions about how or where the different crops were stored. Instead, we can look at the level of crop processing that may have occurred before storage. Predictive models have been created to identify which stage of the crop processing sequence an assemblage represents, based on the assumption that each stage produces a characteristically different ratio of cereal, chaff and weeds within the sample (*Hillman 1984; Jones 1984; Van der Veen 1992; Van der Veen, Jones 2006*). Here we can examine the ratio of glume bases to glume wheat grains, as

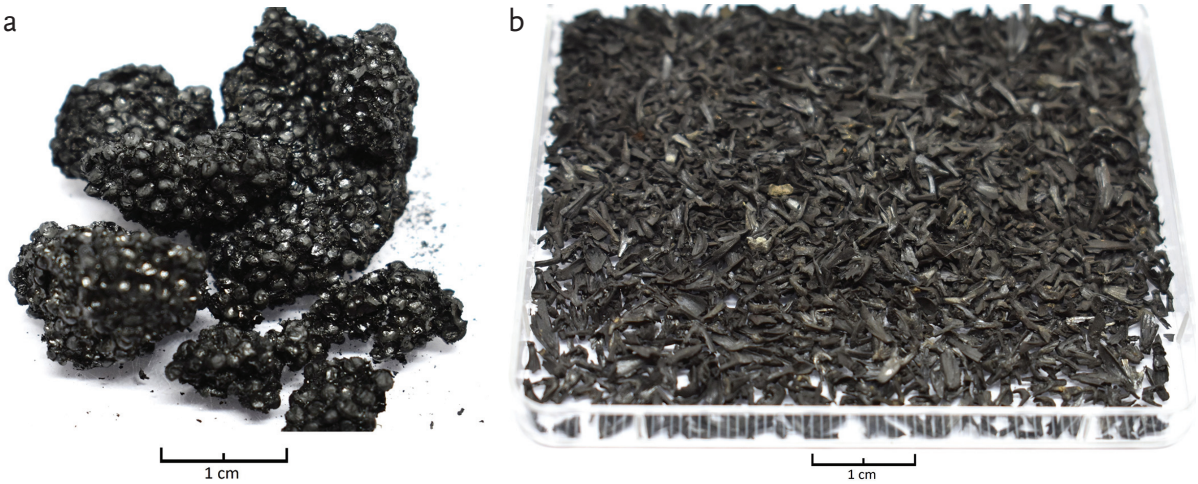

Fig. 3. Carbonized (*a*) lumps of broomcorn millet (*Panicum miliaceum*) from U-134 and (*b*) glume wheat (*Triticum monococcum/dicoccum/spelta*) glume bases from quadrant D21, Lower Cerovačka Cave.

well as the number of weeds to the number of grains to help determine what crop processing has occurred. Unfortunately, the third ratio looking at the number of rachis internodes to grains is not possible, as these were not recovered for the free-threshing wheat or barley. This could be for several reasons, including poor preservation, as experiments have shown a taphonomic bias against chaff, especially under oxidizing conditions and high temperatures (*Boardman, Jones 1990*). However, the most likely reason for the absence of rachis remains is that the free-threshing wheat and barley were already cleaned by the time they reached the cave. This is because both barley and free-threshing wheat grains easily detach from the chaff during the early stages of crop processing (*i.e.* threshing, winnowing and coarse sieving), whereas glume wheats require a further dehusking stage to remove the glumes from the grains (*Van der Veen 1992.81*).



Fig. 4. Image of the layer of carbonized botanical remains recovered from stratigraphic unit 72, quadrant D21.

For emmer and spelt the ear generally contains two grains and two glumes, so the ratio of 2:2 = 1, while einkorn has one grain and two glumes, so the ratio of 1:2 = 0.5. If we apply this to the glume wheats in quadrant D21, we see that nearly every sample has a high to very high ratio of glumes to grain (Fig. 6, based on estimated numbers of remains). This means that there is significantly more chaff than grain in the samples. If we look at the ratio of grains to weed seeds, a ratio of 1:1 = 1, the ratio is extremely low. Of the crop processing stages, this could indicate that the glume wheat grains had been cleaned but not processed through the additional dehusking stages, which would remove the broken spikelet forks (see *Hillman 1984; Jones 1984; Stevens 2003*). Thus, the grains could have still been in their glumes when they reached the cave. Once at the cave, dehusking could have occurred piece meal, as and when grain was required, and the chaff discarded onto the floor of the cave or kept aside for other purposes. Similarly, two different types of storage could have occurred where cleaned grains were stored in containers and the glume bases in another. Cereal by-products could be used for a range of purposes, such as a building material, for fuel, or as fodder for livestock (*Van der Veen 1999; Valamoti, Charles 2005*). Cereal chaff is also used as temper in pottery, as seen at Bronze Age Monkodonia, Istria (*Hellmuth Kramberger 2017.418*), as well as in Eneolithic loom weights found at a Slovenian pile-dwelling sites (*Tolar* et al. *2016*). In Palestine, ethnographic observations noted chaff was laid on top of stored grain before the underground jar-shaped receptacles were sealed with clay (*Turkowski 1969.101–112*). Thus, there could be several reasons to find chaff in this context. Comparing Lower Cerovačka Cave with similar finds of cereal storage at two Late Bronze Age caves in southern France, glume wheat chaff is strongly underrepresented in relation to grains, suggesting that the glume wheats were dehusked before storage (*Bouby* et al. *2005*).

Multi-cropping and mono-cropping

Multi-cropping, or maslins, have been used to describe the growing of more than one crop in a sin-

	Length (mm)	Width (mm)	Thickness (mm)
Triticum aestivum	5.58 (4.66–6.25)	3.59 (3.11–4.08)	2.98 (2.47–3.4)
Triticum dicoccum	6.3 (5.6–7)	3.14 (2.75–3.57)	3.03 (2.64–3.35)
Triticum monococcum	5.97 (4.56–7.42)	2.53 (1.93–2.88)	3.06 (2.35–3.51)
Triticum spelta	6.79 (5.56–7.82)	3.11 (2.45–3.69)	2.42 (2.04–2.85)
Vicia faba	7.31 (5.82–10.37)	5.72 (3.94–8.24)	5.64 (4.36–7.96)
		2r (mm)	
Lens culinaris		3.21 (2.55–3.99)	

Tab. 3. Measurements of free-threshing wheat (*Triticum aestivum*), emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), and spelt (*Triticum spelta*) grains, and broad bead (*Vicia faba*) and lentil (*Lens culinaris*) identified from Quadrant D21 at Lower Cerovačka Cave.

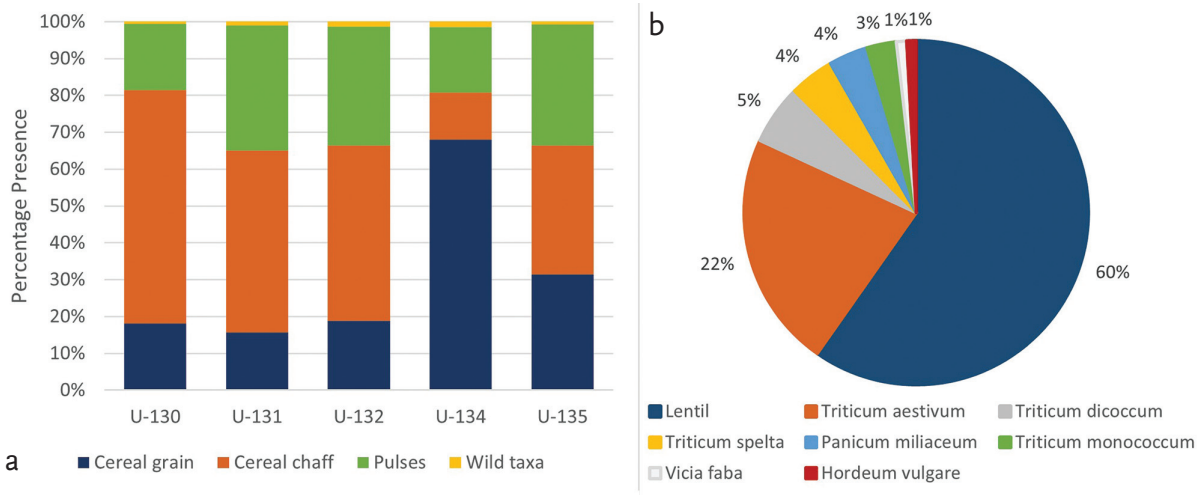

Fig. 5. Composition of the carbonized seed assemblage for (a) each sample in quadrant D21, and (b) the proportion of cereal grains and pulses,excluding cereals chaff, in total from Phase 4, Lower Cerovačka Cave.

gle season on the same land (*Halstead, Jones 1989; Jones, Halstead 1995; Petrie, Bates 2017*). It is suggested that a mixed crop could have been more reliable than a single-grain crop. For example, if the season was colder then rye would flourish, but if the season was hot then wheat would do better. The crops are usually those with similar maturation and/or crop processing stages, but a recent study by Alex C. McAlvay *et al.* (*2022*) highlights other benefits of multi-cropping. This crop practice is distinct from monocropping where only one crop is grown on the same plot for one of more years. Although there are benefits to multi-cropping in terms of reducing risk of total crop failure, what type of grain crop grown would have depended on the local soil and climate, balanced with socio-economic demands.

Where and when multi-cropping may have occurred in the past is debated, and identification in archaeological contexts can be difficult. Marijke Van der Veen (*1995*) compared the relative proportion of grain types and analysed the weed assemblages in relation to growing conditions in different crops to determine that wheat and rye were probably sown together in medieval western Europe. Weed ecology, such as phytosociology, autecology and FIBS (Functional Identification of Botanical Surveys), have been used to understand cropping practices in the past (*e.g., Van der Veen 1992; Stevens 1996; Charles* et al. *1997; Bogaard* et al. *1999; Jones* et al. *2010*). Ethnographic observations by Glynis Jones and Paul Halstead (*1995*) on the Greek island of Amorgos found that sown proportions of up to 80% wheat and 20% barley were considered mixed intercrops by farmers, although this proportion could change depending on the environmental conditions. However, they also highlighted issues of contamination resulting from crops from previous growing cycles becoming incorporated in that season's crop (*Jones, Halstead 1995*). Overall, these methods require the archaeobotanical remains to have enough weeds to study the weed ecologies and be representative of one harvest. However, plant remains that survive in the

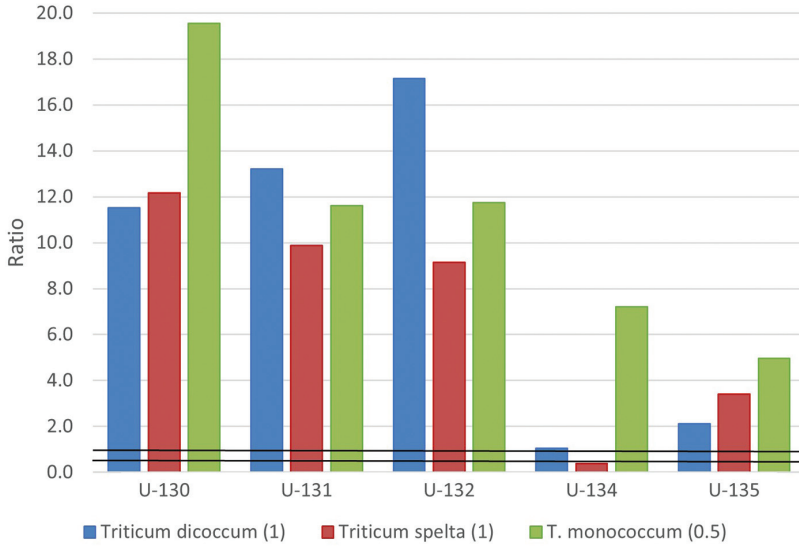

Fig. 6. Ratio between the number of grains and number of glume bases for emmer (Triticum dicoccum), spelt (Triticum spelta) and einkorn (Triticum monococcum) for each sample in area D21, Lower Cerovačka Cave.

archaeological record are typically either discarded waste or accidentally preserved remains, which generally result in contexts where crops from different sources are combined over tens or even hundreds of years, preventing any secure identification of crop husbandry practices (*Jones, Halstead 1995; Van der Veen 2007*).

In prehistoric contexts some suggest that the glume wheats emmer and einkorn were grown as maslins during the Neolithic (*Kreuz 2007*). Einkorn and 'new' glume wheat are also thought to have been cultivated together as a mixed crop during the Neolithic and Bronze Age (*Jones* et al. *2000; Kohler-Schneider 2003*). More recently Rebecca A. Fraser *et al.* (*2013*) examined the stable isotopes of wheat and barley from an LBK storage deposit at Vaihingen in Germany, and found they shared distinctively low $\delta^{13}C$ signatures relative to other samples, suggesting that they grew in similar conditions, possibly in a similar location as a mixed crop.

Whether inter-cropping was practiced by the farmers who used Lower Cerovačka Cave to store their crops is hard to determine. There are very few weeds, which prevents the analyses of weed ecologies. Most cereal remains are free-threshing wheat, with only a very small quantity of barley grains present, far less than 20% if we go with an 80/20 ratio outlined by Jones and Halstead (*1995*). Thus, the presence of barley could simply indicate contamination of the free-threshing wheat crop, maybe from a previous harvest, or could be remnants of a previously stored crop. The glume wheats, emmer, einkorn and spelt are found in smaller quantities, and again it is unclear from the context whether they were grown together. Instead, they could represent smaller harvests or remnants of previously stored crops.

Storage location and containers

The utility of each type of storage depends on perishability and distribution, the predictability and duration of lean periods, as well as the settlement patterns and social ethos of the society (*Testart 1982*). A huge range of food-keeping practices have therefore evolved. Ethnography, historical documents, and imagery highlight a wide range of storage facilities, such as caves, pits, built silos, cellars, and barns, a variety of accompanying equipment used, such as bins, baskets, barrels, sacks, suspension hooks, jars or chests, as well as different preservation methods, such as drying, parboiling, fermenting, *etc.* (*e.g., Peña-Chocarro* et al. *2015*). For cereals and legumes, controlling the humidity is the most important part of maintaining the nutrient quality and usability of the crop (*Păun* et al. *2021*). Before storage, grain must be dry (*i.e.* have a low moisture content) to minimize infestation by insects and microorganisms (bacteria, fungi, *etc.*), and to prevent germination (*Rajendran 2003*). The main objective of storage systems is to therefore preserve food for an extended period with minimal loss.

The recovery of cleaned cereals and pulses in Lower Cerovačka Cave, along with other contextual evidence, suggests that the remains represent stored crops. The cave itself would have had its own micro-climate, though it is uncertain what the conditions would have been in the Bronze Age. Today the dark well-ventilated cave, with low but fluctuating temperatures, could make a practical storage location (*Tresić Pavičić 2020*). Yet the cave has a very high humidity (around 90%), which could cause significant spoilage of the crop, activating sprouting in the surface layer of a store, as well as encouraging contamination by micro-organisms, especially mould. This was noted at Baume Layrou, a Late Bronze Age cave situated in southern France, where the high humidity in the cave was thought to have caused germination in the stored grain (*Bouby* et al. *2005*). Yet in Anatolia, caverns in tuffs have been used for food storage in the past and are still regularly used today for wine and to extend the shelf life of fruits and vegetables. The caves maintain a relatively constant temperature of around 13°C, with good airflow, and humidity can be as high as 80% in places, although it's suggested that the tuff rock holds dehumidifying properties making them ideal caves for short-term food storage (*Emir, Daloğlu 2012; Aydan, Ulusay 2013*). Experiments also show that at low temperatures moisture changes in wheat occur relatively slowly, compared to those stored at higher temperatures (*Pixton, Griffiths 1971*).

At Lower Cerovačka Cave germinated grains were not identified. This may suggest that the crops were not stored for long periods within the cave, or that these specific grains had not been in the cave for enough time to allow germination before they were carbonized. Storing grain in their chaff is also suggested to be a way of protecting glume wheat grains and could have helped preserve the glume wheats discovered in Lower Cerovačka Cave (*e.g., Meurers-Balke, Lüning 1992*). As Laurent Bouby *et al.* (*2005*) conclude, the conditions within the cave probably suggest occasional short-term storage, possibly

through periods of insecurity. They suggest that both caves in southern France are characteristic of refuge caves; being difficult to access, have hidden entrances and lack light. These characteristics are also shared with Lower Cerovačka Cave.

One of the main problems with understanding storage practices in prehistory lies in finding direct evidence of storage, especially if more perishable items such as woven baskets are used, as well as identifying what exactly was being stored. At Lower Cerovačka Cave fragments of ceramic vessels and thin carbonized strips of vegetal material were found within quadrant D21, which could suggest the presence of some sort of wicker basket (Figs. 7 and 8). The carbonized strips have not been identified yet, so it is unclear what type of plant could have been used. Braided plant fibres and basketry are rarely found in archaeological contexts, and mostly in waterlogged contexts, so it is unclear the extent to which these were used in prehistory. The discovery of post holes at Lower Cerovačka Cave could also suggest the presence of a wooden structure, or shelf, that could have stored items off the ground. Several methods of storage could thus have been used within the cave that could have allowed short- to long-term storage, under the right conditions.

Baskets and textiles are both the result of the intentional weaving of fibres. The terms 'basket' and 'textile' are often definitionally separated, perhaps somewhat arbitrarily, by both end-use and construction technique. Baskets generally serve as vessels or other containers or as mats for sitting and sleeping on, floor coverings, in the construction of mud-brick architecture, and as burial shrouds and grave liners. Textiles, which are made from softer and more pliable fibres, are used for clothing, bed linens, and to create soft bags or other containers that need to have more flexibility than a basket. A large variety of fibres are used in weaving textiles and baskets, including bast fibres from plants and trees as well as hair and wool. Textile fibres generally receive more pre-treatment than the fibres used in basket making. Baskets are created from plant fibres that are generally thicker and more resilient than textile fibres, and they are often treated with splitting, heating, dying, bending, and bundling. Moreover, baskets are never woven on a loom and generally have a different end-use than textiles (*Adovasio 1977.1; Crowfoot 1954. 414; Wendrich 1999.31–35*). Tools such as awls and needles are often used in the construction of a basket, and thread or cordage may be used to create a more secure weave or to fasten the end of the weaving bundle or the baskets edge. The techniques of basket making are generally classified into three weave types: twining, coiling, and plaiting. Within each of these three classes are many sub-classes; all are mutually exclusive based on technique or "*features of manufacture*" (*Adovasio 1977.1; Wendrich 1999.41–42*).

The archaeological visibility of storage methods and stored goods varies widely, making it difficult to determine the character, organization and importance of storage within a specific context. For the prehistoric Balkans a range of different storage methods have been identified, but usually from indirect evidence, such as the discovery of large vessels, clay bins or subterranean features, and are usually interpreted from ethnographic analogies (*Filipović* et al. *2018; Papaefthymiou-Papanthimou* et al. *2013*). Observations on construction techniques and methods and materials used for lining and sealing stored crops highlight the wide range of practices that can be used (*e.g., Mobolade* et al. *2019; Peña-Chocarro* et al. *2015*). When storing crops, especially cereals, it is important to keep both moisture and temperature levels low if the items are to be stored succes-



Fig. 7. Thin carbonized strips of vegetal material, possibly from a wicker basket, found within carbonized botanical remains in quadrant D21 Lower Cerovačka Cave.



Fig. 8. Image of the carbonized vegetal material, possibly from a wicker basket, found in quadrant D21 Lower Cerovačka Cave.

sfully for long periods (*e.g., Reynolds 1979; Currid, Navon 1989*). Grain aeration is a technique that is still used today to improve the storability of grain by maintaining a cool, uniform temperature throughout the storage. However, this only works if the aerated air has a relative humidity below the grain's moisture content, otherwise the grain would still slowly absorb water from the air (*Jones, Hardin 2017*). Sealed, airtight, storage is an alternative method to control moisture, and various methods have been observed where things like dung, clay and straw have been used to help seal containers or pits to keep moisture levels low (*e.g., Singh* et al. *2017*). In Syria, clay lined baskets have been observed, as well as sacks and wooden silos (*Al-Azem 1992*). While in Palestine *burgur* and *frikkeh* were seen stored in cloth sacks or in lined straw baskets with some form of protective cover (*Turkowski 1969*).

Lower Cerovačka Cave in Bronze Age Croatia

The discovery of such a large archaeobotanical collection at Lower Cerovačka Cave is unique in Dalmatia and Croatia as a whole. Although Bronze Age material culture has been identified at several cave sites along the Dalmatian coast, only one other site has so far produced botanical remains. Grapčeva špilja, a cave on the island of Hvar in Croatia, yielded only a few plant remains from early and middle Bronze Age occupation horizons, including a few wheat grains (*Triticum* sp.) and acorns (*Quercus* sp.; *Borojević* et al. *2008*). The cave is thought to have had ritual connotations, but the botanical data is inconclusive and could simply suggest transient occupation. Burials in caves are also seen. A recent study at the Middle/Late Bronze Age (1430–1290 BCE) Bezdanjača Cave, located slightly inland in the Lika region of Croatia, identified notable quantities of C4 plant consumption, most likely millet, in 16 individuals (*Martinoia* et al. *2021*). At Pupićina Cave, located in NE Istria, evidence suggests the use of the site periodically by herders as well as for other, as yet unknown activities from the Neolithic through the Iron Age, though a hiatus is noted from the Late Neolithic to middle Bronze Age (*Miracle, Forenbaher 2005*). The use of caves as animal stabling is also suggested for four caves in the Trieste Karst, north-eastern Italy (*Boschian, Montagnari-Kokelj 2020*). Caves were thus utilized in different ways along the Adriatic coast.

At present only 17 sites have published archaeobotanical evidence from Croatia as a whole, and the quality and quantity vary greatly (*Reed* et al. *2022a*). Along the coast, we see a very limited repertoire of remains, with only the settlement at Monkodonja providing any clear evidence of crop cultivation, including emmer (*Triticum dicoccum*), barley (*Hordeum vulgare*) and grape pips (*Vitis vinifera*). In continental Croatia, the Late Bronze Age site of Kalnik-Igrišče revealed thousands of plant remains within a burnt down house, with broomcorn millet, barley, free-threshing wheat (*Triticum aestivum*) and broad bean predominating (*Marekovi*ć et al. *2015; Reed* et al. *2021*). Broomcorn millet, barley and free-threshing wheat are also frequently found at other sites in the region by the Late Bronze Age (*Reed* et al. *2002a*). Recent research on the introduction and adoption of millet has shown its arrival into Croatia by the middle Bronze Age (*Filipović* et al. *2020; Reed* et al. *2022b*), but it is not until the Late Bronze Age that we see clear evidence of its cultivation as a crop within the Croatian assemblage. Overall, the range of taxa identified from Lower Cerovačka Cave fits well with what is already known about Late Bronze Age agriculture in Croatia.

What is absent at Lower Cerovačka Cave is evidence of the collection of fruits and nuts, such as cornelian cherry (*Cornus mas*) and Chinese lantern (*Physalis alkekengi*), from the local environment, which we commonly see at settlement sites during this period in Croatia. We do find a few remains of acorns, although these are largely present in Phases 2 and 6, with only one fragment found in Phase 4. There

are many species of acorn, both sweet and bitter and unfortunately here we have not been able to identify to species. Acorns are nutritionally comparable to cereals, being a good source of carbohydrates, fats, proteins, and vitamins, mostly A and C, and have been consumed in the form of bread, soups, porridge, or even as herbal coffee throughout history (*Sekeroglu* et al. *2017*). Acorns have been found at other Bronze Age sites, including Kalnik-Igrišče (*Mareković* et al. *2015*), but it is unclear whether the few acorns recovered here represent deliberate collection.

Conclusion

At Lower Cerovačka Cave the unique discovery of a large quantity of burnt plant remains dating to the Late Bronze Age indicate crop storage in the cave. Significant mixing of the crops prevents any assumptions about how or where the different crops were stored. Yet the significant quantity of remains indicate the storage of lentil (*Lens culinaris*) and free-threshing wheat (*Triticum aestivum/durum*), as well as emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*), spelt (*Triticum spelta*) and broomcorn millet (*Panicum miliaceum*). The large quantity of glume wheat glume bases could also suggest a multifunctional space where glume wheats were also processed, or alternatively the separate storage of chaff for other purposes. Whether the cave was used for short- or long-term storage is debatable, as the high humidity could cause crop spoilage. At the Late Bronze Age caves in southern France, it was concluded that the caves were used for short-term storage, owing to the high humidity, and that people took shelter in these 'refuge caves' during disturbed times (*Bouby* et al. *2005*). However, if air-tight storage is used then crops can be stored for longer. At Lower Cerovačka Cave possible evidence of woven containers is present, but it is unclear whether these were sealed or simply used to contain each of the crops separately. The large quantity of other materials found within Phase 4, such as bronze dress ornaments and jewellery, and the short date range (*c.* 940–960 BC), could indicate a period of instability.

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Hermetic cereal storage in the Bronze Age: evidence from the Gáva culture settlement at Rotbav, Transylvania

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ABSTRACT – *The present paper explores the possibility to better understand the function of pits through phytolith and starch analysis. A case study from the Late Bronze Age/Early Iron Age settlement phase of Rotbav in southeastern Transylvania is discussed in detail. It appears that a large storage vessel originally sealed with a bowl was kept in a pit filled with chaff or straw to preserve its contents.*

KEY WORDS – *Bronze Age; Transylvania; food storage; phytoliths*

Hermetično skladiščenje žit v bronasti dobi: dokazi iz najdišča kulture Gáva v Rotbavu v Transilvaniji

IZVLEČEK – *V članku raziskujemo možnost za boljše razumevanje namembnosti jam na podlagi analiz fitolitov in škroba. Obravnavamo študijski primer iz pozno bronasto- in starejše železnodobne faze naselbine Rotbav v severovzhodni Transilvaniji. Gre za večjo shrambeno posodo, ki je bila pokrita s skledo in bila postavljena v jamo, zapolnjeno s plevami ali slamo, z namenom konserviranja vsebine.*

KLJUČNE BESEDE – *bronasta doba; Transilvanija; shranjevanje hrane; fitoliti*

Introduction

Several methods have traditionally been employed to keep humidity, oxygen, and insects away from field crops in order to preserve them, with airtight sealed containers, along with pits lined with straw or chaff, being among the most common (*Reynolds 1974; Sigaut 1980; 1988; Fairbairn, Omura 2005, Villers* et al. *2006; Diffey* et al. *2017; Urem-Kotsou 2017*). However, it is difficult to find evidence for such techniques in the archaeological record, particularly regarding regions with earthen architecture and in the absence of carbonized cereals (*Monah 2002; Marinova, Valamoti 2014; Hrisrova* et al. *2017; Valamoti* et al. *2019* for an overview of such evidence from southeastern Europe). So far, the identification of grain storage has mostly been based on the identification of characteristic archaeological features (*Sigaut 1988; Fairbairn, Omura 2005* with references). This approach may to some degree be hindered by the frequent and complex reuse of storage pit features (*Ivanova* et al. *2020*). This pilot study sets out to highlight a pit type that with a high probability is connected to a specific cereal storage technique and a methodology that allows its identification by phytolith and starch analysis. Our case study comes from the Bronze Age/Early Iron Age settlement of Rotbav in Transylvania, a region and time for which so far only scarce macrobotanical evidence exists (*Cârciumaru 1996; Ciută 2012; Ciută, Bejinariu 2012; 2019; Ciută, Molnár 2014* with references).

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The Gáva culture settlement of Rotbav

The archaeological site of Rotbav-La Pârâuţ is situated upon a high terrace formation above the River Olt in southeastern Transylvania at 498 m.a.s.l (Fig. 1; 45°83'N/25°56'E). The plateau is delimited by the Valea Cetăţii stream to the north and a steep hill to the west (Fig. 2); to the east, the Josephinian survey shows a swampy area with an arm of the River Olt. This landscape was heavily transformed by the creation of two lakes to the north of the site in the 1970s, and today the Olt flows at a distance of roughly 500m to the east of the site. The form of the plateau was not affected, but the site has been and still is used for cultivation, the plough horizon reaching a thickness of approximately 40cm.

The settlement has a size of around 4ha, of which 1800m² were excavated, and the site was additionally investigated by archaeological and geophysical surveys. Rotbav-La Pârâuţ is thus the most extensively researched site of this period in the region so far, and has been comprehensively published (*Dietrich 2014a*). Its importance lies in a long stratigraphy comprising the timespan from the Middle Bronze Age (in Romanian terminology) to the Bronze Age/ Iron Age transition, being inhabited roughly between 1900/1800 BC and 1200/ 1100 BC, following radiocarbon data (*Dietrich 2014b*). The stratigraphic sequence covers six distinct building phases. The first three belong to the early Middle Bronze Age Wietenberg culture, followed by two of the Late Bronze Age Noua culture. The last building phase belongs to the Gáva culture, which marks the Bronze Age/ Iron Age transition (*Dietrich 2012*). The pottery from Rotbav (*Dietrich 2012; 2014a. 211–214*) places the Gáva settlement into a developed phase of the culture, described by Marian Gumă as horizon Mahala IV-Somotor II-Mediaş I-II-Teleac II and dated to Ha B (*Gumă 1993.190; cf. Ciugudean 2009; 2011*).

The remains of the Gáva settlement phase were not present in all sections excavated at Rotbav, likely due to erosion and ploughing, but they could be excavated on an area of 1372m² (*Dietrich 2014a. 214–217*). This allowed us insights into the settlement structure, which is characterized by large, regularly dispersed, partly subterranean constructions (Fig. 2). Fireplaces and pit features are located between these buildings. The cultural layer was situated immediately below the plough horizon and had a thickness of approximately 15cm, although likely it was originally much thicker. A total of four semi-subterranean houses could be partially excavated in the main area of the settlement, situated at distances of four to 15m from each other. Postholes and burnt loam with impressions of wickerwork hint at the superstructures, although the entrances or inner divisions of houses could not be identified. Near the houses, concentrations of pottery and other artefacts suggest that activity areas and pits were regularly associated with the dwellings. Most pits were filled with domestic refuse or settlement debris (*Dietrich 2014a* for an extensive presentation of the features), and thus their original functions could not be determined with security. However, one, labelled feature 4/2008, stood out because of its contents – two nearly complete vessels, making an in situ use context highly likely.

Pit feature 4/2008

Feature 4/2008 was located approximately 5m to the south of one of the houses (structure 10, Figs. 2–3) and next to the remains of a fireplace (feature 2/ 2008, Fig. 2) destroyed by ploughing. It first showed as an oval-rounded yellowish spot of *c.* 110cm maximal diameter. The pit filling proved to be very homogenous loamy fine sand. Pottery fragments and burnt loam were observed only in its uppermost part, roughly within the first 10cm. The maxi-

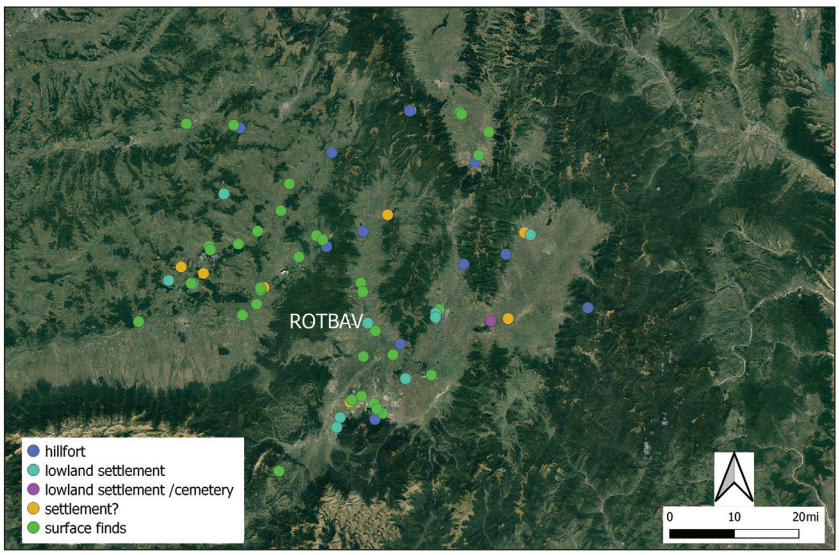

Fig. 1. Gáva finds in southeastern Transylvania and location of the settlement of Rotbav (findspots after* Dietrich 2014a.322–332*; base map Google Satellite, https://mt1.google.com/vt/lyrs=s&x={x}&y={y}&z={z}).

mum depth of the feature was 54cm, a part of the pit likely being destroyed by the plough. After removal of 10cm of sediment, finds became scarce, but the rims of two large vessels became visible. One was a large, bag-shaped vessel decorated with four knobs at the shoulder and a rim drawn towards the exterior (Fig. 3a). The vessel, of which all fragments could be recovered, has a height of 42.7cm, a maximal diameter of 47.6cm and a rim diameter of 35cm. The measurements and formal characteristics – a wide stable bottom and large mouth to enable users to reach the contents – speak in favour of a storage vessel. The second vessel is a so-called 'Zipfelschüssel', a bowl that originally had four pronounced lobes, fluted in the interior (Fig. 3b). This vessel was found broken in several fragments, but unlike the first one not all fragments were present in the pit. The preserved smallest width of the vessel is 41.8cm, and thus it could have served well as a lid for the larger vessel even in a damaged condition.

The sediments from the pit and the inside of the vessel were separated, sieved through a 1mm mesh and flotated. This produced a number of small bone fragments and <1g of charred wood from the pit fill-

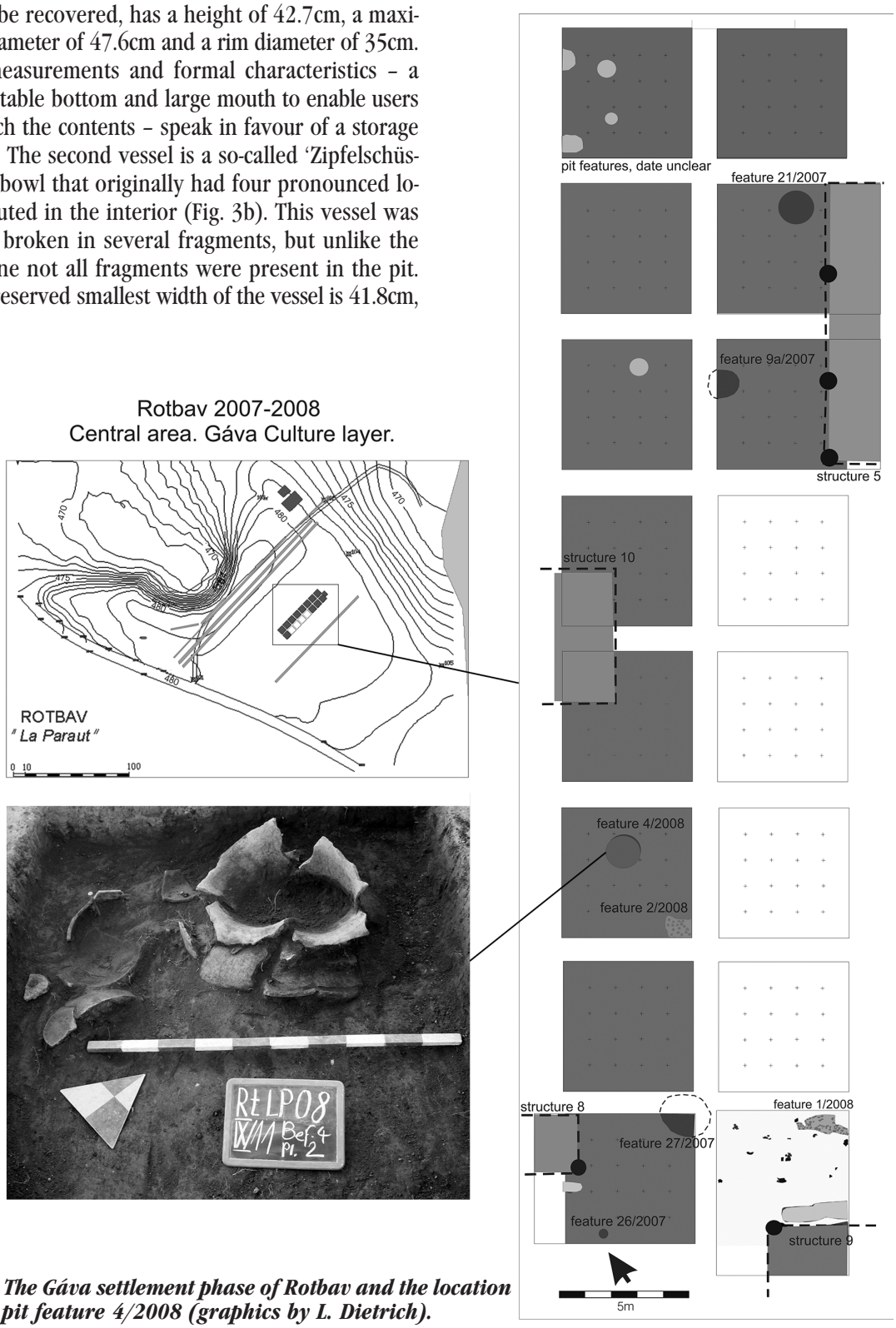

Fig. 2. The Gáva settlement phase of Rotbav and the location of the pit feature 4/2008 (graphics by L. Dietrich).

ing, but no other charred plant macroremains. As charred grains and plant remains were recovered from other contexts at Rotbav (*cf. Dietrich 2014a. Anhang 6*), this is not due to preservation conditions. The vessel contents were completely decayed, or the vessel had been emptied (which could be indicated by the position of the lid besides the large vessel). No food crusts were observed on either vessels' inner surface. However, neither of the two vessels had been placed on the bottom of the pit, indicating that the latter had been filled with some kind of material that held the vessels in place (Figs. 4–5). We suspected that the vessels could have been originally placed in chaff or straw. Accordingly, four sediment samples were taken to check this hypothesis.

Phytolith evidence

Phytolith analyses were conducted on the four soil samples (Tabs. 1–2). RT08-1 is from the upper part of the pit, RT08-2 from inside the pit next to the vessels, RT08-4 is from inside the vessel and RT08-3 from the cultural layer outside the pit (sample locations are marked in Fig. 4).

Phytolith extraction of the samples followed the procedures outlined by Rosa Maria Albert *et al.* (*1999*). To remove carbonates, phosphates, and organic material, approximately 1g of the air-dried sediment was treated with 3 N HCl, 3 N HNO_3, and H_2O_2. The mineral components of the samples were separated according to their densities using 2.4g/ml sodium polytungstate solution [Na_6 ($H_2W_{12}O_{40}$) H_2O]. Slides were prepared by weighing out about 1mg of sediment onto a microscope slide, mounting with Entellan New (Merck). The counting of about 1300 phytoliths per sample was performed using a KERN OBE-114 microscope at 400x magnification. Unidentifiable phytoliths were counted and recorded as weathered morphotypes. To allow quantitative comparisons between the samples, phytolith numbers per gram of sediment were estimated by relating phytolith amounts and weights of the processed sample material to the initial sample weights. Morphological identification of phytoliths was based on standard literature (*e.g., Twiss* et al. *1969; Brown 1984; Mulholland, Rapp Jr. 1992; Piperno 2006*), as well as on modern plant reference collections (*Albert 2000; Albert, Weiner 2001; Tsartsidou* et al. *2007; Albert* et al. *2011; Portillo* et al. *2014*). The International Code for Phytolith Nomenclature was followed where possible (*Madella* et al. *2005*).

Phytoliths were abundant in all four soil samples examined, ranging from 1.1 to 4.0 million phytoliths per gram of sediment (Fig. 6a; Tab. 1). The highest concentrations were observed in samples RT08-2 and RT08-4, while the lowest concentration was observed for sample RT08-3. Phytolith preservation is generally poor, as evidenced by high proportions of weathered phytoliths (mean=21.4%, σ=1.5%, n=4; Tab.1) and the absence of multicellular phytoliths, likely in association with a varied range of depositional and post-depositional processes (*Alexandre* et al. *1997; Cabanes* et al. *2011; Madella, Lancelotti 2012*).

The morphological analyses show that all samples are similar in their morphotype assemblages (Tab. 1). Grass phytoliths, occurring at a rate of about 56.5% (σ=0.6%, n=4), were the most common group identified. According to their short cell morphologies, grasses belong mostly to the C3 *Pooideae* subfamily that include common cereals, such as wheat and barley. However, the absence of multicellular phytoliths in the samples did not allow for identifying the type of grasses and cereals. Grass short cells, commonly produced in leafs, stems and inflorescences, were abundant in all samples, averaging 40.4% (σ=1.8%, n=4). Epidermal cells from grass leaves and stems, including, for instance, prickles and bulliform cells, show similar values with an average amount of *c.* 40.3% (σ=2.1%, n=4). Additio-

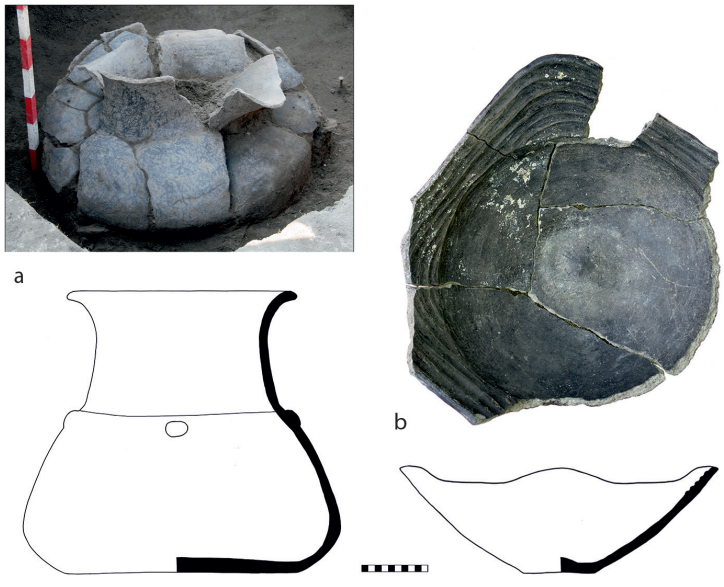

Fig. 3. The two vessels from pit feature 4/2008 (photos/drawings by O. Dietrich).

Sample ID, description of sample location and phytolith amounts			Relative abundances of phytoliths					Anatomical origin of grass phytoliths		
Sample ID	Number of phyt. per 1g of sediment	Layer/areal/ description	Grass phyt. (%)	Dicotyledonous leaves (%)	Dicotyledonous wood/bark (%)	Other phyt. (%)	Weathered morpho types (%)	Leaves and stems (%)	Short Cells (%) Inflorescence	phyt. (%)
RT08-1/MD 5309	2 675 000	inside pit, upper part	56.80	4.18	15.23	0.85	22.95	37.24	42.78	19.98
RT08-2/MD 5310	3 972 000	inside pit next to vessels	56.47	6.38	16.90	0.58	19.66	41.06	38.69	20.25
RT08-3/MD 5311	1 138 000	cultural layer outside pit	55.72	6.97	16.18	0.53	20.60	40.92	39.34	19.75
RT08-4/MD vessel	3 617 500	inside large vessel	57.08	6.27	14.03	0.20	22.42	42.07	40.82	17.11

Tab. 1. Description of samples, phytolith amounts, relative abundances of phytoliths and anatomical origin of grass phytoliths obtained from all sediment samples.

nally, grass phytoliths derived from their floral parts (*e.g.*, decorated elongate dendritic and elongate echinate cells) account for 19.3% on average (σ=1.5%, n=4).

Dicotyledonous phytoliths occur at an average rate of 21.5% (σ=2.0, n=4; Tab. 1). Parallelepipedal blocky phytoliths, for instance, one of the most common wood/bark morphotypes, account for 12.5% (σ= 1.7%, n=4) on average. Other diagnostic dicotyledonous morphotypes such as globulars, polyhedrals or jigsaw-shaped phytoliths were not observed.

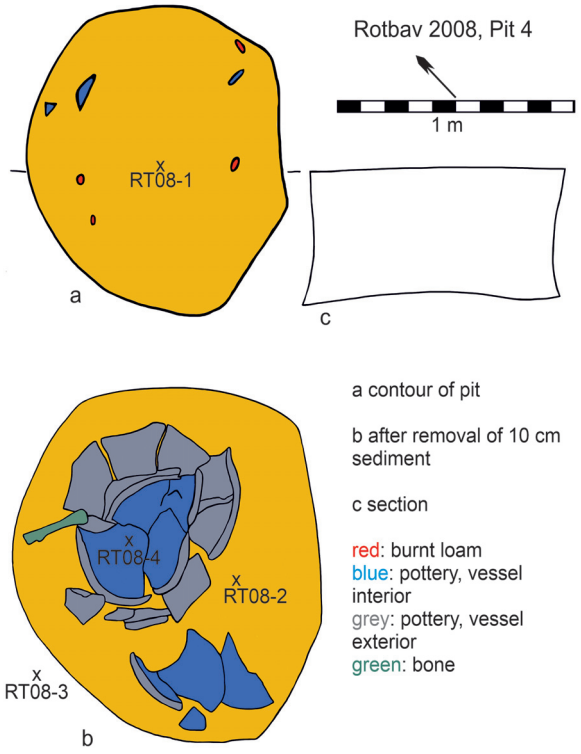

Fig. 4. Pit feature 4/2008.* a *planum view,* b *after removal of 10cm of sediment,* c *section of the pit (drawings made by O. Dietrich).

Starch analysis

To confirm the original presence of cereals within the large vessel, five subsamples from sample RT08-4 (inside of the vessel) and the control sample RT08-3 (cultural layer outside of the pit) were subjected to microscopic analysis in order to identify possibly preserved starch granules. Sample preparation/microfossil extraction followed the protocol established by Li Liu *et al.* (*2018*) with a few modifications. The sediment was mechanically crushed and homogenized. One mg of sediment was put into 1.5ml test tubes, dispersed in distilled water and centrifuged for 5 minutes. Microfossil extraction then followed two procedures: (a) EDTA dispersion; after centrifuge the supernatant was decanted, 0.4ml of EDTA solution was added to each tube. The tubes were left for 2 hours and vortexed each 10 minutes for 30 seconds to disperse the sediment, then filled with distilled water and centrifuged for 5 minutes at 3000 rpm, and the supernatant was decanted. (b) Heavy liquid separation; 0.4ml of SPT at a specific gravity of 2.35 was added to each tube. The tubes were then centrifuged for 15 minutes at 3000rpm. The top layer of organics was removed from each tube by a new pipette and then transferred into a new tube. Distilled water was added, and the samples centrifuged for 5 minutes at 3000 rpm to concentrate the starch at the bottom of the tube, and the supernatant was decanted. The process was repeated two more times.

The samples were mounted in 50% glycerol and 50% distilled water on glass slides and analysed with polarizing filters at x400 for starch with a Bresser Polarisation microscope. Photos were taken with a Bresser Microcam of 12 MP for each slide. The reference collection for starch granule types established by Gismondi *et al.* (*2019*) was used for com-

Phytolith morphotype	RT08-1/ MD 5309 inside pit, upper part	RT08-2/ MD 5310 inside pit next to vessel	RT08-3/ MD 5311 cultural layer outside pit	RT08-4/ MD Vessel inside large vessel
Bulliform	3	7	4	2
Cillindroid psilate	84	121	85	112
Cillindroid scabrate	33	51	45	49
Hair cell	33	65	60	70
Papillae cell	21	22	17	19
Hair cell (prickle)	22	29	32	21
Elongate dendritic	15	20	23	20
Elongate echinate	45	53	44	55
Elongate polylobate	20	24	14	15
Elongate wavy	16	16	15	16
Elongate verrucate	6	8	4	9
Elongate crenate	5	4	2	2
Elongate ruminate	3	5	1	2
Elongate granulate	0	2	3	4
Elongate spilate	3	0	0	3
Elongate corniculate	0	3	2	0
Parallelepipedal blocky psilate square ends	60	86	60	72
Parallelepipedal blocky psilate rounded ends	28	44	29	16
Parallelepipedal blocky scabrate square ends	30	47	31	30
Parallelepipedal blocky scabrate rounded ends	20	11	10	19
Parallelepipedal blocky psilate irregular	11	9	9	8
Parallelepipedal blocky scabrate irregular	3	0	6	6
Parallelepipedal elongate psilate	12	8	17	22
Parallelepipedal elongate scabrate	7	8	13	9
Parallelepipedal elongate facetated	0	0	0	0
Parallelepipedal thin psilate rounded ends	6	11	10	16
Parallelepipedal thin psilate square ends	73	79	55	131
Parallelepipedal thin scabrate rounded ends	0	2	5	4
Parallelepipedal thin scabrate square ends	17	18	21	38
Short cell rondel	187	213	171	226
Short cell tall rondel	2	0	3	5
Short cell trapeziform	68	67	56	95
Short cell saddle	10	8	6	3
Short cell bilobate	19	18	15	15
Short cell cross	11	2	4	5
Trapeziform sinuate	21	25	13	22
Trapeziform polylobate	8	14	13	6
Cylindric sulcate tracheid	8	3	4	5
Weathered morphotype	271	270	234	333
Total number of counted morphotypes per sample	**1181**	**1373**	**1136**	**1485**

Tab. 2. List of phytolith morphotypes identified and their frequencies (counts) in soil samples and a pottery vessel from Rotbav, giving the stratigraphic location and sample information.

parison. Starch preservation was overall bad, and well preserved granules were only observed in three subsamples of RT08-4. These allow a tentative determination as *Triticum aestivum* (common wheat, *cf.* Fig. 6b and *Gismondi* et al. *2019.nr. 30a-b*). *Triticum aestivum* is not among the species identified for the Wietenberg culture layers at Rotbav, from which macrorests of *Triticum monococcum*, *Triticum* sp. and *Hordeum* sp. have been recovered (*Dietrich 2014a.Anhang 6*). For the Noua culture, evidence is lacking so far.

Discussion

Phytolith analysis reveals that two samples have particularly high phytolith concentrations. Sample RT08-2 was taken inside the pit, next to the two pottery vessels, RT08-4 is from the inside of the large bag-shaped vessel. Another sample, RT08-1, was taken inside the pit filling, but in a stratigraphical position above the two vessels. Here, the phytolith concentration is considerably lower. The lowest value comes from sample RT08-3 which represents a

control sample from the cultural layer next to the pit. The phytoliths stem mostly from the C3 Pooid subfamily and come largely from stems and leaves. Both concentrations and origin of the phytoliths fit the hypothesis of a pit filled with chaff or straw to protect the contents of the vessel. Starch analyses indicate that the vessel contained cereals, likely *Triticum aestivum*.

In addition to being covered with the bowl (fragment), the vessel could have been sealed airtight with clay. As the upper part of the pit was absent, the possibility that also the pit was sealed in that way cannot be excluded. Sealing in an airtight container would have reduced moisture and kept insects or mice away, conserving the grains for several years (*Diffey* et al. *2017.1–3*). The capacity of the vessel at Rotbav may indicate that it was used to store a part of the provisions for the winter or seed grains. The find context with the bowl next to the large vessel and the vessel itself filled with straw (phytoliths do not form in grains, starch being scarce) makes it highly possible that the vessel was emptied and then left there (damaged during retrieval?) while the straw/chaff decayed and the pit in its upper part was slowly refilled with sediments. Originally there could have been more such vessels stored in the pit.

Phytolith or starch analyses have so far not been published for Gáva sites. Organic remains have only sparsely been reported from contexts of the Gáva culture or the Early Iron Age in general. From Şimleu Silvaniei – 'Observator' foxtail millet (*Setaria italica*), and two wheat species (*Triticum monococcum* and *Triticum dicoccum*) are mentioned (*Ciută, Bejinariu 2019*). Beatrice Ciută and Ioan Bejinariu recently collected the evidence published to date of other finds of cereals from Early Iron Age contexts, and their list contains three more sites (Teleac: *Triticum durum* and *Hordeum vulgare* from a grave; Bernadea: millet; Tăşad: mostly *Triticum aestivum*, but also *Triticum monococcum, Triticum dicoccum, Triticum spelta,* and *Panicum miliaceum; Ciută, Bejinariu 2019.47*). Rotbav now adds to this list, although any sensible discussion of Early Iron Age cereal use still needs much more data.

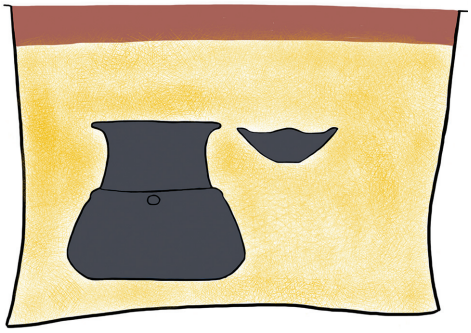

Fig. 5. Tentative reconstruction of the pit feature with two vessels embedded in straw and the pit sealed by clay (drawing by O. Dietrich).

Summing up, our case study proves that combined phytolith and starch analysis are an interesting (and not overly costly) approach to determine the probable use of prehistoric pits in the absence of preserved macrorests.

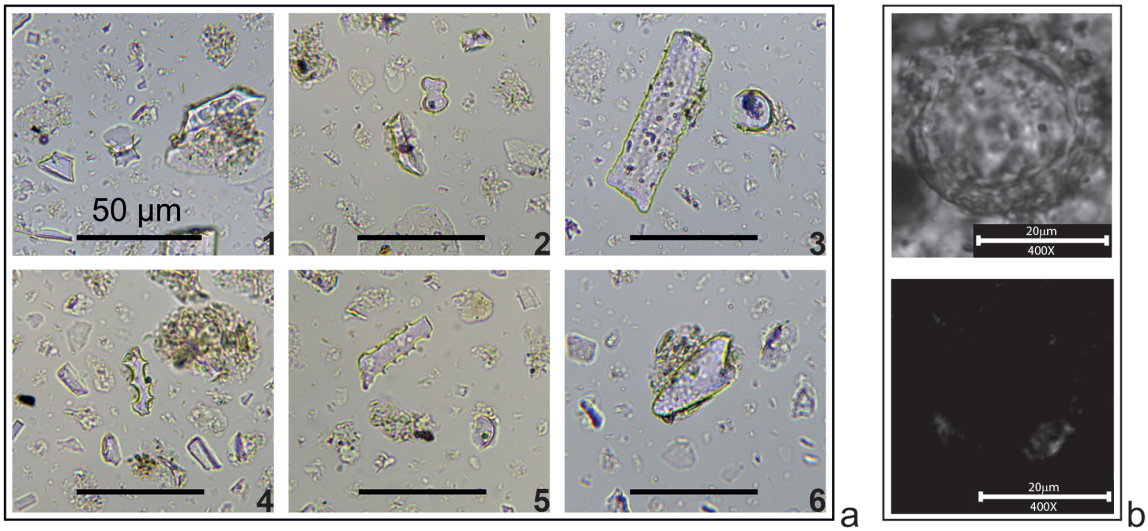

Fig. 6.* a *photomicrographs of selected phytolith morphotypes identified in the Rotbav samples. The photographs were taken at 400x magnification:* 1 *short cell rondel;* 2 *short cell trapeziform (left), short cell bilobate (right);* 3 *elongate entire (left), short cell rondel (top view, right);* 4 *elongate dentritic;* 5 *elongate echinate;* 6 *prickle (photos made by C. Binder).* b *photomicrograph of a starch granule (*Triticum aestivum*), taken at 400x magnification.

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Grinding and abrading activities in the earlier Neolithic of northern Greece: a multi-proxy and comparative approach for the site of Pontokomi-Souloukia

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ABSTRACT – *Despite their widespread presence and potential to shed light on various aspects of prehistoric life, for a long time Neolithic macrolithics attracted little scholarly attention. The situation, however, is rapidly changing as more and more assemblages are being studied and published systematically. The study of the grinding and abrading tools from the earlier Neolithic site of Pontokomi-Souloukia in northern Greece is part of this recent trend, as it integrates macroscopic examination, use wear, microbotanical and macrobotanical analysis, an experimental program, ethnographic data, as well as contextual analysis. In this article, we present the results of our study and make comparisons with other assemblages, placing the Pontokomi-Souloukia material in its wider Aegean Neolithic context.*

KEY WORDS – *Neolithic; Greece; grinding and abrading tools; use wear analysis; residue analysis*

Mletje in brušenje v zgodnjem neolitiku v severni Grčiji: multi-proksi in komparativni pristop k najdišču Pontokomi-Souloukia

IZVLEČEK – *Kljub razširjenosti in sposobnosti osvetliti različne vidike življenja v prazgodovini, so neolitski makroliti pritegnili le malo raziskovalne pozornosti. Ocena se hitro spreminja, saj je sistematično analiziranih in objavljenih vse več zbirov. Mednje sodi tudi študija orodij za mletje in brušenje iz zgodnje neolitskega naselja Pontokomi-Souloukia v severni Grčiji, saj vključuje makroskopsko analizo, analizo sledov uporabe, mikro in makro botanične analize, eksperimentalni program, etnografske podatke in kontekstualno analizo. V članku predstavljamo rezultate naše študije in zbir primerjamo z drugimi. Gradivo z najdišča Pontokomi-Souloukia tako umeščamo v širši egejski neolitski kontekst.*

KLJUČNE BESEDE – *neolitik; Grčija; orodja za mletje in brušenje; sledi uporabe; analize rezidijev*

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Introduction

Despite their ubiquitous presence at Aegean Neolithic sites, involvement in most (if not all) *chaînes opératoires*, and potential to illuminate various aspects of prehistoric life, for a long time macrolithics[1] attracted little scholarly attention. It is not an exaggeration to state that traditionally they represented one of the most neglected materials from Neolithic Greece. When relevant information was reported, it often consisted of a few cursory paragraphs in the 'small finds' section of a site publication (*e.g., Evans 1964.229–231*). Some tools, abandoned at the site after the completion of the excavation, were not considered worthy of even such a superficial treatment. This is the bad news.

The good news is that the situation is rapidly changing. In the last fifteen years or so, the field of Aegean Neolithic macrolithics has witnessed dramatic growth as more and more assemblages are being studied and published systematically. As a result, significant progress has been made in exploring raw materials, manufacturing processes, aspects of use, practices of discard, as well as social and symbolic dimensions (*e.g., Almasidou 2019; Bekiaris 2007; 2018; 2020; Bekiaris* et al. *2017; 2020; in press; Chadou 2011; Chondrou 2018; 2020; Chondrou* et al. *2018; 2021; Chondrou, Valamoti 2021; Lewis* et al. *2009; 2011; Ninou 2006; Stergiou* et al. *2022; Stroulia 2002; 2010a; 2010b; 2018a; 2018b; 2020; Stroulia, Chondrou 2013; Stroulia* et al. *2017; 2022; Tsoraki 2008; 2011a; 2011b; 2011c*).

Despite these developments, the field suffers from two serious imbalances. The first is geographic. Much more is known about the macrolithic industries of northern Greece than those from sites farther south; reports (of varying length and quality) are available for almost 30 assemblages from Macedonia, Thrace, and Thessaly compared to roughly 10 from the southern part of the country. The second imbalance is chronological. The available information for industries dated to the later part of the Neolithic by far exceeds that for earlier materials; there are roughly twice as many reported Late or Final Neolithic assemblages as those belonging to earlier phases (*see Bekiaris* et al. *2020.146–147; Stroulia in press*).[2]

By focusing on the earlier Neolithic material from the site of Pontokomi Souloukia in the Kitrini Limni Basin, in the prefecture of Kozani, west Macedonia, this article tackles none of the geographic bias but does address the chronological one. As such, (1) it sheds light on the macrolithic implements of the first agropastoral communities that occupied the Aegean; (2) it contributes to an understanding of the diachronic evolution of the macrolithic industries and related practices in this part of the world.

The Site

Kitrini Limni was a busy place in the Neolithic. As revealed by surface surveys or accidental discoveries related to various development projects, from the 7th to the 4th millennium BCE, this 35km² basin

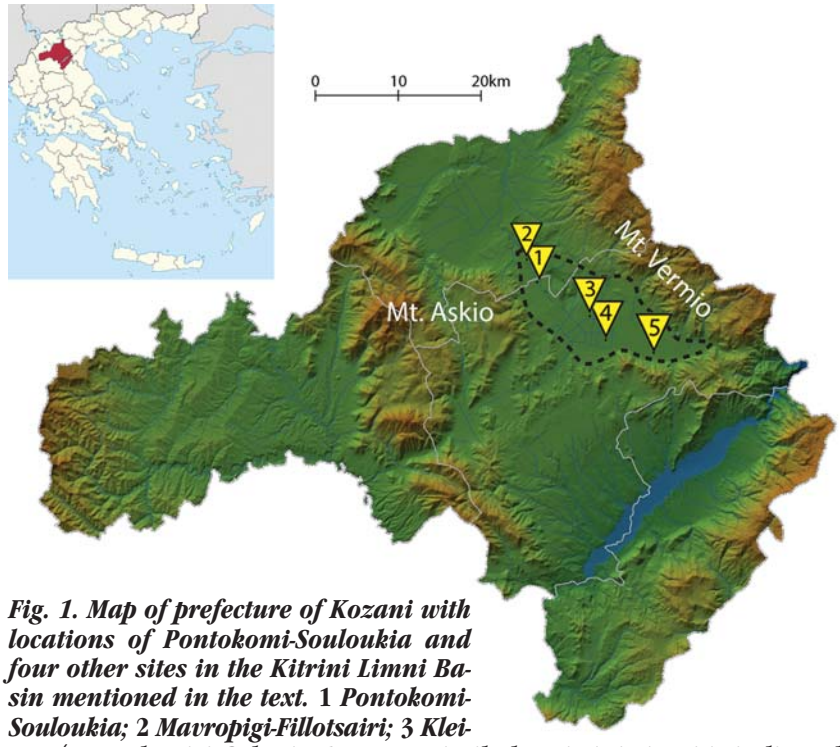

Fig. 1. Map of prefecture of Kozani with locations of Pontokomi-Souloukia and four other sites in the Kitrini Limni Basin mentioned in the text.* 1 *Pontokomi-Souloukia;* 2 *Mavropigi-Fillotsairi;* 3 *Kleitos;* 4 *Megalo Nisi Galanis;* 5 *Kremasti-Kilada. Kitrini Limni is indicated by dashed line. Graphics by Sofia Vlahopoulou.

1 For a discussion of the term 'macrolithics' and its advantages over the traditional term 'ground stone', see Adams *et al.* (*2009. 43–44*) and Stroulia (*2018a.202*).

2 The few assemblages that span the Neolithic period were not taken into account in these calculations.

served as the homeland for 30 settlements (*Chondroyianni-Metoki 2020; in press a; b; c*). One of the earliest among them is Pontokomi Souloukia (henceforth Souloukia) (Fig. 1).

Located on the western edge of the basin, Souloukia covers *c.* 1.0–1.2ha and dates to the second half of the 7th millennium and the beginning of the 6th. Roughly half of the site was severely damaged in the past few decades by the construction of a highway, a railroad, and other infrastructure-related projects. The other half (*c.* 0.4ha) was targeted by salvage excavations in the context of large-scale coal mining operations (*Chondroyianni-Metoki in press b; Karamitrou-Mentessidi* et al. *2010.39–46; Ziota* et al. *2014.77–79*).

Carried out by the Ephorate of Antiquities of Kozani between 2010 and 2017, the excavations revealed two contiguous but distinct areas. The centre of the site has the form of a low tell with anthropogenic deposits reaching a maximum thickness of 2m. This represents the residential sector as indicated by the remains of successive post-framed buildings. Five (mostly infant) human burials and one animal burial were found inside the buildings, while a concentration of 15 or so pits was excavated immediately to the south. A preliminary study of the stratigraphy and pottery of a single trench revealed three Early Neolithic building horizons and one dating to the early Middle Neolithic. Only *c.* 0.1ha was dug, but the residential area is estimated to have covered between 0.25 and 0.5ha (*Chondroyianni-Metoki in press b*) (Fig. 2a–d).

The surrounding flat area comprises the non-residential sector and includes three types of features: ditches, pits, and clay structures. Two ditches were uncovered. The first – on the western edge of the site – was linear, measuring *c.* 55m in length, 2m in maximum width, and 2.1m in maximum depth (*Chondroyianni-Metoki in press b*). The second – on the site's eastern part – was roughly curvilinear, measuring *c.* 14.5m in length, 2.4m in maximum width, and 1.4m in maximum depth (*Karamitrou-Mentessidi* et al. *2010.41–43, 45*). The functions of the ditches remain enigmatic, as there is no evidence that they connected with each other or surrounded the site (Fig. 2e).

Dispersed around the non-residential area are more than 40 pits of various sizes.[3] Their contents consist of pottery, lithics, faunal material, and figurines, but generally speaking, they yielded a small number of finds (*Chondroyianni-Metoki in press b; Karamitrou-Mentessidi* et al. *2010.43–44; Ziota* et al. *2014.78*). It is tempting to interpret these features as containers for ordinary waste disposal, but their dispersal over a large area is certainly intriguing.

East of the residential area (not far from the eastern ditch), the excavations uncovered a partially preserved clay structure with ashes – probably the remains of a hearth. North of the residential area, a second clay structure was excavated. It was elliptical in plan, with whitish clay coating the interior walls. Another structure may have existed west of the residential sector where masses of clay were uncovered along with, among others, a large number of grinding tools (Fig. 2f). Additional clay structures are vaguely mentioned in the preliminary reports (*Chondroyianni-Metoki in press b; Karamitrou-Mentessidi* et al. *2010.43; Ziota* et al. *2014.78–79*).

Significantly, the bipartite settlement structure, with a tell-like residential centre and a surrounding flat, extra-residential periphery, recognized at Souloukia, does not characterize Mavropigi-Fillotsairi, the other extensively excavated Early Neolithic site of Kitrini Limni (*Karamitrou-Mentessidi* et al. *2013; 2015*). It has, however, been identified at Kremasti-Kilada, which dates to the Late Neolithic (*Chondroyianni-Metoki 2009; 2020*). To the best of our knowledge, this settlement layout is not known from other parts of Greece and thus may represent a regional variation. Whether regional or not, this bipartite configuration argues against the long-held, simplistic dichotomy between tell sites and flat/extended sites and underlines the diversity of the ways in which Aegean people organized their settlements in space during the Neolithic (see also *Kotsakis 1999.69–70; Krahtopoulou 2019.77–82; Sarris* et al. *2017; Toufexis 2017.23–30, 333–362*).

Materials and methods

The Souloukia excavations uncovered large amounts of pottery, various quantities of stone and bone tools, an unusually high number of figurines, as well as a few rather uncommon artefacts (*i.e.* two clay house models, a marble vessel, and a bone flute) (*Chondroyianni-Metoki in press a; b; Karamitrou-Mentessidi* et al. *2010.44–45; Ziota* et al. *2014.79*).

The stone tool inventory includes nearly 400 macrolithics. Among them are the roughly 170 grinding

3 Intriguingly, a single pit dates to the Final Neolithic (*Chondroyianni-Metoki in press b*).



Fig. 2. Excavation views. Residential sector:* a *remains of burnt building;* b *postholes;* c *pits;* d *pot burial. Extra-residential sector:* e *ditch;* f *area with grinding tools, pieces of raw material, as well as masses of clay possibly from a clay structure. Photos by A. Chondroyianni-Metoki.

tools, abrading implements, and related pieces of raw material that make up the focus of this paper.

The term 'grinding tools' refers to implements used to pulverize or crush foodstuffs and minerals. These artefacts operate in pairs comprising a lower stationary component and an upper mobile one. In the literature, the first is often referred to as a millstone, quern, metate, grinding slab, *etc*., the second as a handstone, mano, grinder, rider, roller stone, rubber, *etc*. (*e.g., Adams 2014.142–145; Cappers* et al. *2016. 391–392; Elster 2003.186; Evans, Renfrew 1968.71; Hamon, Le Gall 2013.113; Hayden 1987.187; Tsoraki 2008.91, 97; Wright 1992.61; Wright, Baysal 2012.3*). Here we use the more neutral terms 'passive tool' and 'active tool', respectively. The term 'abrading tools' refers to implements used without a complementary component for shaping/maintaining other artefacts (*e.g.*, celts, bone tools, and ornaments) through abrasion. We should emphasize that the differentiation between grinding and abrading tools as well as that between passive and active grinding implements serve analytical purposes. As seen below, the Souloukia residents did not always conform to these distinctions.

Since the systematic study of both the stratigraphy and pottery is pending, a distinction between Early Neolithic and early Middle Neolithic specimens has not been possible. However, given that three of the four building horizons in the residential area are Early Neolithic, we assume this to be the date of the majority of specimens. Be that as it may, in this article all specimens are referred to collectively as earlier Neolithic.

All but six of the roughly 130 abrading and grinding tools were subjected to use wear analysis with a stereoscope (10–80x magnification) and a metallographic microscope (100x and 200x magnification) (Ro-

bitaille). Preservation of microwear was moderate to low. Acetate and polyvinyl siloxane casts were made of used surfaces that were preserved reasonably well. Use wear analysis was conducted in conjunction with an extensive experimental program that involved a variety of materials: cereals, pulses, nuts, bone, shell, stone, and wood (Robitaille, Stroulia). Microwear was identified on a total of 63 specimens.

Residue analysis following a protocol and nomenclature defined by Rosa M. Albert *et al.* (*1999*) and Marco Madella *et al.* (*2005*) was carried out on 14 unwashed specimens: 13 grinding tools (both work and dorsal faces were sampled) and one abrading implement (both used surfaces were sampled). Six control samples were analysed as well. The detected phytoliths were examined with a Leica DM 750 microscope at 400x magnification. For each sample, calculations were made for the number of phytoliths per 1g of sediment, the percentages of grass and dicotyledonous phytoliths, as well as those of weathered and multicellular morphotypes. Phytoliths that can be associated to use with a reasonable degree of confidence were identified on only five of the sampled artefacts (*Ögüt 2018*).

The Souloukia grinding and abrading tools are among the first from Neolithic Greece to have been subjected to use wear and residue analyses.[4] In this paper, we present the general results of these analyses, but more detailed data on both, as well as the experimental program, will be published elsewhere.

While the analysis of microbotanical remains has been completed, the examination of the macrobotanical material has not. No more than a small sample has so far been analysed (Kotsachristou). Only preliminary observations have therefore been possible regarding the plants processed and consumed at the site.

The study of the Souloukia grinding and abrading tools is particularly important. The severe underrepresentation of earlier Neolithic assemblages in the literature (noted above) is one reason. There are another two: these assemblages have been treated superficially or happen to be very small. For example, over 100 grinding and abrading tools from Achilleion were presented in fewer than two pages (*Winn, Shimabuku 1989.268–272*), while the roughly 70 specimens from Nea Nikomedeia were discussed in only seven paragraphs (*Pyke 1993.103, 108–109, 111*). The macrolithic material from Prodromos, on the other hand, was studied systematically, but includes fewer than 15 grinding and abrading tools (*Moundrea 1975.92–99*).

By integrating macroscopic examination with use wear and residue analysis, experimental, macrobotanical, and ethnographic data, as well as contextual analysis, our study of the substantial Souloukia assemblage helps fill this gap and thereby clarify the role these implements played in the lives of the communities that made Greece their home in the earlier part of the Neolithic.

This paper operates at three levels: (1) It presents the results of our multi-proxy study of the Souloukia tools by discussing the raw materials and their acquisition; the choices made in the context of manufacture and the priorities that these reflect; the specimens' morphometric and technofunctional characteristics; the processed food and non-food substances; as well as the tools' spatial distribution and processes of discard. (2) It makes references to assemblages from four sites in Kitrini Limni (Kremasti-Kilada, Kleitos, Megalo Nisi Galanis, and Mavropigi-Fillotsairi) as well as others elsewhere, placing the Souloukia material in both its regional and wider Aegean Neolithic context. (3) It utilizes the limited available information on contemporary industries and makes comparisons to later ones in an attempt to place the Souloukia material in its synchronic and diachronic framework.

Abrading tools

Only six specimens were securely identified as abrading tools. All derive from the residential sector. An additional specimen – found outside the residential area – carries no use wear but may represent raw material intended for an abrading tool.

The Souloukia abrading tools share two basic commonalities: (1) all are *a posteriori* – the raw material was put directly to use without modification; (2) all were used passively. These tools, on the other hand, exhibit significant morphological and lithological differences that allow a distinction between two groups.

Group 1 comprises four specimens of tabular fine-grained sandstone. This type of raw material is not

4 For other studies, see Danai Chondrou *et al.* (*2021*) and Anna Stroulia *et al.* (*2017.3–7*).

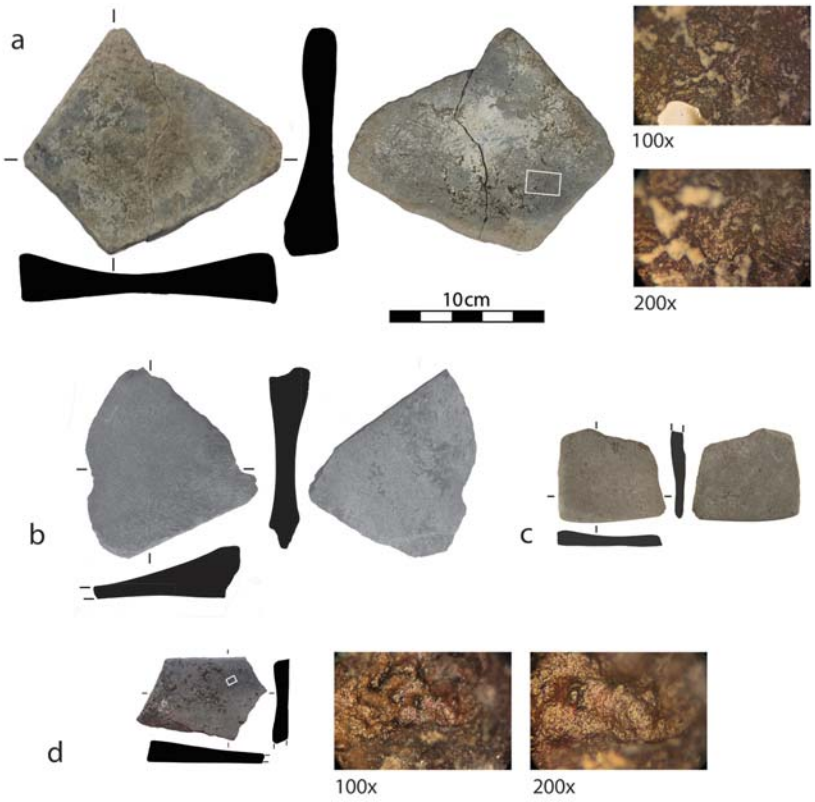

Fig 3. Abrading tools (Group 1):* a *faces A (left) and B (right), sections, and use wear views of complete specimen GS325 (metallographic microscope);* b *faces and sections of fragmentary specimen GS95;* c *faces and sections of fragmentary specimen GS190;* d *used face, sections, and use wear views of fragmentary specimen GS56 (metallographic microscope). Drawings by T. Gouliafas, photos by A. Stroulia and J. Robitaille.

found in the Kitrini Limni Basin, the bottom of which consists of clay marl and lacks stones larger than 5cm (*Fotiadis 1988.45; Fotiadis* et al. *2019.5–6*). It is not found anywhere else in the local landscape either. The closest source is located on the slopes of Mt. Vourinos, close to the village of Agia Paraskevi, about 25km south of the site.[5] The sandstone crops out naturally in the form of plaques of varying thickness (*Stroulia, Dubreuil 2011.3*).

Only one tool in this group is complete. It is not however intact, as it was found in two pieces (the breakage probably being post-depositional). This specimen is polygonal and measures 14.3x13.8x3.4cm. The other three are fragmentary. None appears to derive from a tool larger than the complete one. On this basis, it is fair to say that all specimens in Group 1 are small and thin.

The extent and intensity of use, as well as the ensuing morphological changes, vary from tool to tool. The two thickest specimens – one complete, the other fragmentary – were used on both faces. The use was intensive enough to create concave configurations. The faces of the complete specimen are parallel, but one (A) is deeper than the other (B) (Fig. 3.a). Face A features a central ovate, concave *c.* 9x6cm area. Due to the presence of concretion, no microwear was identified on this face, but that detected on face B appears compatible with the abrasion of bone. This is the only abrading tool subjected to residue analysis. A relatively high proportion of wood phytoliths were detected on face A. However, since many of them consist of skeletons rather than weathered morphotypes, they may not be use-related (*Ögüt 2018*). The faces of the fragmentary specimen are diagonal (Fig. 3.b). Again, one face is deeper than the other, but both show an increasing depth towards the thinnest edge. We were not able to specify the material that was processed on these faces, but according to the use wear analysis, it was neither bone nor wood.

One of the thinnest specimens was also used on both faces. Judging by the fact that one face is more or less flat, while the other is lightly concave with an increasing depth from one side to the other, the two faces were not used with equal intensity. Use wear analysis points to wood processing, at least for one of the faces (Fig. 3.c). Finally, the fourth and equally thin specimen was used on only one face, resulting in the formation of a slightly concave area. The processed material was most likely bone. This is the least utilized of the Souloukia abrading tools (Fig. 3.d).

Group 2 includes two tools. Both are much more massive than those making up Group 1. This is well illustrated by the complete specimen, which measures *c.* 31x19x11cm (Fig. 4). The raw material consists of waterworn boulders, gneiss in one case and sandstone of a coarser variety than that used for

5 This is probably the only primary source of fine-grained sandstone in the prefecture of Kozani.

Group 1 in the other. In both tools, one of the faces is lightly convex but has a lightly concave used area measuring *c.* 15x8cm. In neither case has the processed material been determined.

Our general conclusion is that the Souloukia abrading tools were involved in the production (and/or maintenance) of bone objects such as those that were excavated (see *Karamitrou-Mentessidi* et al. *2010.45*) as well as wooden artefacts that were not preserved. It is important to note that bone or wood abrasion has been hypothesized for certain Greek Neolithic macrolithic tools on a macroscopic basis (*e.g., Bekiaris 2018.276–277; Chondrou 2018.227–228; Fotiadis* et al. *2019.31; Stroulia 2010a.40–54, 2018a.211–212; Tsoraki 2008.102–10*), but this is the first time that such functions are documented for the Neolithic Aegean.

Significantly, no wear related to stone abrasion was detected. This is unexpected in light of the over 100 excavated celts. We find it plausible that celt shaping and resharpening took place outside the settlement. Such a hypothesis is compatible with the almost complete absence of unfinished specimens. On the basis of ethnographic evidence, both practical and non-practical considerations may have been behind the off-site production and maintenance of celts at Souloukia. Among several Irian Jaya groups, celt grinding is carried out away from the compounds, usually by a river or stream. This activity is invested with a strict prohibition along gender lines as it must take place out of view of women (*Pétrequin, Pétrequin 1993.373*).

Abrading tools of tabular fine-grained sandstone have been uncovered at three other Kitrini Limni sites: Kremasti-Kilada (*Chondrou 2011.101–102; Stroulia, Dubreuil 2011.1*), Megalo Nisi Galanis (*Fotiadis* et al. *2019.31*), and Kleitos (*Chondrou 2018. 200–230*). Similar artefacts have also been reported from Servia,[6] a site in the prefecture of Kozani but not in Kitrini Limni (*Mould* et al. *2000.155–157*). Microscopic analysis of a sample from Kremasti-Kilada by Laure Dubreuil revealed use wear somewhat compatible to that produced experimentally through stone abrasion and scraping unfired bone-dry clay vessels (*Stroulia, Dubreuil 2011.2*). Kremasti-Kilada, Megalo Nisi Galanis, Kleitos, and Servia date to the Middle, Late, or Final Neolithic and are thus later than Souloukia, but the presence of such tools on all five sites points to a certain regional tradition of exploiting fine sandstone tabular pieces from the same source for a variety of abrading purposes. Finally, we should note that farther north and west, but also in Macedonia, the Late Neolithic site of Avgi yielded over 60 tabular pieces of fine-grained sandstone. They are of generally larger dimensions than those found at the above sites and were employed in a cooking rather than an abrading context (*Bekiaris* et al. *in press*).



Fig. 4. Complete abrading tool GS243 (Group 2): work face and profile. Photos by A. Stroulia.

Grinding Tools

Raw material type, procurement

The Souloukia excavations yielded a much higher number of grinding than abrading tools. One hundred twenty-six specimens were securely identified as grinding tools, while one and possibly up to four specimens represent roughouts (Figs. 5–9). In addition, 31 pieces of gravel were recovered of material similar to that employed for grinding tools but without traces of manufacture or use. At least 20 of these are complete or substantially preserved and thus likely represent unworked nodules intended for grinding tools. Of the remaining specimens, some are very fragmentary, while others have surfaces covered by concretion or altered by fire. Whether these belong to tools or raw nodules is impossible to tell.

If tabular sandstone was the preferred material for abrading implements, it was used rarely for grinding

6 They are referred to as 'palettes' by the excavators.

tools. For the latter, Souloukiotes almost always chose gneiss in the form of cobbles and boulders. In this sense, the grinding tool assemblage is remarkably homogeneous, a reflection of a deeply embedded tradition that spanned several generations. The gneiss used comes in various degrees of coarseness, is often oxidized with a characteristic red/brown colour, has a high quartz content and is thus quite hard, typically includes no mica, and its surface is usually anomalous and/or has vesicular areas (Figs. 5–9). As we found out by experimentally producing a work face through pecking, this type of gneiss is characterized by high workability. Moreover, because of its hardness it does not require frequent resharpening, nor does it produce much grit during use. Or so we discovered through our grinding and cooking experiments. This was a good choice.

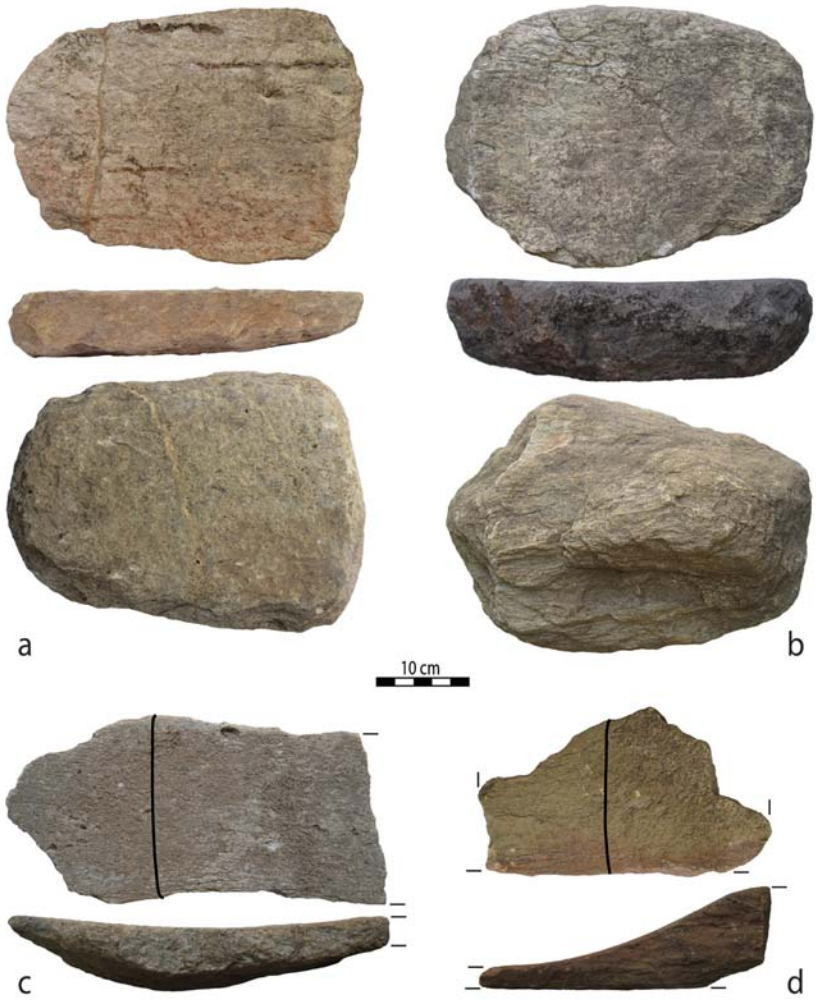

Fig. 5. Passive tools:* a *intended work face, dorsal face, and longitudinal profile of complete roughout specimen GS307;* b *concave/concave work face, dorsal face, and longitudinal profile of complete specimen GS71;* c *concave/convex work face and longitudinal profile of fragmentary specimen GS244;* d *concave/convex work face and longitudinal profile of fragmentary specimen GS250. Photos by A. Stroulia.

Primary gneiss sources are found on two of the mountains surrounding Kitrini Limni: Mt. Askio to the west and Mt. Vermio to the east (Fig. 1). Both sources are extensive, but Mt. Askio is the closest to Souloukia. Although no petrographic analyses have been conducted, macroscopic similarities indicate that as a rule Mt. Askio gneiss was utilized by the Souloukiotes. Nevertheless, with a handful of possible exceptions procurement did not take place at primary sources. The material is waterworn and thus must have been collected at more proximate secondary locations.

A comparison between Souloukia and other Kitrini Limni sites regarding the raw materials of grinding tools revealed one fundamental similarity. In all cases, secondary sources were exploited (Kremasti-Kilada: *Chondrou 2011.81, 106; Stroulia, Dubreuil 2011.1;* Kleitos: *Chondrou 2020.291;* Megalo Nisi Galanis: *Stroulia 2002.576*).

This comparison also revealed two patterned variations:

❶ The almost exclusive focus on a singular material noted at Souloukia is not paralleled in the later Neolithic assemblages of Kremasti-Kilada (*Chondrou 2011.80–81; Stroulia* et al. *2017.3*), Kleitos (*Chondrou 2020.290–291*), and Megalo Nisi Galanis (*Fotiadis* et al. *2019.30–31*), which are characterized by a variety of materials. Gneiss is part of this variety but never the dominant lithology. On this basis and in a preliminary fashion, we would like to hypothesize that in Kitrini Limni an earlier Neolithic focus on a single material was followed by the exploitation of diverse lithologies. What needs and/or opportunities could have led to such a diversification cannot be systematically discussed with the available data. However, a simplistic and straightfor-

ward equation between the number of raw material types and processed substances does not appear to be the answer. As seen below, the use wear of the Souloukia specimens points to processing a variety of substances. Be that as it may, the nearly exclusive use of a single material for grinding tools appears to have been rare in Neolithic Greece. To the best of our knowledge, the only other sites in which this practice has been documented are Dikili Tash (*Bekiaris* et al. *2020.147*) and Alepotrypa Cave (*Stroulia 2018a.205*), in the northern and southern parts of the country, respectively. Both date to the later part of the Neolithic.

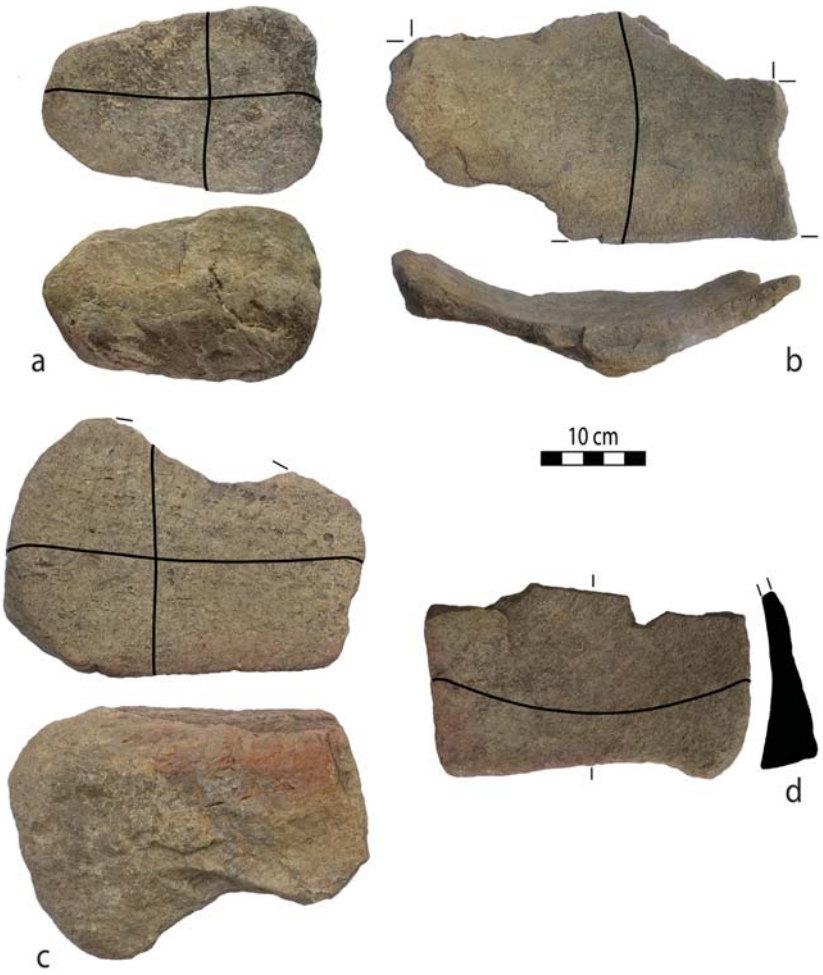

Fig 6. Passive tools:* a *complete specimen GS277 with concave/concave work face and dorsal face used in the context of recycling;* b *concave/concave work face and longitudinal profile of fragmentary specimen GS255;* c *concave/concave work face and dorsal face of nearly complete specimen GS324;* d *concave/concave work face and transverse section of fragmentary specimen GS388. Drawing by T. Gouliafas; photos by A. Stroulia.

❷ The Mt. Askio gneiss used at Souloukia is macroscopically different from the varieties employed at Kremasti Kilada and Megalo Nisi Galanis (observations by Stroulia) that appear to originate in Mt. Vermio. Notably, these two sites are located in the eastern part of the basin and thus closer to Mt. Vermio than Mt. Askio. On this basis, we would argue that western and eastern Kitrini Limni communities exploited different regional sources of gneiss. Since all these varieties are of good quality, the distance from the sources may very well have been the determining factor behind these choices. Hopefully, these hypotheses will be tested in the future through comparative petrographic analyses.

Manufacture

As mentioned above, the Souloukia excavations uncovered at least 20 unmodified gneiss cobbles and boulders that were probably intended for grinding tools. Their presence is indicative of two practices: (1) raw material was brought to the site without prior processing at the sources; (2) larger quantities of raw materials than those immediately needed were periodically collected in anticipation of future needs – the hallmark of curation practices. With the available evidence, it is impossible to tell how the collected raw material was distributed, but the recovery of raw nodules from both the residential and non-residential areas at the very least points to the lack of a single communal spot where raw material was kept awaiting future use. The fact, moreover, that only one roughout was positively identified (Fig. 5.a) indicates that no designated manufacturing locus existed either (at least in the excavated area).

The scarcity of unfinished specimens noted at Souloukia matches that known from other Kitrini Limni sites; see Kremasti Kilada (*Chondrou 2011.81–82, 134; Stroulia* et al. *2017.4*), Kleitos (*Chondrou 2020. 291*), and Megalo Nisi Galanis (observation by Stroulia). No such match applies to unworked specimens. While by no means high, the number of such specimens at Souloukia is rather substantial when com-

pared to Kleitos (*Chondrou 2020.291*) and Megalo Nisi Galanis (*Stroulia 2002.576*),[7] which are characterized by an almost complete absence of unmodified cobbles and boulders. Indeed, the combined paucity of raw nodules and roughouts in the huge assemblage of the almost fully excavated site of Kleitos led to the hypothesis that tools arrived in a more or less finished state (*Chondrou* et al. *2018.31; Chondrou 2020.291*). A similar scarcity characterizes assemblages from sites beyond Kitrini Limni such as Makriyalos (*Tsoraki 2008.81*), Alepotrypa Cave (*Stroulia 2018a.234*), Avgi (*Bekiaris 2018. 221*), and Platia Magoula Zarkou (*Stroulia in press*). This pattern deserves systematic investigation, but it appears to suggest a widespread practice of off-site grinding tool production in Neolithic Greece.

Two manufacturing techniques were employed for grinding tools at Souloukia: pecking and flaking (Figs. 5.a, 9.a). Both are known from other sites in Kitrini Limni and elsewhere; see Kremasti-Kilada (*Chondrou 2011.82–83, 106–107; Stroulia, Dubreuil 2011*), Megalo Nisi Galanis (*Stroulia 2002.576*), Kleitos (*Chondrou 2020.291–293*), Avgi (*Bekiaris 2020.4*), Makriyalos (*Tsoraki 2008.114*), Koroneia (*Almasidou 2019.90, 99–100*), Franchthi Cave (*Stroulia 2010a.35*), Alepotrypa Cave (*Stroulia 2018a. 206*), and Platia Magoula Zarkou (*Stroulia in press*).

The process of manufacture at Souloukia was neither comprehensive nor systematic: work faces were most often created through pecking. Portions not intended for use, on the other hand, were as a rule left in their raw state or received localized treatment in order to facilitate the tool's gripping/resting or ensure a specific plan (Figs. 5.b, 6.a and c, 9.a–c).

This manufacturing approach was aided by a raw material acquisition strategy that favoured cobbles/boulders with sizes and shapes similar to those of the intended tools or with portions that could be strategically incorporated into the final tool shape. Two examples: the first is a roughout of a passive tool measuring *c.* 33x23x5.5cm., with one naturally flattish surface that could be converted into a work face with minimal pecking (Fig. 5.a); the second example – an active tool – measures *c.* 20x19x 17.5cm, pointing to use with two hands. Its dorsal face has a naturally ridged shape that must have facilitated gripping during grinding (Fig. 8.c).

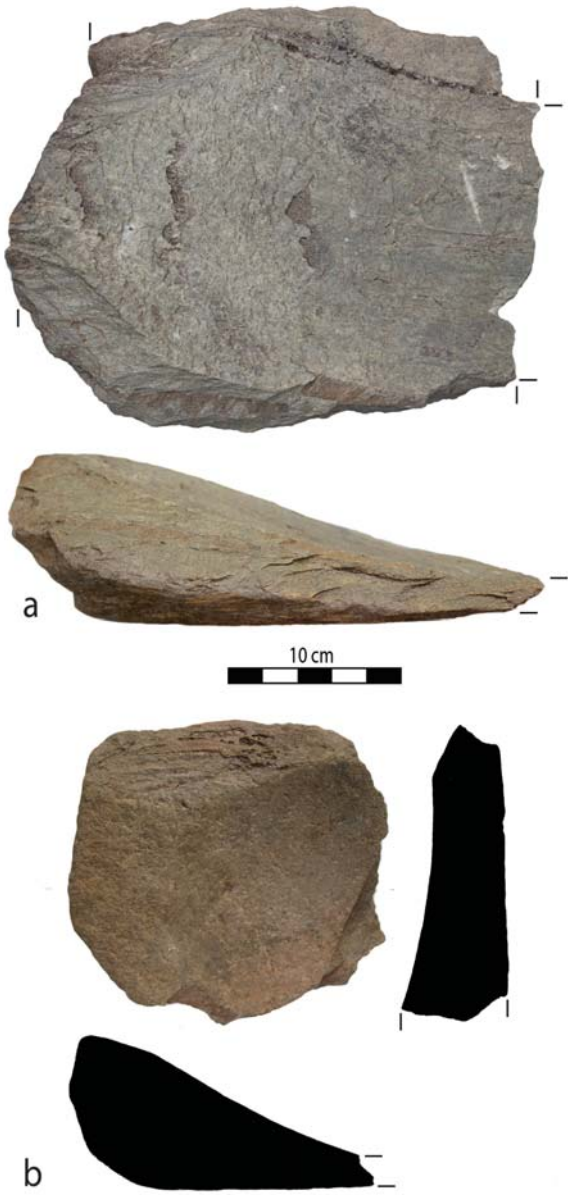

Fig. 7. Passive tools:* a *concave/concave work face and longitudinal profile of fragmentary specimen GS389;* b *concave/concave work face and sections of fragmentary specimen GS385. Drawings by T. Gouliafas, photos by A. Stroulia.

The above strategy expedited manufacture, it did result, however, in tools with uneven/anomalous dorsal and peripheral surfaces or asymmetrical plans (Figs. 5.b, 6.a and c, 8.c, 9.c). Clearly, this was not considered a sufficiently serious problem to make the people of Souloukia invest more effort in tool making. Clearly, saving time and energy took priority over appearance. A similar attitude is reflected in the assemblages of other Kitrini Limni sites and

7 The case of Kremasti-Kilada is ambiguous. More than 300 fragmentary specimens without traces of manufacture or use were excavated, but how many represent unworked raw materials and how many consist of unmodified tool portions we cannot tell (*Stroulia* et al. *2017.23*).

beyond, which are also characterized by a low manufacturing investment and/or non-comprehensive treatment of the raw materials – see Megalo Nisi Galanis (*Stroulia 2002.576*), Kleitos (*Chondrou 2020.291*), Kremasti-Kilada (*Chondrou 2011.82–83, 106–107; Stroulia* et al. *2017.4*), and Makriyalos (*Tsoraki 2008.114*).

Morphometric characteristics

Only 30 (24%) of the Souloukia grinding tools are complete or nearly so. The vast majority (n=96) are fragmentary. This imbalance is far from remarkable, since Aegean Neolithic grinding tool assemblages (at least those with available preservation information) are dominated by fragments (see *Bekiaris* et al. *2020.157–158; Stroulia in press*). What is noteworthy is the stark contrast between the frequencies of complete specimens at Souloukia and other Kitrini Limni sites. As it turns out, at Kremasti-Kilada, Kleitos, and Megalo Nisi Galanis, such specimens are extremely rare, accounting for <4%, 3%, and <1% of the total, respectively (*Chondrou 2011.91–95, 111–113, 164–165; 2020.290; Fotiadis* et al. *2019.31; Stroulia 2002.576; Stroulia, Chondrou 2013.125–126; Stroulia* et al. *2017.3*). The hypothesis of deliberate breakage has been put forward for all three assemblages. The fact that the Souloukia material is earlier than the other three raises the possibility that grinding tools were subjected to different treatments and assigned different dimensions by earlier and later Neolithic communities in Kitrini Limni.

On the basis of microwear analysis, morphometric characteristics and/or work face configuration, 63 tools (50%) were identified as passive, 47 (37%) as active. All identifications refer to primary uses. Due to fragmentation or surface alteration, it has been impossible to determine whether the remaining 16 specimens were used passively or actively.

The numerical prevalence of passive tools is intriguing. As known from ethnographic sources, active tools wear out faster and thus have shorter life spans than passive ones (see *Delgado Raack, Risch 2016.129; Hayden 1987.193; Nixon-Darcus, D'Andrea 2017.206; Risch 2008.22; Robitaille 2016.438*). That is why, for example, among the Minyanka of Mali two active tools are produced for each passive one (*Hamon, Le Gall 2013.112*), while among the Konso, Hamar, Mursi, and Dorze of Ethiopia each passive tool is used with two active ones over its lifespan (*Robitaille 2016.445; 2021.240, 546*). On this basis, one would expect the Souloukia assemblage to feature precisely the reverse imbalance, *i.e.*, a higher proportion of active than passive tools.

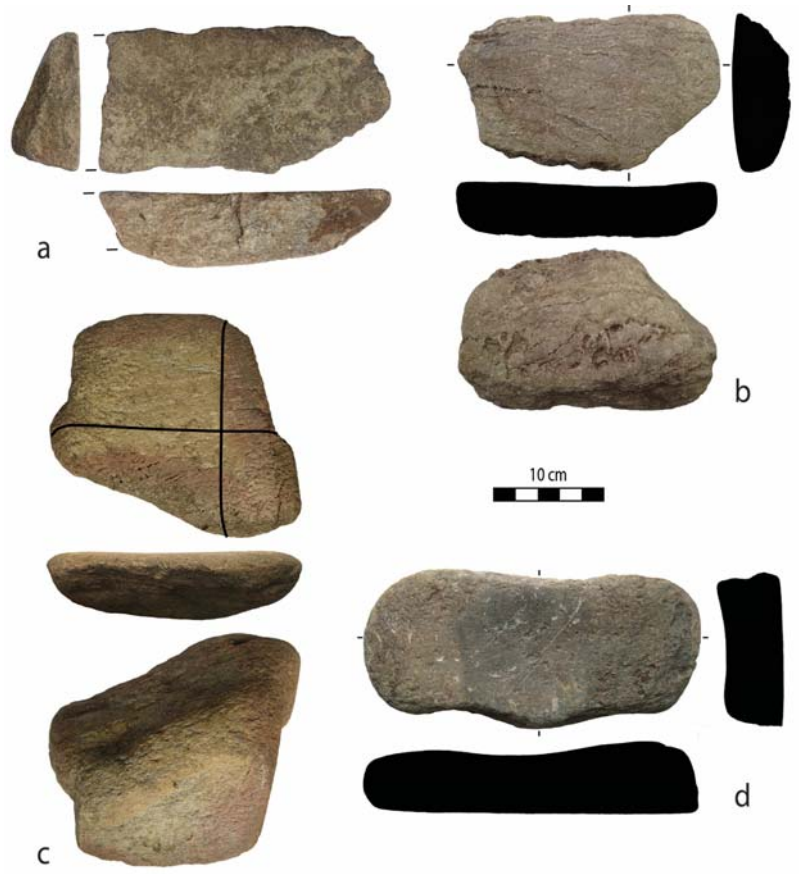

Fig. 8. Active tools:* a *concave/convex work face and profiles of fragmentary specimen GS97;* b *concave/convex work face, dorsal face, and sections of complete specimen GS292;* c *slightly concave/convex work face, dorsal face, and profile of complete specimen GS247;* d *recycled dorsal face and sections of complete specimen GS238. Drawings by T. Gouliafas, photos by A. Stroulia.

What is even more unexpected, similar discrepancies between passive and active tools have been noted at other Greek sites such as Alepotrypa Cave (*Stroulia 2018a.208*), Franchthi Cave (*Stroulia 2010a.79–94*), Iliotopos (*Chadou 2011.134*), and Makriyalos (*Tsoraki 2008.Tab. 5.28*). They are also known from other periods or countries; see, for example, several Neolithic sites in Serbia (*Galdikas 1988.*

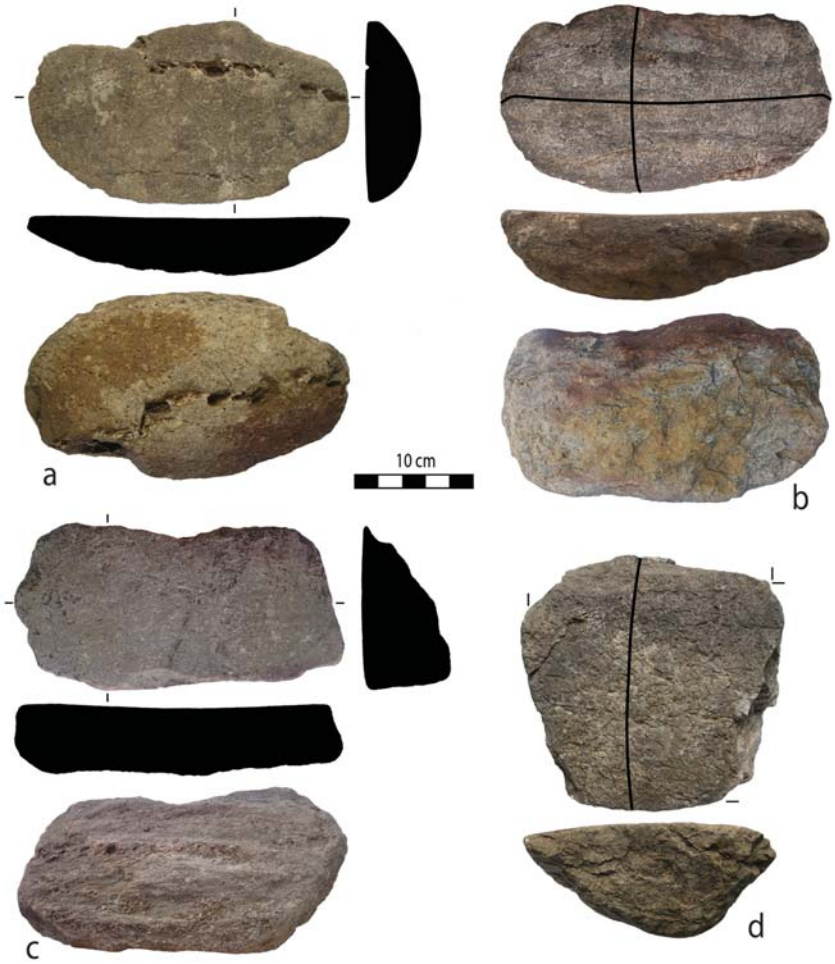

Fig. 9. Active tools:* a *concave/convex work face, dorsal face, and sections of complete specimen GS257;* b *concave/convex work face, dorsal face, and longitudinal profile of complete specimen GS254;* c *concave/convex work face, dorsal face, and sections of complete specimen GS289;* d *convex/convex work face and transverse profile of fragmentary specimen GS316. Drawings by T. Gouliafas, photos by A. Stroulia.

341; Vučković 2019. 228), the Greek Bronze Age site of Toumba Thessalonikis (*Tsiolaki 2009.61–62*), certain Pre-Dynastic and Bronze Age Egyptian sites (*Robitaille 2015; Samuel 2010.466*), as well as Bronze Age sites in southern Iberia (*Delgado Raack, Risch 2009.10; 2016.129; Risch 2002.111–127*). We suspect that this is a widespread phenomenon, one that has been severely underappreciated in the literature.

Risch and his colleagues attributed the predominance of passive implements in southern Iberian assemblages to the use of unpreserved wooden active specimens (*Delgado Raack, Risch 2009.17; 2016. 139; Menasanch* et al. *2002.108; Risch 2002.111–127*). Such a hypothesis does not appear valid for Souloukia. The microtopography of the work faces of passive tools points to active counterparts made of stone. There must be another explanation, and this will be discussed later in this work.

The Souloukia passive tools are typically elongated. Their plans are subrectangular, subtrapeze, or ovate, with occasional subsquare or elliptical cases (Figs. 5–7). Active tools are also elongated, with subrectangular, ovate, and, more rarely, subtrapeze, subsquare, or subtriangular plans (Figs. 8–9).

The eleven complete (or nearly so) passive specimens range from *c.* 23 to 45.5cm in length, from *c.* 15.5 to 28.5cm in width, and from *c.* 4.5 to 17.5cm in thickness, averaging *c.* 31cm, 19cm, and 7.7cm, respectively. The 52 fragments average *c.* 23.5cm in length, 17cm in width, and 7.5cm in thickness. The average length of the complete specimens is slightly over the standard limit of 30cm between small and large specimens. This may lead to the general conclusion that the Souloukia passive tools were of moderate size. However, the average length of the many more incomplete specimens is relatively high – an indication that most tools were originally large. This hypothesis is reinforced by the fact that quite a few of the fragments represent half or less of the complete tool, as well as by the high mean width and thickness of the fragmentary specimens in general. On this basis, we would argue that the Souloukia assemblage includes several small (mostly complete) passive specimens, but large ones make up the majority (Figs. 5–7).

The picture conveyed by the active tools is more straightforward. The 17 complete specimens are clearly large. They range from *c.* 16 to 30cm in length, from *c.* 10.5 to 19cm in width, and from *c.* 4.5 to 9cm in thickness, averaging *c.* 23cm, 15cm, and 6cm, respectively. With respective averages of *c.* 15cm, 12cm, and 6cm, the 30 fragments appear to derive from equally big tools. With one possible

exception, we consider all active specimens to have been two-handed (Figs. 8–9). The combined metric data of all specimens (passive and active, complete and incomplete) suggest that the grinding toolkits employed by the residents of Souloukia were for the most part large.

The active tools could have been used in conjunction with large passive implements such as those found. Active specimens that would have been compatible with the identified small passive ones, on the other hand, appear to be missing. This is a second discrepancy between passive and active tools.

Given their large sizes, it is tempting to assume that the active implements operated in an overhanging manner. However, both macroscopic and microscopic examination suggest that, as a rule, their length was roughly similar to or slightly higher than the width of the associated passive tools. Specimens whose length substantially exceeded the width of their passive counterparts are not common in this assemblage. Overhanging specimens have been reported from Kleitos (in Kitrini Limni), Ayios Vlasis, Stavroupoli, and Dikili Tash (*Chondrou 2020.293–294; Chondrou* et al. *2021.6–9*). It is, however, unclear whether these tools were slightly or substantially longer than the width of the associated passive tools.

Given that a number of passive and active specimens weigh over 7kg and 4kg, respectively, it is also tempting to assume that at least some of the Souloukia grinding toolkits were fixed in place. However, no grinding installations were uncovered by the excavators. In fact, such an assumption projects to the past our Western modern relationship with heavy objects. The relationship of prehistoric people with such objects may have been different, as illustrated by ethnographic examples from Ethiopia. Among the Dorze, passive tools weighing 11–25kg are regularly moved from their storage location inside the house to the yard of the compound where they are used. The Hamar passive tools range in weight from 8 to 60kg. The heaviest among them remain inside the house, but the lighter ones are often moved between indoor and outdoor areas. In most cases, tools are transferred on a daily basis. Other movements are periodical, depending on the season, the substances to be processed, or the context of use of the ground product. With certain exceptions, the tools do not leave the boundaries of the compound. The exceptions refer to special occasions. Among the Mursi and the Hamar, tools are taken to farther locations for processing large quantities of grain in a group context. The processed grain is then used to make beer for weddings or other festive events (*Robitaille 2021.181;* see also *Hamon, Le Gall 2013.117*).

We close this section with the overall sizes of Neolithic Aegean grinding tools. General claims have been made about "*the predominance of milling tools of relatively limited dimensions in many...sites*" (*Chondrou* et al. *2018.37*; see also *Valamoti* et al. *2013.171, 184*). We disagree with this characterization and consider it to be a misconception shaped by high rates of fragmentation. Our examination of the sizes of both complete and fragmentary specimens has revealed a more nuanced picture. Some Neolithic assemblages include both small and large specimens; see Servia (*Mould* et al. *2000.146–155*), Stavroupoli (*Alisøy 2002*), and Platia Magoula Zarkou (*Stroulia in press*). Others comprise primarily small tools; see Franchthi Cave (*Runnels 1981.101; Stroulia 2010a.37–38*) and Lerna (*Banks 2015.184; Runnels 1981.101*). Yet others, like Souloukia, appear to include primarily large specimens; see Kremasti-Kilada (*Stroulia* et al. *2017.4*; observation by Stroulia) and Alepotrypa Cave (*Stroulia 2018a.204, 208–209*).[8]

With its earlier Neolithic date, the Souloukia assemblage demonstrates that the use of large-sized grinding tools was not a later development. Rather, such implements were a part of the material culture of the first sedentary communities established in the Aegean. What is more, the four largest specimens from Souloukia (Fig. 5.b–c)[9] are among the most massive known from Neolithic Greece (for examples from Kitrini Limni and elsewhere, see *Chondrou 2011.83–84; Mould* et al. *2000.150; Stroulia* et al. *2017.4; Touloumis 2002.108–109*). Not only did early Aegean farmers have grinding tools of large dimensions, they had some of the largest ones yet found.

Morphofunctional characteristics

The Souloukia tools typically have only one work face. There are nine exceptions to this rule. Two passive (3%), five active (11%), and two indeterminate specimens have two parallel or diagonal work faces

8 See also *Bekiaris* et al. *2020.154*.

9 They measure 45.5x21x17.5cm, 42x28.5x20cm, 41x28.5x9cm, and 40x19.5x7cm.

with similar or different configurations. These numbers do not include tools with localized use wear on the dorsal face (see below). The scarcity of double work-face specimens indicates that creating two work faces was not a common means for prolonging a tool's use life at Souloukia. The higher percentage of active tools with two work faces, on the other hand, suggests that these were considered more appropriate for use with both faces than passive ones.

Regarding other Kitrini Limni assemblages, the situation varies. Double work-face tools are rare at Kleitos (*Chondrou 2020.299*), but more common at both Kremasti-Kilada (*Chondrou 2011.74–113; Stroulia* et al. *2017.4*) and Megalo Nisi Galanis (*Stroulia 2002.576*). Since all sites are found in the same region, the variation cannot be attributed to differences in raw material availability and accessibility, and instead possibly reflects individual or cultural preferences (see also *Robitaille 2021.815*). Whatever the case, a similar variation characterizes the Aegean as a whole. For example, specimens with two work faces account for roughly a quarter of the assemblage at Makriyalos (*Tsoraki 2008.91, Tabs. 5.14 and 5.24*), but close to 60% at Alepotrypa Cave (*Stroulia 2018a.207, 209*). There is a constant in the midst of this variation, however. Among tools with two work faces, active ones always represent the majority.

As documented by use wear analysis, the Souloukia grinding tools functioned in a reciprocal fashion. None was used in a circular/elliptical manner, even though such a suspicion was initially raised for a couple of roughly square or elliptical passive tools whose work face is concave along both axes. Use wear analysis, macroscopic examination, and/or morphometric characteristics of specimens from sites, such as Kremasti-Kilada (*Chondrou 2011.95–96; Stroulia* et al. *2017.4*), Kleitos (*Chondrou* et al. *2018.31; Chondrou 2020.293*), Avgi (*Bekiaris 2018. 230, 243*), Makri (*Bekiaris 2007.45*), Makriyalos (*Tsoraki 2008.98–100*), Koroneia (*Almasidou 2010. 100*), and Franchthi Cave (*Stroulia 2010a.40–46*), indicate that use in a back and forth manner was typical not only in Kitrini Limni but Greece in general (see also *Bekiaris* et al. *2020.143–144*).

Due to fragmentation, it has not been possible to securely identify the configuration of the work faces of all the Souloukia specimens. That said, a variety of configurations have been identified. Opposed work faces may or may not have the same shape.

Most commonly, the work faces of passive tools are concave both longitudinally and transversally (or concave/concave). At least 30 such specimens (48%) were identified (Figs. 5.b, 6–7). In this respect, the Souloukia assemblage appears to be atypical. No other assemblage from Kitrini Limni exhibits a preponderance of concave/concave passive tools; see Kleitos (*Chondrou 2020.293–294*), Kremasti-Kilada (*Chondrou 2011.85–88*; observation by Stroulia), and Megalo Nisi Galanis (observation by Stroulia). With a couple of exceptions, the same is true for assemblages from other sites, such as Franchthi Cave (*Stroulia 2010a*), Makriyalos (*Tsoraki 2008.99*), Iliotopos (*Chadou 2011.73*), Platia Magoula Zarkou (*Stroulia in press*), Dispilio (*Ninou 2006.28–56*), and Apsalos (*Ninou 2006.72–90*). The exceptions refer to the assemblages of Avgi (*Bekiaris 2018.228*) and Alepotrypa Cave (*Stroulia 2018a.207*).

Nineteen of the Souloukia passive tools (30%) have a work face that is concave longitudinally but convex transversally (or concave/convex) (Fig. 5.c–d). This is the second most frequent configuration among passive specimens. Both concave and convex curvatures can be only slight. Concave/convex specimens tend to be larger than concave/concave ones. Regarding other Kitrini Limni sites, concave/convex passive tools represent the majority at Kleitos (*Chondrou 2020.293–294*) but are rare at Megalo Nisi Galanis (observation by Stroulia). Likewise, in the Aegean in general such tools are common at some sites (see Platia Magoula Zarkou: *Stroulia in press*), less common at others (see Avgi: *Bekiaris 2018.228*), and nearly absent at others still (see Makriyalos: *Tsoraki 2008.Tab. 4.39*).

Lastly, four of the Souloukia passive tools have work faces that are convex along both axes (or convex/convex). This is an odd configuration and we can only hypothesize that these specimens were used *a posteriori*, the convexity representing the natural shape of the raw material.[10]

According to established typologies as well as ethnographic and experimental data, passive tools with concave/concave work faces are compatible with active tools whose work faces are convex/convex. Passive tools with concave/convex faces, on the other hand, are compatible with active tools that are also concave/convex (*e.g., Delgado Raack, Risch 2009.7; 2016; Lidström Holmberg 2004.213; Risch 2008.20; Robitaille 2016.443; Stroulia* et al. *2017. 19*).

10 For some Copper Age Iberial parallels, see Risch 2008.20.

Given the higher ratio of concave/concave *vs.* concave/convex passive tools at Souloukia, one would expect a concomitant higher ratio of convex/convex *vs.* concave/convex active specimens. Yet this is not the case: concave/convex active specimens surpass convex/convex ones by a ratio of 2.5 to 1. There are, moreover, three active tools with flat/flat work faces. These would have been compatible with passive flat/flat tools. No such specimens have been identified, however. The discrepancy between passive and active tools regarding work face configurations is as intriguing as those mentioned above with respect to numbers and sizes. More about this later, but it is worth noting that a discrepancy regarding work face shapes has also been noted in the assemblage of Alepotrypa Cave (*Stroulia 2018a.209*).

We close this section with two more morphofunctional features referring to active and passive tools, respectively.

❶ A small number of active tools are characterized by a wedge-like transverse section – the result of differential wear between the proximal and distal sides (Fig. 9.c). A similar configuration has been noted at Kremasti-Kilada (*Chondrou 2011.108; Stroulia* et al. *2017.4*) and Kleitos (*Chondrou 2020.295*). In the literature, this uneven wear has been mainly interpreted as the result of application of extra pressure on the proximal side of the tool during grinding (*Adams 2014.114; Bartlett 1933.11–16; Stroulia* et al. *2017.17–18*).[11] To avoid the negative effect of this unevenness on the tools' use lives, Hopi grinders traditionally employed a specific wear management strategy as they periodically rotated their 'manos' so that the proximal side became the distal one, and vice versa (*Bartlett 1933.15–16*). Clearly, such a strategy was not used for the wedge-like Souloukia active tools. Yet it may have been popular among the Souloukia grinders, or so is suggested by the lack of a wedge-like configuration among the majority of active tools.

❷ The work face of a handful of passive tools exhibits a very strong longitudinal angle (Figs. 5.d, 7). We assume that highly inclined gravels were deliberately selected. The rationale behind this choice remains elusive, however. We are not aware of such passive specimens from other Greek Neolithic sites, and if they exist, they are rare.

Processed materials

Before discussing the substances processed with grinding tools at Souloukia, we should note the following:

❶ Although almost all specimens were subjected to traceological analysis, microwear was identified on roughly half (n=59 or 47%). The microwear discussed in this section resulted from primary uses (for that pertaining to secondary functions, see next section).

❷ The series of experiments conducted in conjunction with use wear analysis involved: grinding free threshing wheat (both dry and parched); dehusking emmer wheat and subsequently grinding the clean grain; dehusking hulled barley and subsequently grinding the clean grain; grinding lentils (both dry and soaked); grinding dry and parched chickpeas; grinding acorns. All these experiments were carried out with the same gneiss grinding toolkit. The last two experiments – abrading a piece of stone and a bovine femur – involved the passive component of the toolkit only.

❸ Thirteen grinding tools (six passive, six active, and one indeterminate) were subjected to residue analysis. In eight cases, very few or no phytoliths were detected (*Ögüt 2018*). A low amount of phytoliths may be the result of prehistoric cleaning or a non-plant related use. The first hypothesis is likely for five of these specimens, which according to use wear analysis were used for plant processing. The second hypothesis is plausible for two specimens with use wear associated with an unspecified abrasive but flexible material. None of these hypotheses could be evaluated for the eighth specimen, whose use wear remains undetermined.

❹ The excavations yielded a large quantity of charred macrobotanical remains, only a small sample of which has so far been analysed. The sample is dominated by cereal remains – a reflection of the importance of cereal cultivation, processing, and consumption at the site. Four cereal varieties have been identified: einkorn wheat (*Triticum monococcum*), emmer wheat (*Triticum dicoccum*), 'new' glume wheat type, and hulled barley (*Hordeum vulgare*). A very high proportion of the assemblage consists of glume wheat chaff, presumably the by-product of dehusking. Whether the chaff was burnt in the context

11 But see Chondrou (*2020.295*), who considers the wedge-like transverse sections of active tools at Kleitos as the result of specific raw material choices and/or design.

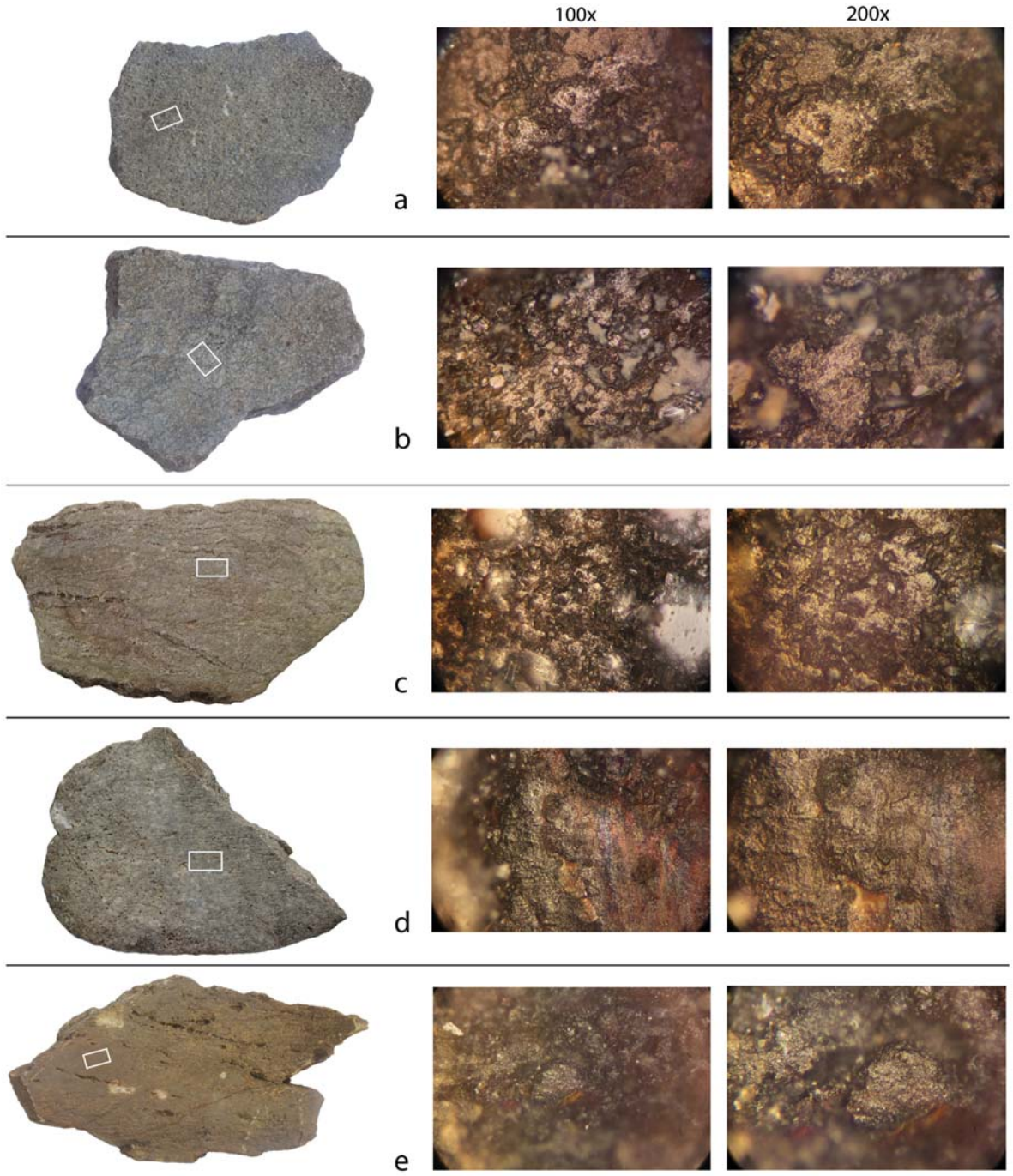

Fig. 10. Use wear views of work faces of specific tools at 100x and 200x magnifications (metallographic microscope):* a *GS252, use wear that appears consistent with cereal grinding;* b *GS268, use wear that appears consistent with cereal grinding;* c *GS292, use wear that appears consistent with grinding of wet (possibly soaked) lentils;* d *GS288, use wear resulting from processing an undetermined flexible but abrasive material;* e *GS285, use wear that appears consistent with grinding dry dirt or clay. Photos by J. Robitaille and A. Stroulia.

of accidents or utilized as fuel is impossible to tell. Pulses are present in low proportions, with lentils (*Lens culinaris*) being the most common. Fruits, such as cornelian cherry (*Cornus mas*), are also represented in very small amounts, while wild/weed species (*Chenopodium* sp. and *Polygonum aviculare*) occur very sporadically.

The cereal dominance noted among macrobotanical remains is mirrored in the results of use wear analysis. Over 75% of tools with identifiable microwear show traces compatible with processing cereals – dry emmer and barley, to be more specific (Fig. 10.a and b). Five of these specimens were subjected to residue analysis. Of these, the phytoliths found on the

work faces of four also suggest a cereal-related function (Fig. 11). However, differences in the proportions of weathered and multicellular morphotypes lead us to suggest that two were used for grinding, while the other two may have been used for dehusking.[12] The morphotypes found on the work face of the fifth specimen were too weathered to allow a determination of the processed plants (*Ögüt 2018*). At any rate, it appears that cereals were processed on passive tools with work faces of all configurations (concave/concave, concave/convex, and convex/convex). The active tools used for these tasks are both concave/convex and convex/convex. Clearly, there is no association between cereal grinding and a specific toolkit type.

Judging from the results of traceological analysis of specimens from other sites – *e.g.*, Kremasti-Kilada, Kleitos, Ayios Vlasis, Stavroupoli, and Dikili Tash (*Chondrou* et al. *2021; Stroulia, Dubreuil 2011.3*) – cereal processing may have been the dominant function of grinding tools in both Kitrini Limni and the Aegean as a whole. As a rule, clean grain was ground. Only a few specimens from Ayios Vlasis, Stavroupoli, and Dikili Tash carry evidence of hulled grain grinding. However, an association with dehusking was proposed with a reasonable degree of confidence for only a couple of specimens from Ayios Vlasis. In all other cases it was not possible to assess whether the end goal of grinding was dehusking or the production of a fibrous meal that may or may not have been later subjected to some kind of cleaning (*Chondrou* et al. *2021.7–9*; see also *Procopiou 2003.23–33*). Either way, the available data suggest that in Neolithic Greece grinding tools were not typically used for dehusking. Given the pervasiveness of chaff (*Valamoti 2010*) and the paucity of (suitable) stone mortars (*Bekiaris* et al. *2020. 144; Stroulia 2020.5*), it can be assumed that this task was carried out by pounding grains on wooden mortars or with other ethnographically known methods that would leave no archaeological signature under ordinary taphonomic conditions (see *David 1998.25–28; D'Andrea, Mitiku 2002.204; Hillman 1984.129–131; Peña-Chocarro, Zapata 2003. 107–110; 2014.230–231; Robitaille 2021.241–242*).

The use wear of a handful of Souloukia specimens appears compatible with that produced by the experimental grinding of wet (probably soaked) lentils (Fig. 10.c). Four are active with concave/convex or convex/convex work faces, and one is passive with a concave/concave work face, suggesting a lack of differentiation between the toolkits employed for cereal and pulse processing.

While known for some time for Bronze Age Cyclades (*Sarpaki 2001.32*), legume grinding was documented only recently for prior time frameworks through use wear analysis of later Neolithic tools (*Chondrou* et al. *2021.2*). The Souloukia findings now extend Aegean pulse flour production farther back, to the earlier part of the Neolithic, as do the new findings from the neighbouring site of Mavropigi-Fillotsairi (*Ninou forthcoming*).

Use wear analysis of four tools points to grinding a flexible but abrasive material (Fig. 10.d). Residue analysis carried out on two of these specimens detected a minor amount of phytoliths, raising the possibility of a use unrelated to plants (*Ögüt 2018*). All tools are passive, with work faces that are concave/concave or concave/convex. What was processed on

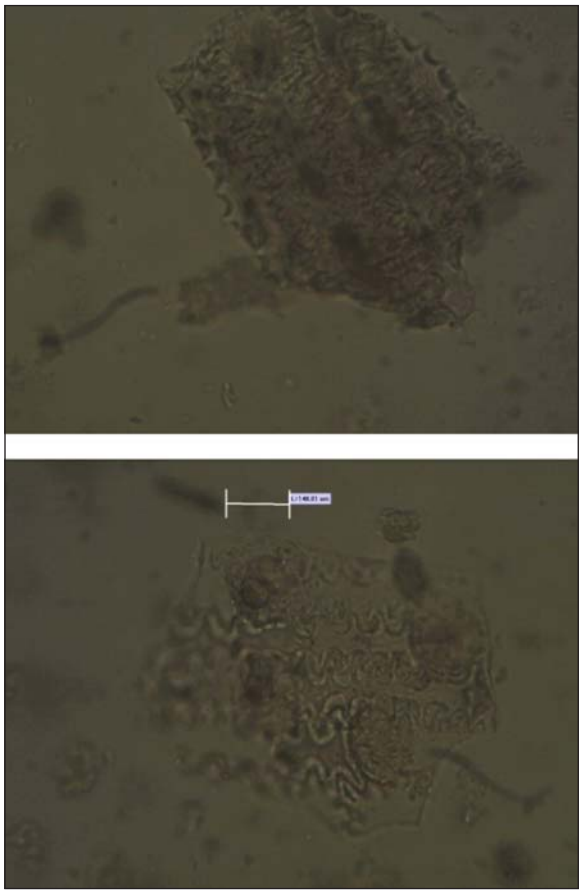

Fig. 11. Cereal phytolith silica skeletons from passive grinding tool GS309. Photos by B. Ögüt.

12 Regarding dehusking, the results of use wear analysis were inconclusive. The possibility that the same work faces were used for both grinding and dehusking cannot be ruled out.

these tools will hopefully be clarified through further experimentation.

No use wear compatible with acorn processing has been detected on the Souloukia tools. Danai Chondrou *et al.* (*2021.5*) reported Greek Neolithic specimens with microwear consistent with processing of 'greasy' substances, but whether the term refers to nuts, oily seeds, or both has not been clarified.

The Souloukia tools yielded no evidence of pigment processing either. In this sense they appear to follow a more general pattern. The association of grinding tools with pigment is relatively uncommon in the Neolithic Aegean. For some reported specimens, see Makri (*Bekiaris 2007.45*), Theopetra Cave (*Kyparissi-Apostolika 1996.68*), Stavroupoli (*Alisøy 2002. 573*), Dikili Tash (*Séfériadès 1992.91*), Avgi (*Bekiaris 2018.229–232, 244*), Makriyalos (*Tsoraki 2008. 95, 98*), and Drakaina Cave (*Bekiaris in preparation*).

To conclude, the Souloukia grinding tools were primarily meant for processing foodstuffs. This is precisely what is expected on the basis of ethnographic data (*e.g., Bartlett 1933.3; Hamon, Le Gall 2013.109; Nixon-Darcus, D'Andrea 2017.193; Robitaille 2016. 433; 2021.773; Roux 1985.34–38; Searcy 2011.1*).

Reuse, recycling, use intensity

With one uncertain exception, there is no evidence of redesigning among the Souloukia grinding tools. The assemblage, nevertheless, includes 27 specimens (21%) with traces of reuse and recycling. The term 'reuse' refers here to similar uses of different parts of a tool, while 'recycling' refers to different uses of the same tool. Only one tool carries firm evidence of reuse. It is active with two work faces, both of which show wear consistent with cereal grinding. A large portion of the tool is missing, but the two faces appear to have different configurations – possibly a reflection of use with different passive work faces or kinematics.

Firm evidence of recycling has been identified on many more tools. Most (n=13) are passive. We have distinguished three varieties of recycling among passive tools. In none did recycling entail an active function. In the first and most common variety, the face which served the primary use was also involved in recycling. There are several combinations. In the most frequent among them, a work face was used first for grinding and later (only locally) for abrading (five instances). Other combinations are rarer, each typically represented by a single specimen: grinding an undetermined substance followed by (a) grinding a flexible but abrasive material; (b) grinding an unspecified soft material; (c) grinding dry dirt or clay (Fig. 10.e); (d) percussion. The last case involves the largest specimen in the assemblage (weighing over 25kg). Percussion took place in two stages, resulting in a larger, roughly ovate, concave area and an overlapping smaller, deeper, more circular area. Unfortunately, microwear was not preserved, leaving the precise use/s of these areas undetermined. Given their shallowness and the lack of clear borders, however, cereal dehusking is unlikely. In the second variety, the primary use involved one work face, recycling another. This variety is represented by two specimens: in the first, one of the work faces was used for cereal grinding, the other for processing a flexible but abrasive material; in the second, the work face was used for grinding an unspecified substance, the dorsal one for abrading. The third variety blends the previous two, with recycling involving both the work and dorsal faces. It is represented by a single specimen: its work face was used first for grinding and then (locally) for abrading, while the dorsal face was used for (localized) abrading as well (Fig. 6.a).

Seven active specimens were recycled. In all cases, recycling consisted of a double conversion of an active grinding tool to a passive abrading one. In all but one case, both primary and secondary uses involved a single face (Fig. 8.b). In the exception, primary and secondary uses were carried out by the work face and dorsal face, respectively (Fig. 8.d).

Finally, one of the indeterminate passive or active specimens was first used for cereal grinding and then for abrading with the same face.

Determining the abraded material was not possible in all cases. When it was, use wear was associated with bone or wood processing. No evidence of stone abrasion was identified.

Generally speaking, the recycling of several grinding tools at Souloukia into abrading implements suggests a certain flexibility on the part of the users regarding the two categories. That most cases of recycling involve such a conversion suggests that this was considered an appropriate use life trajectory for grinding tools. The fact, moreover, that most of the grinding tools used for abrading are complete and/or relatively thick indicates that recycling was not typically associated with breakage or exhaustion. Rather

the choice was made to divert some perfectly good grinding tools to abrading usages. The infrequent secondary use of active specimens for passive grinding and the complete absence of the reverse type of recycling, on the other hand, indicate that passive and active grinding implements were largely conceived as different categories. Finally, that only one grinding tool was used in a percussive manner suggests that grinding and pounding functions were largely performed by different tools, and therefore grinding and pounding implements were conceived as distinct categories as well.

Not only do grinding tools exhibit a relatively low rate of reuse and recycling, but they were also used less than expected. This is well illustrated in both the thickness range (3.1–20cm) and average (6.9cm).[13] Schön and Holter (*1990.362–363*) reported that among the Mahria of Sudan, a passive tool is considered useless "*when it is thinner than 1cm,* i.e., *when a hole appears*". Active tools "*become useless when they ... get too thin,* i.e. *become barely 3cm or less in the middle and measure only a few millimetres at the edges*". Writing on Guatemalan tools, Michael T. Searcy (*2011.103*) noted that: "*It was not uncommon to see manos that were extremely thin (around 3cm), leaving the woman grinding only enough stone on the edges to hold with her fingertips*". If the Souloukia grinders had similar degrees of tolerance and similar ideas about the limits of their tools as their ethnographic counterparts, then none of the specimens can be considered exhausted. However, the situation is slightly more nuanced, as explained below.

Both the thickness range and average of the Souloukia specimens mentioned above refer to maximum measurements. However, minimum thickness is informative about use intensity and exhaustion, too. A handful of passive tools have a high maximum thickness but a very low minimum one. In fact, these specimens are broken in the area of minimum thickness. We consider these to be worn out (Fig. 5.d, 6.d).

If thickness offers a way to assess tool exhaustion, it is not the only one. The degree of concave curvature can also serve as an exhaustion indicator, at least in passive tools. According to Roux's ethnoarchaeological study in Mauritania, reciprocally operating passive tools with unrestricted work faces are discarded when reaching a depth of 4–5cm since they are not comfortable to use (*Roux 1985.57*). A comparable limit has been noticed by Jérôme Robitaille (*2021.398–399*) among the Hamar of Ethiopia who discard or recycle their passive tools when the work faces become 4–7cm deep. On this basis, two Souloukia tools with work faces deeper than 4cm can be considered as exhausted, too (Fig. 6.b). However, another Ethiopian group provides a note of caution: some of the passive implements used by the Konso are 25–30 cm deep. These tools are passed from generation to generation, their use lives reaching up to a hundred years (*Robitaille 2021.Appendix 138–142*) (Fig. 12).

Be that as it may, the vast majority of grinding tools at Souloukia were abandoned long before the end of their use lives. Why this is so is a question that will be addressed when the study of the stratigraphy, features, and other finds is completed, and the assemblage is viewed in the context of the site occupation as a whole. What we can say for the moment is that a similar conclusion was reached with respect to the assemblage from Kleitos (*Chondrou 2020.300–301*). Indeed, as a rule, Greek Neolithic assemblages are not dominated by exhausted tools. For a couple of exceptions, see Dikili Tash and Ayios Vlasis (*Chondrou, Valamoti 2021. 68*).

Spatial distribution, processes of discard

All six abrading tools, 45 grinding tools, three possible roughouts, and 15 unmodified pieces of raw material derive from the main residential area of the settlement.[14] Forty percent of the tools are complete or nearly so (15 grinding and three abrading tools). These were not found in association with the substances and objects they processed or (in the case of grinding implements) as parts of toolkits. The majority were likely not *in situ*. Both this and the absence of joining fragments suggest a certain post-use or post-breakage[15] movement of tools around space. This hypothesis is supported by the fact that a couple of fragments were converted into building materials, while another ended its biography in a pit.

However, the largest portion of the assemblage (almost 60%) was excavated outside the main residential area. This material comprises 81 of the grinding

13 These numbers refer to both complete and fragmentary specimens.

14 Whether they come from house interiors or open areas is unclear since the analysis of the excavated features and stratigraphy is pending.

15 As appealing as it may be, the hypothesis of storage of complete grinding tools in-between use episodes is not satisfactory, since it raises the question as to why only one component of the toolkit was stored away.



Fig. 12. Passive tools with very concave work faces used by Konso women in Ethiopia. Photo by J. Robitaille.

tools (64%), one roughout, as well as 17 gneiss gravels and one tabular sandstone piece without traces of manufacture or use – a total of 100 specimens. Notably, fifteen of the grinding tools are complete, representing half of all the complete specimens found at the site. Equally significant, grinding tools make up the only macrolithic type with a higher representation in the non-residential sector. Abrading tools, celts, hammerstones, and so on were exclusively or primarily found in domestic contexts.

Even more remarkably, most of the extra-residential grinding tools (n=63), along with several unworked gneiss cobbles and boulders, derive from an area measuring *c.* 300m^2 and located about 40m away from the house remains. These specimens were found in no particular arrangement, along with sherds, a substantial number of quartz pieces, a few figurine fragments, a concentration of rocks, as well as masses of clay probably from a small structure (Figs. 2.f, 13). Residue analysis of soil samples from this area detected a significantly lower density of phytoliths than those found on the tools (*Ögüt 2018*), arguing against the *in situ* use of these specimens. This hypothesis is reinforced by both the extremely high tool density in this area as well as the lack of a match between the work face configurations of passive and active specimens (most of the former are concave/concave, while most of the latter are concave/convex). More likely, these implements were transferred to this spot after utilization somewhere else. In fact, general differences in the characteristics of phytoliths identified on the tools and the control soil samples appear to indicate that these tools were amassed not at once, but gradually, over a period of time (*Ögüt 2018*). Where these specimens originated, we cannot tell for sure. Yet we consider the residential area as the most likely candidate, especially given the aforementioned indirect evidence of post-use and post-breakage movement of tools.

We do not know why this material would have been taken out of the residential space. However, the hypothesis that this area served as a locus of discard for broken or worn-out grinding implements should be ruled out, since this assemblage includes roughly ten complete specimens, none of which is exhausted. Nor is the provisional storage of tools with the intention of future reuse/recycling in the domestic arena (see *Tsoraki 2008.143*) a better explanation, since this assemblage includes several recycled specimens.

Be that as it may, the movement of material outside the residential area is not new in Aegean Neolithic archaeology. It is known, for example, from Kremasti-Kilada, a site in the Souloukia neighbourhood where massive quantities of artefacts, animal bones, building material, and so on were found within roughly 460 non-residential pits (*Chondrou 2011. 52; Chondroyianni-Metoki 2009.387–389; 2020.54–56; Stroulia 2010b.63; Stroulia, Chondrou 2013. 109; Stroulia* et al. *2017.2–3*). It is also known from Makriyalos, a site farther east in Macedonia, where enormous amounts of material were deposited into a huge negative feature known as Pit 212 (*Pappa* et al. *2004.84; Tsoraki 2008.126, 135*). Macrolithics, and grinding tools in particular, feature prominently in both deposited assemblages. Both Kremasti-Kilada and Makriyalos are later than Souloukia, but the combined evidence from all three sites possibly suggests that the transfer of material to areas outside the residential space took place at a small scale in the earlier phases of the Neolithic, but intensified in the later ones.

Moving perfectly usable tools out of domestic contexts may have not been enough for the people of Souloukia. The fact that the extra-residential concen-

tration contains 66% of all active specimens but 51% of the passive ones raises the suspicion of an extra layer of manipulation. If our suspicion is correct, active and passive tools were treated differently, or to be more specific, the former were targeted for transfer more often than the latter. Why Souloukiotes would engage in such behaviour is anyone's guess, but if they did, they may have also moved active tools to other portions of the site that remain unexcavated. That would explain both the discrepancy between the numbers of passive and active specimens and the mismatch between their sizes and work face configurations mentioned above.

The differential treatment of passive and active tools is unexpected in light of the practical complementarity of the two implements. As stated by Cecilia Lidström Holmberg (*2004.226*), grinding toolkits represent "*dual objects with two parts that continuously construct each other*". It is also striking in light of ethnographic evidence that underscores the symbolic complementarity of the two grinding components. Among the Bemba of Zambia and the Hopi of the US Southwest, the relationship between a passive tool and an active one was used as a metaphor for the relationship between male and female identities and roles (*Lidström Holmberg 2004.227*), while among the Mursi of Ethiopia (*Robitaille 2016.434*), the Minyanka of Mali (*Hamon, Le Gall 2011.27*), and the Zapotec of Mexico (*Lidström Holmberg 1998.134; 2004.228*), it is/was used to convey the close link between a mother and a child. According to the Mursi in particular, "*the handstone must rest well on the grinding slab, just as a baby does on its mother's back*" (*Robitaille 2016.434, Fig. 3*) (Fig. 14).[16]

Unexpected as a differential treatment of passive and active tools may be, unequivocal evidence for such behaviour has been identified at another Kitrini Limni site. According to Chondrou (*2020.302–303*), all but one of the specimens found inside pits at Kleitos (I) are passive. Comparable patterns are known from two sites beyond Kitrini Limni. At Stavroupoli, one of the pits included mostly passive tools, while another featured primarily active ones, indicating a certain "*structuring of how and where material was deposited*" (*Alisøy 2002.581–582*). At Makriyalos, the passive specimens found within Pit 212 outnumber active ones by a ratio of *c.* 6:1 (*Tsoraki 2008.143, Tab. 6.28*).[17]

This phenomenon deserves systematic comparative study, but at this point we would like to point out three differences between Souloukia and these three sites. The first has to do with the state of preservation of the tools subjected to differential treatment. While at the other sites almost all specimens are broken, at Souloukia some are fragmentary, others are not. The second difference has to do with the features from which these tools were recovered. While at the other sites they were found in negative features, at Souloukia they were not. The third difference has to do with time. While the other sites date to the later Neolithic, Souloukia belongs to the earlier Neolithic. The significance of these differences remains to be investigated, but for the moment we would like to suggest that Kitrini Limni was the locus of selective grinding tool deposition in both the earlier and the later part of the Neolithic.

Epilogue

Despite the recent dramatic growth of Aegean macrolithic studies, very little is known about materials from the earlier part of the Neolithic. Our study of the grinding and abrading tools from the site of Pon-



Fig. 13. Partial view of concentration of grinding tools and unworked gravels in the non-residential sector of the site. Photo by A. Chondroyianni-Metoki.

16 For a different perspective, see Chondrou (*2020.303*).

17 For a few non-Greek examples of a differential treatment of passive and active tools, see Lidström Holmberg (*2004.222, 229–230*).

tokomi Souloukia, in the Kitrini Limni Basin, represents an attempt to address this gap.

By integrating systematic macroscopic examination, use wear and residue analysis, as well as macrobotanical, experimental, contextual, and ethnographic data, we explored these tools' raw materials, technomorphological characteristics, and functions, discussed their spatial distribution, and shed light on the ways they were conceived by their producers and users.



Fig. 14. Mursi lady grinding wheat outside the house with her baby on her back. Among the Mursi, 'golu oiné', the term used for the passive implement, means mother, while 'golu joiné', used for the active tool, refers to a baby. Photo by J. Robitaille.

The assemblage includes a small number of abrading tools. All are *a posteriori* and mostly of fine-grained sandstone obtained from a regional source. According to traceological analysis, wood and bone are the two materials processed with these tools. No evidence of stone processing was identified, but the several dozen celts excavated from the site hint at the presence of unrecovered abrading implements, perhaps close to sources of water.

The number of grinding tools is much higher, comprising over a hundred specimens. These were made of gneiss (another regional material) in a manner that was far from involved. Most were used in processing foodstuffs, cereals being the most common. A number were used for abrading purposes in the context of recycling. Generally speaking, grinding tools were not used as intensely as one would expect given the substantial masses of raw material they represent. Our study, moreover, pointed to discrepancies between the numbers and configurations of passive and active specimens that possibly resulted from differential discard processes.

Throughout this paper, comparisons were made with other sites in the area and elsewhere in an attempt to place the Souloukia assemblage in both a regional and a broader Aegean framework. These comparisons revealed, for example, that: similar abrading tools of similar material were employed at various sites of the Kitrini Limni basin; sites located at different parts of the basin used the type of gneiss that could be found in the nearest sources; the high proportion of concave/concave passive tools noted at Souloukia is not known from other Kitrini Limni assemblages and is extremely rare in Neolithic Greece as a whole; and the deposition of substantial amounts of material in non-residential areas at Souloukia parallels that known from a few later Neolithic sites in Kitrini Limni and elsewhere.

For the most part, these comparisons refer to later Neolithic assemblages. The one with which we close this paper references earlier assemblages, offering some insights into the roles of grinding tools in the context of the first Aegean agropastoral communities. While sufficient data for a meaningful and systematic assessment of the morphometric, techno-functional, and contextual characteristics of the few known earlier Neolithic assemblages is for the most part missing, basic information about the sizes of some of them is available. It thus appears that at certain sites – *e.g.*, Achilleion (*Winn, Shimabuku 1989. 268*), Sossandra (*Georgiadou 2015.42–43*), Revenia Korinos (*Besios, Adaktylou 2004.363*), and Ayios Vlasis (*Bekiaris* et al. *2020. 145*) – grinding tools were common as they were at Souloukia. At other sites – *e.g.*, Mavropigi-Fillotsairi (*Ninou* et al. *in press*), Paliambela Kolindros (*Tsartsidou, Kotsakis 2020.11*), and Prodromos (*Moundrea 1975.92–99*) – they were rare. The paucity of grinding implements cannot be considered an artefact of excavation biases since substantial areas were investigated at these sites or other macrolithic tools were found in considerable quantities. For example, the extensively excavated site of Mavropigi-Fillotsairi yielded only one specimen positively identified as a grinding tool (*Ninou* et al. *in press*). Prodromos yielded over 40 celts but only two passive grinding tools and (as far as we can tell) no active ones (*Moundrea 1975. 92–99*). The Early Neolithic strata of Paliambela Ko-

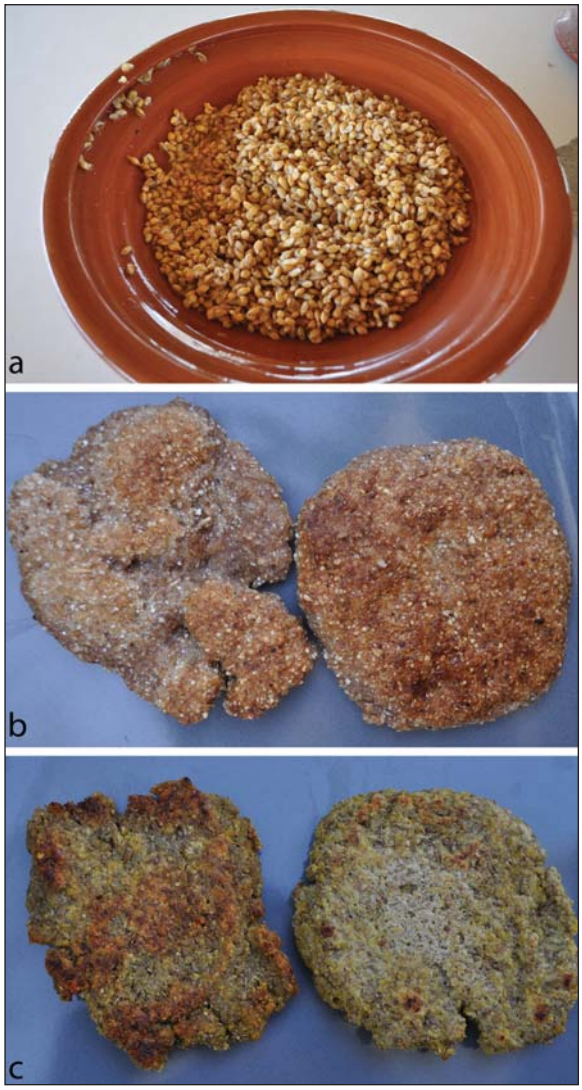

Fig. 15.* a *Boiled wheat grains such as those used for the traditional Greek dish koliva:* b *emmer wheat flat cakes;* c *lentil flat cakes. Photos by A. Stroulia.

lindros – one of the most systematically excavated sites in Greece – are characterized by an almost complete absence of grinding tools (*Tsartsidou, Kotsakis 2020.11*). This scarcity does not appear to reflect a different kind of occupation either. None of these sites represents a special use or seasonal settlement. Nor, lastly, does it appear to correlate with an absence of cereals and pulses, the types of substances typically processed with grinding tools. Such plant remains were found, for example, at both Mavropigi-Fillotsairi (*Karamitrou-Mentessidi* et al. *2013.2*) and Paliambela Kolindros (*Kotzamani, Livarda 2018.86–89; Tsartsidou, Kotsakis 2020.12*).

Without a thorough study and publication of earlier Neolithic assemblages, this discrepancy cannot be explained systematically. However, we would like in a preliminary fashion to offer two alternative hypotheses.

According to the first hypothesis, the discrepancy reflects two broad types of cereal and legume preparations. On the one hand, there were recipes that involved boiling, toasting, or parching of whole, split, or cracked seeds; *e.g.*, soups, stews, gruels, bulgur, koliva, *etc*. (for experimental versions of such preparations, see Fig. 15.a, *Dimoula* et al. *2020.Fig 5g*).[18] Grinding had no part in these preparations. On the other hand, there were recipes that involved flour/meal and thus required the use of grinding tools; *e.g.*, regular bread, flat bread (*e.g.*, pita or naan type), falafels, *etc*. (for experimental versions of two of these preparations, see Fig 15.b–c). In the context of this hypothesis, in some earlier Neolithic Aegean communities there was an emphasis on the first type of recipes. In others, the second type of recipes was used, either exclusively or alongside those of the first type.

If real, this distinction existed even within the same area: Mavropigi-Fillotsairi is less than 3km from Souloukia, while Paliambela Kolindros is not far from Revenia Korinos. Such culinary identities may have had a cultural/ethnic origin, reflecting the ancestral homelands of the different groups that occupied the Greek landscape at the beginning of the Neolithic (see also *Valamoti 2017.178–184*).

According to the second hypothesis, the scarcity of grinding tools at some sites is due to specific practices that involved the removal of tools from residential areas. Such practices would have amounted to more massive versions of the deliberate transfer of specimens identified at Souloukia.

We consider the former hypothesis as more likely than the latter, but both (and possibly others) should be tested when we acquire a better understanding of each individual assemblage. Be that as it may, such strong discrepancies in the sizes of grinding tool assemblages are not visible in the archaeological record of the later part of the Neolithic. During this period, more or less substantial numbers were the norm.

18 According to Sonya Atalay and Christine A. Hastorf (*2006.298–311*), these were common preparations for cereals and pulses in the Early Neolithic component of Çatalhöyük.

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'Animal farm': the faunal record from the Chalcolithic Ota site (Alenquer, Portugal) and its regional significance

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ABSTRACT – *This paper presents the results of the excavations carried out in the Chalcolithic contexts from the walled enclosure of Ota (Alenquer, Portugal). Six new absolute dates allow the discussion of the stratigraphical evidence and chronologically frame the zooarchaeological and taphonomical analysis of the faunal assemblage. Domesticated swine, caprine and bovine are prevalent, while wild species, most notably leporids, but also red deer, auroch and wild boar, among others, are less common. Exploitation and management of animals for the acquisition of primary and secondary products are inferred. Existing data suggests that the economic intensification that started during the previous phases was ongoing.*

KEY WORDS – *Chalcolithic; southwestern Iberia; zooarchaeology; taphonomy; walled enclosure*

'Živalska farma': favnistični zapis iz halkolitskega najdišča Ota (Alenquer, Portugalska) in njegov regionalni pomen

IZVLEČEK – *V članku predstavljamo rezultate izkopavanj halkolitskega konteksta v ogradi v Oti (Alenquer, Portugalska). Šest novih absolutnih datumov omogoča razpravo o stratigrafiji in kronološko zamejuje arheozoološke in tafonomske analize živalskega zbira. V njem prevladujejo udomačeni prašiči, drobnica in govedo. Manj pogoste so divje vrste, zajci, navadni jelen, tur in divji prašič. Domnevamo, da so z živalmi upravljali in jih izkoriščali za primarne in sekundarne produkte. Podatki kažejo, da se intenzivna izraba, ki se je začela v predhodnih fazah, nadaljuje.*

KLJUČNE BESEDE – *halkolitik; jugozahodni Iberski polotok; arheozoologija; tafonomija; ograde*

Introduction

The third millennium BCE is a key phase of human history in the Iberian Peninsula. It is marked by an important social complexity and economic intensification that started during the Late Neolithic (~3500/3200–3000 cal BCE) and further developed during the Chalcolithic (3000–2000 cal BCE). The appearance and development of complex societies throughout the Chalcolithic (*Cruz Berrocal* et al. *2013*) and the different social perspectives in the transition to the Early Bronze Age (*Valera 2015*) are some of the important topics that have been a matter of debate among our colleagues.

The beginning of the third millennium BCE marks the emergence of new domestic architectures in the archaeological records, understood as "*Walled enclosures*" (*Jorge 2003*). Although not exclusive to this area (*Gonçalves 1989; Molina, Cámara 2005;*

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Jorge et al. *2006; Mataloto 2010*), the Portuguese Estremadura presents a high density of these types of sites. Its Western region concentrates 14 out of the 22 known walled enclosures, but the information on these is imbalanced – only four have had archaeological excavations in the last decade and a half, and only four have absolute chronologies, with the large site of Zambujal having 25 dates and the remaining three sites only having eight dates. Because they are generally placed on the top of hills that grant them wide visual control of the surrounding landscape, these sites are characterized by a new way of occupying space. They are recurrently placed near water sources that would function as a source of raw materials and subsistence, but also as a way of communication and connection to other areas and social networks. Other common characteristics are architecture and construction techniques. Structures such as 'walls', towers and doors are built with the drystone technique reaching areas with a maximum of 5ha (*Kunst 2010*) and structures with 200m in length (*Texugo 2022*). These structures are a novelty in the region, and continuously go through reformulations and changes that might bias the preservation of the archaeological record.

Fauna has also been an important part of the discussion regarding economic intensification (*Valente, Carvalho 2014; Almeida, Valera 2021; Almeida* et al. *2021b*). The larger sites from the Portuguese Estremadura have historically been used as guidelines for palaeoeconomic debates (*e.g., Driesch, Boessneck 1976; Cardoso, Detry 2001/2002*), but at the same time hindered the understanding of possible variability. The publication of other assemblages from the Estremadura (*Correia 2015; Moreno-García, Sousa 2015; Detry* et al. *2020*) and the comparison with the southern Alentejo region (*Arnaud 1993; Davis, Mataloto 2012; Costa 2013; Moreno-García 2013; Almeida, Valera 2021*) is only more recently being achieved. The first results for animal diet and mobility have been published (*Waterman* et al. *2015; Žalaité* et al. *2018; Wright* et al. *2019; Valera* et al. *2020b*), showing differences in the management and exploitation of fauna not only between the Neolithic and Chalcolithic but also within the Chalcolithic.

In the western region, the 666m Montejunto hill is oriented NE-SW, visually impacting the area while also polarizing the surrounding landscape and cultures (*Basílio, Texugo 2017; Basílio in press*). This hill has several river springs that determine its relationship with the surrounding areas. From an archaeological perspective, its natural caves have funerary uses dated at least from the Middle Neolithic (*Carvalho* et al. *2019*) to the Bronze Age (*Gonçalves 1992*). This highlights that there seem to be different spatial relationships and meanings that might dictate how the communities were spread throughout the territory and the different cultural influences and expressions (*Basílio in press*), as is the case of the archaeological site of Ota. In this paper, we present the results of the archaeological excavation of the Ota walled enclosure (Alenquer, Portugal), located less than 10km from Montejunto hill. We will focus on the unpublished absolute dates and the faunal record aiming to contribute to debates on resource exploitation and management during the Chalcolithic in western Iberia. We will also present an in-depth taphonomical analysis of the assemblage, uncommon for the period and region under analysis, which will allow for a clearer understanding of the faunal accumulation and site use.

Materials and Methods

Materials

Ota site is located about 50km north of Lisbon in the heart of the Portuguese Estremadura region, and, like its 22 counterparts, belongs to the walled enclosure phenomenon (Fig. 1). It shares, along with the great majority of these, chronological synchrony in its discovery in the first half of the 19th century, by Hipólito Cabaço, when the ground visibility scenario was different, mostly due to efficient forest management and the existence of communal herds. Currently, Ota is densely populated with *Quercus coccifera, Olea europaea* var. *sylvestris, Rubus ulmifolius, Pinus pinaster* and, in scarce instances, *Eucalyptus globulus*. This vegetation results from thin soils, already attested in Ota during 2019, 2020 and 2021 fieldwork, reducing the surface visibility and the results of archaeological surveys. In lithological terms, the region is composed of Mesozoic sedimentary rocks and a small area of Cenozoic sediments, meaning that past communities were surrounded by limestones, sands and clays (*Ramos-Pereira* et al. *2020*), using them as the raw materials for different architectures and artefacts. The geological framework originates in a landscape marked by small mountains, hills, interior plateaux, plains, and littoral platforms (*Ramos-Pereira* et al. *2020*), with the western region, where Ota is integrated, being particularly relevant.

Regarding climate, paleoenvironmental reconstructions suggest that the first changes in regional vege-

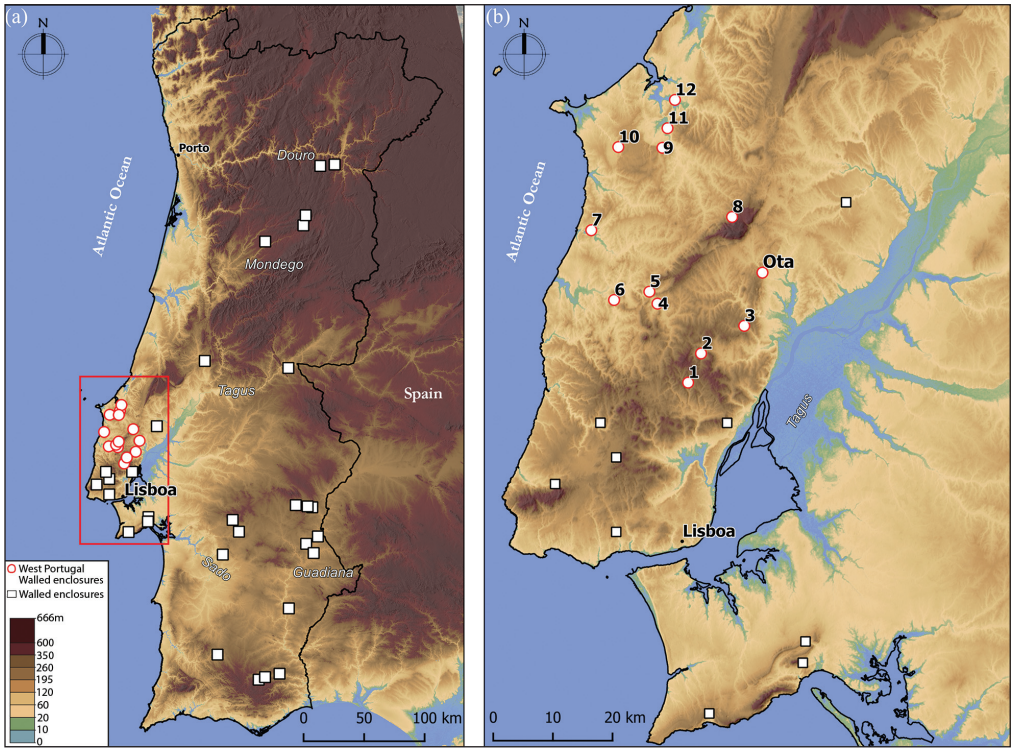

Fig. 1. Distribution of Walled Enclosures in Portugal (a) with a zoom-in at the western cluster (b), where the Ota archaeological site is located. The sea level reconstruction is based on Lord* et al. *(2011). 1 Moinho do Custódio; 2 Castelo; 3 Pedra d'Ouro; 4 Penedo; 5 Fórnea; 6 Zambujal; 7 Pitagudo; 8 Pragança; 9 Columbeira; 10 Paço; 11 Outeiro de S. Mamede; 12 Outeiro da Assenta.

tation by anthropic influence, detected in pollen shifts, occurred around 5400 BCE, with the beginning of cereal cultivation (*Lord* et al. *2011*). As for the mean sea level and coastline changes, it was observed that they remained stable between 9300 BCE and 2900 BCE (*Lord* et al. *2011*). In this period, periodic floods were identified, a behaviour that changed with the progression of marine transgression (*Lord* et al. *2011*). In sum, the chalcolithic climate seems close to the current Estremadura climate, characterized by a 'Csa' hot-summer Mediterranean climate (*Kottek* et al. *2006.Fig. 1*) with average temperatures of 17°C and annual precipitation between 700mm and 900mm (*Mora, Vieira 2020*).

The archaeological site of Ota was the target of the archaeological surveys in the framework of a more exhaustive investigation (ROSETTA project) which aims to study the Chalcolithic architectures of the western walled enclosures through remote sensing. In the case of Ota, the LiDAR survey allowed the discovery of 21 high potential archaeological anomalies through the use of the LiDAR sensor in a system mounted in a UAS (a DJI Matrice 600 Pro with a Phoenix LiDAR Scout-8). To understand, evaluate, test and confirm the results obtained by remote sensing, three excavation campaigns were carried out. These resulted in 90 days of intervention between 2019 and 2021.

The selected excavation areas relate not only to the anomalies detected but also to potential chalcolithic structures. The strategy adopted thus aimed to determine, in the first place, a vital structure for the definition of the walled enclosures – the wall. Next, and based on the previous knowledge of Wall 1, we understood the potential use of the natural geological platforms to define an occupation made in embankments. This corresponds to Structure 9, which materializes the symbiotic relationship between the anthropic architectures and the limestone substratum. Finally, the area where more work has been carried out relates to Structure 3, not only to understand the structure itself, possibly unique within the Chalcolithic walled enclosure phenomenon, but also to understand the sites' historiography and Cabaço interventions, of which no records are available.

Structure 1

The two surveys carried out on the wall, at different points of its layout, aimed at the typological classification and clarification of its construction rhythms and temporalities. The first one is to the north end (survey 1), and the second survey is in the south

end, 150m away from the first one, giving a total of 38m² of excavated area (Fig. 2).

In stratigraphic terms, only two sedimentary deposits were intervened. The first, [1007], is also the oldest, lying directly on the limestone base platform. In this one, there were few records of fauna, ceramic and lithic artefacts. However, there was very considerable chronological homogeneity, with all the elements pointing to prehistoric contexts. This deposit was covered and sealed by a second deposit, [1006], composed of a group of small and medium-sized stones enclosed in compact clayey sediment. The [1006] deposit contains the most significant archaeological materials from Structure 1 – the wall – in which the bone of *Ovis/ Capra* was found, providing the absolute dating of this structure.

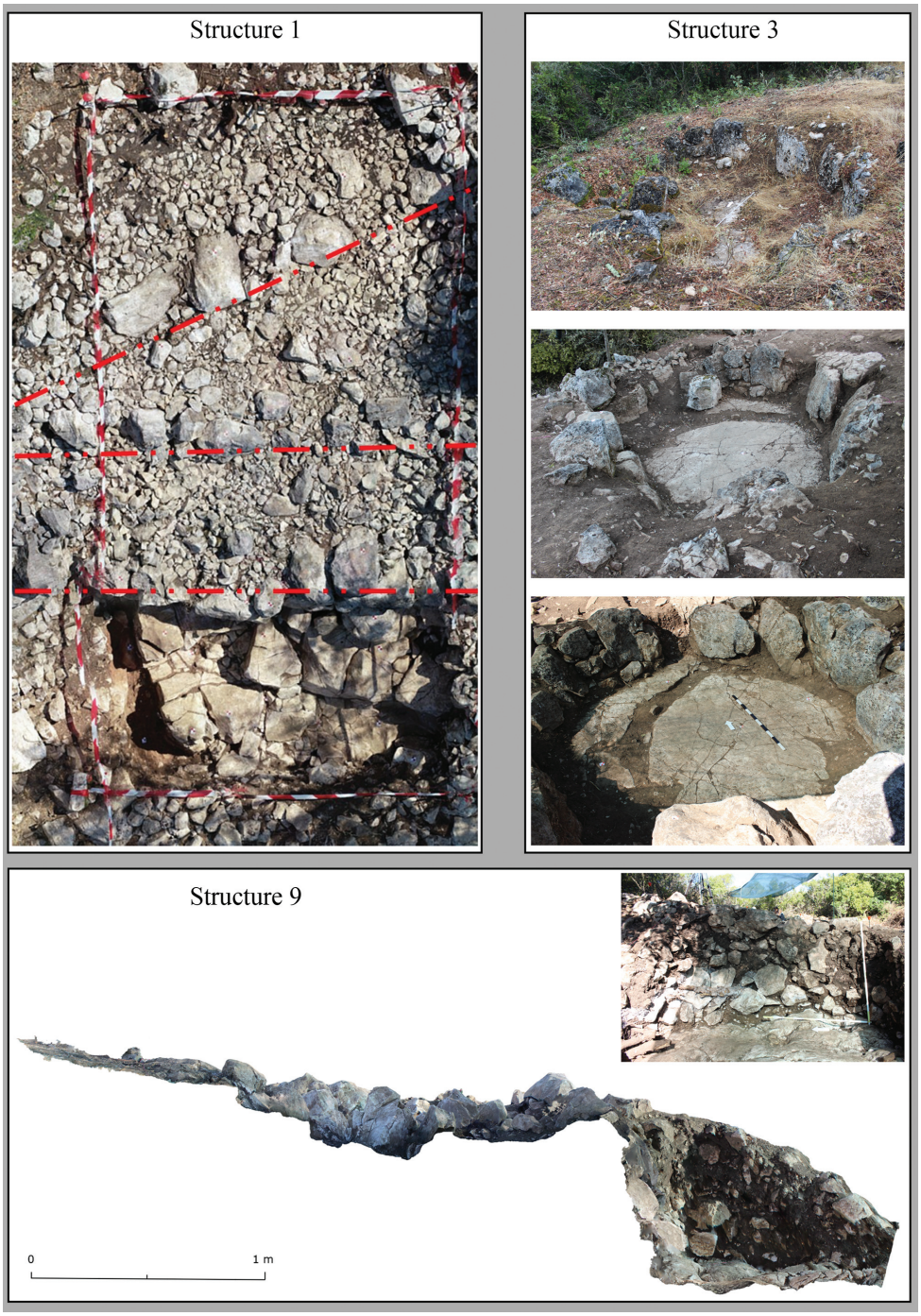

Fig. 2. Examples of the structures found in Ota: the final record of Structure 1 with the indication of possible wall alignments in red; different stages of the excavation process of Structure 3; final record and section of Structure 9 with the upper and lower bedrock platforms separated by the structure.

Both the information relating to the materials and the ^{14}C information (Tab. 1) allowed for the understanding that this structure was already active during the third quarter of the third millennium BCE (the regional Middle/Late Chalcolithic), serving as a *post-quem* indicator. As such, the identified dynamics that were already broadly replicating some of the regional prehistoric behaviours seem to be chalcolithic.

Structure 9

The approach to Structure 9 (Fig. 2) arises from two main vectors. On the one hand, following its identification through the data obtained by LiDAR. On the other, the results and information gathered at Wall 1, pointed to an occupation made through multiple platforms. These seemed to result from the nature of the base geology and the addition of structures carried out by the first communities that occupied this site. With this in mind, a 2 by 6m survey was set up between the two platforms to characterise three apparently distinct spaces: (1) the upper platform; (2) the lower platform; (3) the possible natural or artificial structure between the two platforms. The analysis determined that the bedrock was between 5 and 20cm deep and that there were no preserved deposits. However, it was clear that the top and slope of the hill had an intense prehistoric occupation, since most of the collected materials corresponded to hand-made pottery, with and without the traditional regional chalcolithic motifs, siliceous lithic materials, and even a fragment of a limestone vase.

Structure 3

This is the only 'negative' structure identified so far at the Ota archaeological site (Fig. 2). It was discovered during the field surveys, but it was also recorded in the LiDAR scanning. However, it corresponds to a structure already intervened by Hipólito Cabaço, although no record or mention of its existence has been recovered. This is a reality of a circular tendency that replicates the construction strategy observed in the other structures of Ota, based on a combination between the local geology and the addition of constructive elements. This symbiosis is particularly noticeable in this structure, being partially modelled on the limestone bedrock, complemented by the placement of large stone blocks that help in the definition of the apparently intended circular layout. Besides these large blocks, which cover about 40 to 50% of the circumference of the structure, a possible containment structure composed of an agglomerate of medium and small-sized limestones was detected to the west. Its functionality seems to be related to an eventual stabilization and support of the larger blocks (*Texugo* et al. *in preparation*). Another aspect of the manipulation of the base geology is the surface inside the structure. Relatively flattened outcrop benches were also detected at other points of the archaeological site; however, the interior of this structure is perfectly smoothed, suggesting human activity in the formation of a flattened floor.

Regarding its excavation, the sediments from this structure were entirely sieved, and there was a double approach to the fieldwork: interior and exterior areas of the circular structure, resulting in an excavated area of 98m^2. As for the stratigraphic sequence, we can state that the deposits around Structure 3 come from last century's excavations, and that the present materialities were selected with the clear obliteration of materials with greater value – the decorated ceramics and other goods of greater aesthetic value. This situation is opposite to that reflected by the materials collected by Hipólito Cabaço, where no undecorated ceramics are present. After the excavation of these superficial contexts – [1104] to [1110] – it was possible to understand that none of the deposits were preserved, either because they

Lab.	Sample	Context	BP date	Cal BCE (2σ)
Beta-561854	*Ovis/Capra* rib	Structure 1 [1006]	3960±30	2571–2516 (32.8%) **2502–2400** (52.7%) 2383–2347 (10%)
Beta-568786	*Capra hircus* horn core	Structure 3 [1103]	3970±30	**2575–2444** (87.6%) 2424–2404 (3.3%) 2379–2350 (4.6%)
Beta-612398	*Sus* sp. phalange	Structure 3 (exterior) [1120]	3860±30	**2460–2276** (80.5%) 2256–2206 (15%)
Beta-612399	*Bos* sp. phalange	Structure 3 [1115]	3990±30	**2576–2454** (93.4%) 2418–2409 (0.9%) 2369–2356 (1.1%)
Beta-612400	*Sus* sp. cranium	Structure 3 (exterior) [1120]	3980±30	**2576–2454** (93.4%) 2418–2409 (0.9%) 2369–2356 (1.1%)
Beta-612401	*Sus* sp. tooth	Structure 3 (exterior) [1120]	4000±30	**2578–2463** (95.4%)

Tab. 1. Absolute dates obtained for Structures 1 and 3 of Ota. Calibration of ^{14}C dates using IntCal20 calibration curve (*Reimer *et al.* 2020*) and the OxCal v4.4 program (*Bronk Ramsey 2009*).

were previously excavated or because they were decisively affected by intense bioturbation. Nonetheless, it is possible to conclude that the overwhelming majority of the archaeological materials in these strata belong to late prehistory. Overall, only five stratigraphic units were preserved, with coherent contextual information. Inside Structure 3, [1003] and [1115] correspond to the remains left by Cabaço, having provided a sample of a *Capra hircus* horn core with a date fitting into the Middle Chalcolithic (2574–2350 BCE) and of a *Bos* sp. phalange with a very similar date – 2577–2459 BCE (Tab. 1). The sediments outside Structure 3 were quite affected and it was only possible to record two preserved contexts in an area with strong anthropic alterations of the base lapis. In addition to this manipulation of space, the presence of several horizontally deposited faunal elements – [1120] – further corroborates the probable preservation of the deposits, with the repeated presence of human action in the organization of the elements. [1120] was on top of [1121], which, in line with what was noted in the last deposit, included various unstructured faunal elements with cohesive materials framed in regional Chalcolithic social dynamics.

Methods

The assemblage provenance is diverse and comprises remains from all the stratigraphical units with absolute or relative chronologies pointing to the Chalcolithic period, independently of the degrees of bioturbation recorded. A larger amount of remains comes from [1104] (n=1450, 24.1%), [1111] (n=959, 16%), [1114] (n=777, 12.9%), [1117] (n=427, 7.1%), [1120] (n=385, 6.4%), and [1113] (n=357, 5.9%). Remaining units have <5% of the NSP: [1000], [1006], [1007], [1008], [1101], [1102], [1103], [1105], [1106], [1107], [1108], [1109], [1110], [1115], [1116], [1118], [1119], and [1121].

Methodologies for the zooarchaeological and taphonomical analysis of faunal assemblages were followed (*Lyman 1994; Reitz, Wing 2008*). Data are presented according to the number of specimens (NSP), number of identified specimens (NISP), minimum number of elements (MNE), and minimum number of individuals (MNI) (*Grayson 1984; Lyman 2008*). The MNI was calculated by distinguishing stratigraphic units (MNI_{su}) and as a general cumulative estimate not considering differences between stratigraphic units (MNI_{g}).

Linear biometrics analysis was carried out by measuring bones and teeth with a Lux digital calliper following current standards (*Driesch 1976; Payne, Bull 1988; Davis 1996; Albarella* et al. *2005; Salvagno, Albarella 2017*). The results were compared to regional 'contemporaneous' published measurements and were considered together with morphology to better characterize bovine, swine, caprine and leporids (*Boessneck* et al. *1964; Boessneck 1970; Callou 1997; Zeder, Pilaar 2010; Zeder, Lapham 2010*). Taxonomically indeterminate remains were tentatively classified according to generic weight groups (*Brain 1981; Bunn 1983; 1986*): indeterminate (WG 0), <20kg (WG 1), 20–100kg (WG 2), 100–300kg (WG 3), and >300kg (WG 4). The age-at-death estimate considered bone (general ossification and epiphysis fusing) and teeth development (eruption, replacement, wear) according to data published for the main species documented in the assemblage (*Payne 1973; 1987; Bull, Payne 1982; Grant 1982; Jones 2006; Zeder 2006; Lemoine* et al. *2014; Zeder* et al. *2015*). The results were grouped in general age groups, namely perinatal, infant, juvenile, sub-adult, adult, and senile.

The assemblage breakage patterns were assessed following Henry T. Bunn (*1983*) and Paola Villa, and Eric Mahieu (*1991*). Diaphysis length (<25%, 25–50%, 50–75%, >75%) and section (<25%, 25–75%, >75%) completeness are presented in relation to the original figures. Breakage planes outline (oblique, longitudinal, transverse), angle (mixed, oblique, right), and surface (jagged, smooth) are considered according to the weight groups mentioned above. The surfaces of the remains were macroscopically and microscopically analysed to record possible BSMs (bone surface modifications) related to processing and consumption, but also the sedimentary environment. We searched for anthropogenic breakage (*e.g.*, peeling, percussion impacts, cones, fissures), cutmarks (*e.g.*, incisions, chop marks, scrape marks), tooth marks (*e.g.*, pits, punctures, crenulated edges), other consumption indicators (*e.g.*, furrowing, digestion), and thermal alteration (*i.e.* boiling, burning) (*Binford 1978; 1981; Brain 1981; Shipman 1981; White 1992; Stiner* et al. *1995; Pickering* et al. *2013; Solari* et al. *2015*). When present, their location, disposition, relations, typology, morphology, size and intensity are described (*Almeida 2017*). The furrowing evaluation follows the proposal of Saladié *et al.* (*2011; 2013*) according to the intensity of tissue loss distinguishing between light, moderate, and heavy furrowing. The location of tooth marks was also recorded considering the type of tissue affected (cortical, thin cortical, cancellous – *Selvaggio, Wilder 2001; Domínguez-Rodrigo, Piqueras 2003*).

Weathering is presented according to the degrees suggested by Behrensmeyer (*1978*). Other taphonomical indicators, such as the presence of vermiculations (*Lyman 1994*), manganese oxide precipitation (*López-González* et al. *2006*), indeterminate chemical corrosion (*Fernández-Jalvo* et al. *2002*), trampling (*Behrensmeyer* et al. *1986; Shipman, Rose 1984*), rodent gnawing (*Shipman 1981*), or concretions (*Courty* et al. *1989*) were qualitatively recorded according to the intensity and surface altered (<25%, 25–50%, 50–75%, >75%) (*Almeida 2017*).

Results

Anatomy and taxonomy

The assemblage comprises a majority of Mammalia (NISP% 96.5%) remains, with some amount of Bivalvia (NISP% 2.4%) and to a lesser extent Amphibia (NISP% 0.5%), Reptilia (NISP% 0.5%), and Aves (NISP% 0.2%) (Tabs. 2, 3, 4). Swine are prevalent, with the majority of them being specifically indeterminate, and some remains being identified as possible wild boar and pig due to morphology and size. As can be seen in Figure 3, there is some superimposition between Mesolithic wild boar and Late Prehistory (presumable) pig for the astragalus Greatest Lateral length (GLl) measurement. For the case of Ota and considering the results for other large Chalcolithic assemblages, it seems that some of the astragali correspond to small swine, and at least the larger one would probably correspond to wild boar. Still, the possible presence of hybrids in the assemblage must be considered, as pigs were probably bred free. Swine show an important number of isolated teeth (n=68). All parts of the skeleton are present, but vertebrae and ribs are under-represented. A higher number of anterior in comparison to posterior long bones is evident according to NISP and MNE values. The obtained MNIs indicate the presence of adult and senile wild boar; juvenile, sub/adult and adult pigs; and infant/juvenile, juvenile, and subadult swine that further enlarge the MNIs (Tab. 5). Hence, different age groups are represented in the assemblage.

Caprine are well represented, comprising a majority of goat/sheep and similar NISP values for remains identifiable specifically as goat or sheep. Similarly to swine, isolated teeth are also frequent in caprine remains (n=75), with the appendicular skeleton being more abundant than other body parts. The distinction between goat and sheep was achieved based on the morphology of horn core fragments, isolated teeth, humerus, radius, metapodial, calcaneus, phalanges, and both morphology and measurements of astragali following Simon J. M. Davis (*2017b*). Sub-adult, adult and adult/senile individuals of goats, and juvenile, sub-adult and adult individuals of sheep are countable. The goat/sheep follow this pattern even if adding one juvenile individual in the MNI_g.

Bovine comprises domesticated cattle and wild aurochs. The latter are scarce in comparison to the

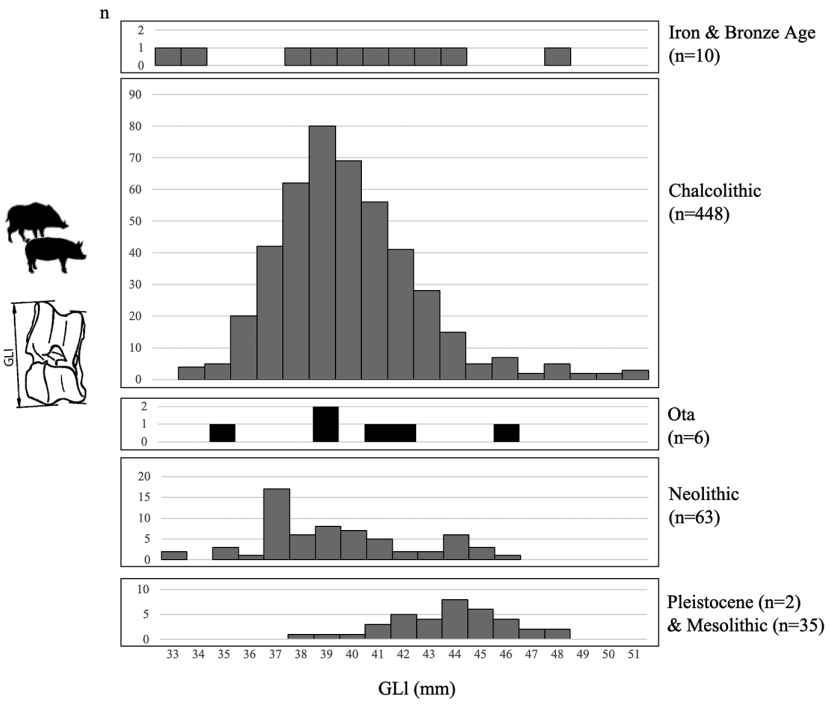

Fig. 3. Histogram of results obtained for the Greatest Lateral length (GLl) of swine astragalus from the Ota site and other Portuguese and adjacent Spanish sites dated to the Pleistocene and Mesolithic (*Detry 2007*); Neolithic (*Almeida 2017; Davis *et al.* 2018; Encarnação, Almeida 2017; Almeida *et al.* 2021b*); Chalcolithic (*Driesch, Boessneck 1976; Cardoso, Detry 2001/2002; Castaños 1992; 1997; Rodríguez-Hidalgo, Cabezas 2011; Davis, Mataloto 2012; Moreno-García 2013; Correia 2015; Moreno-García, Sousa 2015; Detry *et al.* 2020; Almeida *et al.* 2021a; Almeida, Valera 2021; Cardoso *et al.* 2021; Pereiro *et al.* 2021*); Iron and Bronze Age sites (*Davis 2006; Almeida *et al.* 2020b*).

	NSP	%	MNE	%	MNI_{su}	%	MNI_{g}	%
MAMMALIA								
Artiodactyla	17	1.7	0	0.0	0	0.0	0	0.0
Bos taurus	78	7.6	63	10.1	16	12.5	3	6.5
Bos cf. *primigenius*	13	1.3	11	1.8	7	5.5	2	4.3
Bos sp.	92	8.9	48	7.7	1	0.8		
Capra hircus	22	2.1	15	2.4	7	5.5	1	2.2
Ovis aries	16	1.6	15	2.4	8	6.3	6	13.0
Ovis/Capra	177	17.2	81	13.0	6	4.7	1	2.2
Cervus elaphus	72	7.0	50	8.0	12	9.4	2	4.3
Sus cf. *scrofa*	7	0.7	4	0.6	5	3.9	2	4.3
Sus cf. *domesticus*	21	2.0	17	2.7	9	7.0	5	10.9
Sus sp.	271	26.4	157	25.2	7	5.5	6	13.0
cf. *Equus* sp.	1	0.1	1	0.2	1	0.8	1	2.2
Herbivore	28	2.7	0	0.0	0	0.0	0	0.0
Canis sp.	3	0.3	3	0.5	2	1.6	1	2.2
Felis silvestris	1	0.1	1	0.2	1	0.8	1	2.2
Oryctolagus cuniculus	151	14.7	120	19.2	28	21.9	9	19.6
Leporidae	25	2.4	16	2.6	0	0.0	0	0.0
Sub-total Mammalia	*995*	*96.8*	*603*	*96.5*	*0*	*0.0*	*0*	*0.0*
AVES								
Aves ind.	1	0.1	1	0.2	1	0.8	1	2.2
Sub-total Aves	*1*	*0.1*	*1*	*0.2*	*0*	*0.0*	*0*	*0.0*
AMPHIBIA								
Amphibia	2	0.2	1	0.2	1	0.8	0	0.0
Anura	2	0.2	2	0.3	1	0.8	1	2.2
Sub-total Amphibia	*4*	*0.4*	*3*	*0.5*	*0*	*0.0*	*0*	*0.0*
REPTILIA								
cf. *Mauremys leprosa*	3	0.3	3	0.5	2	1.6	1	2.2
Sub-total Reptilia	*3*	*0.3*	*3*	*0.5*	*0*	*0.0*	*0*	*0.0*
BIVALVIA								
Bivalvia ind.	7	0.7	4	0.6	3	2.3	0	0.0
Ruditapes decussatus	4	1.4	7	1.1	6	4.7	1	2.2
Cerastoderma edule	2	0.2	2	0.3	2	1.6	1	2.2
Pecten sp.	2	0.2	2	0.3	2	1.6	1	2.2
Sub-total Bivalvia	*25*	*2.4*	*15*	*2.4*	*0*	*0.0*	*0*	*0.0*
Sub-total identified	*1028*	*100*	*625*	*100*	*128*	*100*	*46*	*100*

Indeterminate		
Weight group ind.	2294	46.1
WG <20kg	81	1.6
WG <100kg	294	5.9
WG 20-100kg	1421	28.5
WG <300kg	231	4.6
WG 100-300kg	102	2.0
WG >100kg	281	5.6
WG >300kg	276	5.5
Sub-total indeterminate	*4980*	*100*
Total	6008	

Tab. 2. Absolute and relative values obtained for the taxonomically identified and unidentified faunal remains according to the number of identified specimens (NSP), minimum number of elements (MNE), and minimum number of individuals by stratigraphic unit (MNI_{su}) and minimum number of individuals general (MNI_{g}).

large number of remains identified as *Bos taurus* and *Bos* sp., the latter generally also have smaller sizes and probably corresponded to the domesticated form as well. The most abundant measurable bone used for this distinction are proximal phalanges, which in the case of the Ota assemblage are generally coincident with the sizes considered to correspond to cattle, even if a larger specimen falls within the admitted variability of the much larger auroch (Fig. 4). One astragalus allowed for the measurement of the GLl, which also showed its small size (Fig. 5). Bovines have all body parts, but the higher frequency of phalanges and carpal/tarsal bones is of interest. Older individuals, *i.e.* adult or adult/senile, and several sub-adult/adult individuals are present. Noteworthy is the presence of one infant/juvenile cow and one juvenile/sub-adult auroch.

Leporids correspond mostly to the European wild rabbit and also have an important number of remains. Except for one sub-adult, all individuals are adults. Both the cranial and appendicular body parts are well represented, mainly mandibles, innominate, femur and tibia. The smaller bones from the extremities are underrepresented, but it is not clear if this relates to the selection, survival or recovery bias since sieving was implemented in the area containing the majority of the assemblage. Red deer are the second more numerous species representing wild game, and the different bones, teeth and antlers seem to correspond to adults. Canids are represented by two metapodial and one phalange, with a possible equid phalange and a wild cat phalange recovered.

One must emphasize the recovery of some Bivalvia shell fragments (Fig. 6). Although some of them are considered taxonomically indeterminate (n=7, 28%), the grooved carpet shells are abundant, and the scarce common cockle and scallop are present.

Taphonomy

The assemblage is composed by a majority of remains with maximum dimensions <5cm (n=5242, 87.3%), others between 5 and 10cm (n=727, 12.1%) and only a few with 10–15cm (n=32, 0.5%) or 15–

Tab. 3. Values of the number of identified specimens (NISP) per body part. Legend: **AR *artiodactyl*, BT Bos taurus, BP Bos *cf.* primigenius, BOS Bos *sp.*, CH Capra hircus, OA Ovis aries, O/C Ovis/Capra, CEE Cervus elaphus, SS Sus *cf.* scrofa, SD Sus *cf.* domesticus, SUS Sus *sp.*, EQ *cf.* Equus *sp.*, HE *herbivore*, CAN Canis *sp.*, FS Felis silvestris, ORC Oryctolagus cuniculus, LEP *Leporidae*, AV Aves *ind.*, AMP *Amphibia ind.*, AN *Anura*, ML *cf.* Mauremys leprosa, BIV Bivalvia, RD Ruditapes decussatus, CE Cerastoderma edule, PE Pecten *sp.*, IND *indeterminate*.**

	AR	BT	BP	BOS	CH	OA	O/C	CEE	SS	SD	SUS	EQ	HE	CAN	FS	ORC	LEP	AV	AMP	AN	ML	BIV	RD	CE	PE	IND	Total
axial cranial skeleton																											
horn core/antler				2	7	1		20																		18	48
cranium (maxilla)		1					2	1		5	8					11	1									159	188
mandible		3		7			5	1	1	1	9		1			18										32	78
isolated incisor		1					9				19					1										1	31
isolated canine									3		14															0	17
isolated pre-molar		2	1	6	3		11	3			10															4	40
isolated molar		7	1	22	1	1	50	3		3	18		24			8										4	142
isolated tooth											1		2				1									61	65
axial post-cranial skeleton																											
vertebra				6			2				9					5	5									203	230
rib																										124	124
sacrum				2			1									2										5	10
appendicular skeleton																											
scapula		1	1	1			4	1		4	12					12	2									24	62
humerus		2	1	1	1	1	6	3		2	20					8	1									13	59
radius	1	1	1	1	1	1	10	2		2	12					6										20	58
ulna		4		3			6	2			11					7	1									2	36
metacarpal		1		4	1	1	4	1			7			1												0	20
ilium																				1						0	1
pelvis		2		2			2	2		1	13					22										13	57
femur		1		1			1	1			11					17	5									16	53
patella							2				3															0	5
tibia		1		3			3	2		2	6					14	5									4	40
fibula											6															3	9
tibio-fibula																				1						0	1
tarsal-metatarsal																		1								0	1
metatarsal		4		2	1		9	2			9			1		11	1									0	40
metapodial	15	4		4			24	4	1		15		1				1									6	75
astragalus		3		1	2	6	2	4	1	1	4															2	26
calcaneus		2			1		2	2			10					9										3	29
carpal/tarsal		7	5	3			8	5			6															10	44
sesamoid				10																						1	11
phalange 1	1	18	1	5	3	2	5	7	1		14	1		1	1		2									5	67

continue

phalange 2		8	1	1	1	2	3	4			14													2	36
phalange 3		5	1	5		1	6	2			10													0	30
phalange																								6	6
other																									
long bone																								1292	1292
flat bone																		2						1587	1589
indeterminate bone																								1360	1360
carapace/plastron																			3					0	3
shell																				7	14	2	2	0	25
total	17	78	13	92	22	16	177	72	7	21	271	1	28	3	1	151	25	1	2	2	3	7	14	2	2	4980	6008

Tab. 4. Values of the minimum number of elements (MNE) per body part, excluding loose teeth. Legend: **BT Bos taurus, BP Bos *cf.* primigenius, BOS Bos *sp.*, CH Capra hircus, OA Ovis aries, O/C Ovis/Capra, CEE Cervus elaphus, SS Sus *cf.* scrofa, SD Sus *cf.* domesticus, SUS Sus *sp.*, EQ *cf.* Equus *sp.*, HE *herbivore*, CAN Canis *sp.*, FS Felis silvestris, ORC Oryctolagus cuniculus, LEP *Leporidae*, AV *Aves ind.*, AMP *Amphibia ind.*, AN Anura, ML *cf.* Mauremys leprosa, BIV Bivalvia, RD Ruditapes decussatus, CE Cerastoderma edule, PE Pecten *sp.***

	BT	BP	BOS	CH	OA	O/C	CEE	SS	SD	SUS	EQ	CAN	FS	ORC	LEP	AV	AMP	AN	ML	BIV	RD	CE	PEC	Total
axial cranial skeleton																								
horn core/antler			2	4	1		6																	13
cranium (maxilla)	1					1	1		4	4				10										21
mandible	3		4			4	1	1	1	7				15										36
axial post-cranial skeleton																								
vertebra			5			2				8				5	4									24
rib																								0
sacrum			1			1								2										4
appendicular skeleton																								
scapula	1	1	1			4	1		4	7				11	2									32
humerus	2	1	1	1	1	5	3		2	9				7	1									33
radius	1	1		1	1	7	2		2	10				6										31
ulna	3		1			6	2			9				7										28
metacarpal	1		3	1	1	4	1			7		1												19
ilium																		1						1
pelvis	2		2			2	2		1	10				18										37
femur	1		1			1	1			9				6	3									22
patella						2				3														5
tibia	1		3			2	2		2	4				13	3									30
fibula										3														3
tibio-fibula																		1						1
tarsal-metatarsal																1								1

continue

metatarsal	3		1	1		4	2		9		1		11									32
metapodial	4					11	3	1	4					1								24
astragalus	3		1	2	6	2	4	1	1	4												24
calcaneus	2			1		2	2			7			9									23
carpal/tarsal	7	5	3			8	5			6												34
sesamoid			10																			10
phalange 1	16	1	4	3	2	4	7	1		13	1	1	1		2							56
phalange 2	7	1		1	2	3	3			14												31
phalange 3	5	1	5		1	6	2			10												30
other																						
flat bone																1						1
carapace/plastron																	3					3
shell																		4	7	2	2	15
total	73	13	61	19	16	129	55	7	20	199	1	3	1	121	16	1	2	3	4	7	2	756

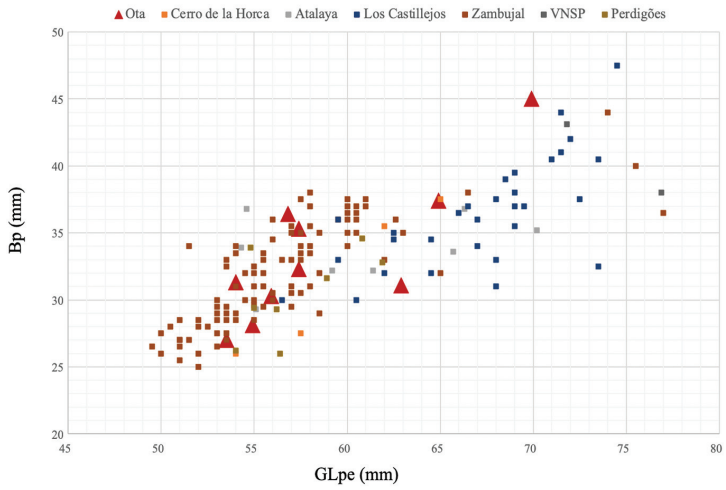

Fig. 4. Scatterplot showing the breadth of the proximal end (Bp) and the greatest length of the peripheral half (GLpe) measurements obtained for bovine phalange 1 from Portuguese and adjacent Spanish Chalcolithic assemblages (*Driesch, Boessneck 1976; Castaños 1992; 1997; Rodríguez-Hidalgo, Cabezas 2011; Detry *et al.* 2020; Almeida, Valera 2021*).

18cm (n=7, 0.1%) (Fig. 7). The results obtained for the diaphysis completeness are interesting, with clear differences between long bones of WG 1 and 1/2 and the remaining WGs. In the latter, both WG 2+2/3+3 and WG 3/4+4 show higher frequencies of length and section <25% of the original, while in WG 1+1/2 the length of 25–50% and 50–75%, and the 25–75% section are better represented. It thus seems that the long bones of smaller animals, which correspond mostly to leporids or animals of similar size, are better preserved in comparison to larger animals, from the size of caprine, swine, cervids and bovids.

To better understand this data, we looked at the breakage planes (Fig. 7). Longitudinal outlines are abundant in the different samples, followed by oblique outlines, but these have values between around 28–35%. Angles and edges show a similar pattern, with right degrees and smooth surfaces always above 66%. These patterns together with the diaphysis completeness and the indicators of anthropogenic breakage suggest that although fragmentation occurred, an important amount of green breakage exists. The different degrees of preservation occurring with the smaller size animals can also relate to the breakage of near to epiphysis portions commonly occurring with human-induced breakage to access marrow that can result in shaft cylinders.

Complete remains (3.2%) comprise mainly 49 teeth (23.4%), 60 carpal and tarsal bones (31.1%), 65 phalanges (33.7%) and 10 metapodia (5.2%). Body parts with greater nutritional value are rarely complete, but this can also relate to density-mediated attrition.

Indicators of thermal modification are present (Tab. 6). Burning damage (2.9%) is more common than other human-related indicators, and is present mainly in taxonomically indeterminate re-

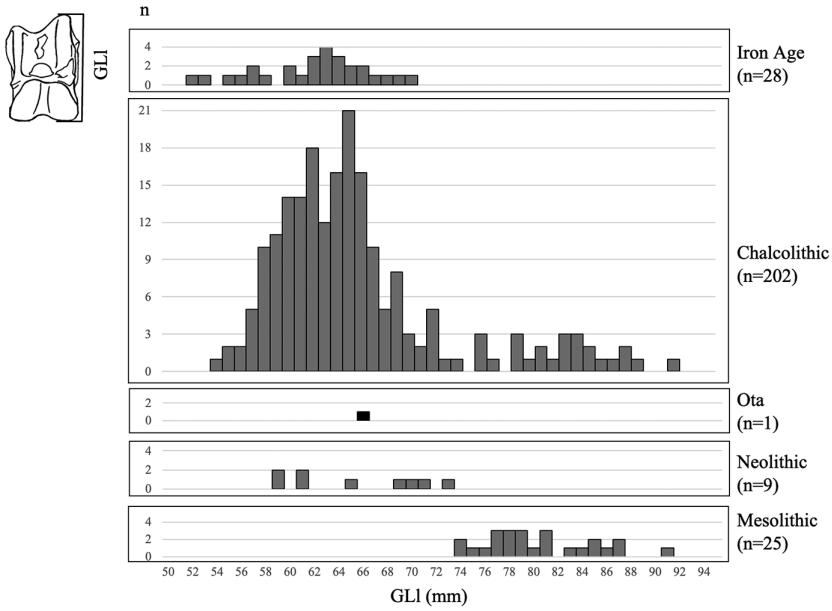

Fig. 5. Histogram of the results obtained for the Greatest Lateral length (GLl) of bovine astragalus from the Ota site and other Portuguese and adjacent Spanish sites dated to the Mesolithic (*Detry 2007; Valente 2008; 2013*); Neolithic (*Davis *et al.* 2018; Almeida *et al.* 2021b*); Chalcolithic (*Driesch, Boessneck 1976; Castaños 1997; Rodríguez-Hidalgo, Cabezas 2011; Davis, Mataloto 2012; Moreno-García 2013; Correia 2015; Moreno-García, Sousa 2015; Aleixo 2018; Davis *et al.* 2018*); Iron and Bronze Age sites (*Davis 2006; 2017a*).

mains, of which we must emphasize WG2 and larger animals. When present in identified remains (n=19), they are mostly in rabbits (n=7) and bovines (n=4). The body parts altered are generally elements from the appendicular (n=93, 54.1%) skeleton or indeterminate (n=68, 39.5%), although some axial bones (n=19, 5.8%) and a scallop shell were also burnt. The degrees are generally low, with degrees 1 (n=5, 2.9%) and 2 (n=91, 52.9%) being prevalent, but degrees 3 (n=32, 25%), 4 (n=27, 15.7%) and 5 (n=6, 3.5%) are also present. Double colourations occur in 14.5% (n=25) of the cases. Possible boiling is almost entirely restricted to indeterminate fragments (n=110, 91.7%), half of which are from 20–100kg animals. The axial skeleton (n=2, 1.7%) has lower frequencies in comparison to the appendicular (n=78, 65%) or indeterminate (n=40, 33.3%), and indeterminate long bones are prevalent (n=68, 56.7%).

Butchering practices are recognizable in the collection (Tab. 7), with cutmarks comprising chop marks (n=14), incisions (n=116), zigzag marks (n=2) and complete sectioning (n=2) of bones. All main butchering phases are present, including dismemberment, skin removal, evisceration, segmentation of the axial skeleton, disarticulation and filleting. Among anthropogenic breakage, impact points (n=63) are the most abundant type of stigma, followed by cortical extractions (n=24) and impact cones (n=18). Other percussion stigmas (n=28) such as fissures, possible counterblows, pitting, anvil abrasions and adhering flakes, are recorded.

Considering consumption, the majority of remains with taphonomical indicators were associated with carnivore action (n=127, 77.9%), with possible human tooth marks (n=20, 9.8%) being almost entirely circumscribed to leporid remains (n=18), and some considered indeterminate (n=16, 12.3%). Taxonomically identified tooth-marked bones (n=78) are mostly from swine (n=30), leporid (n=25) or caprine (n=12), whilst indeterminate bones (n=71) are

	IN/JU	JU	JU/SU	SU	SU/AD	AD	AD/SE	SE	MNI_{su}/MNI_g
Bos taurus	1–1	0–0	0–0	0–0	9–0	6–2	0–0	0–0	16–3
Bos cf. *primigenius*	0–0	0–0	1–1	0–0	5–0	0–0	1–1	0–0	7–2
Bos sp.	0–0	0–0	1–0	0–0	0–0	0–0	0–0	0–0	1–0
Capra hircus	0–0	0–0	0–0	0–0	1–0	5–0	1–1	0–0	7–1
Ovis aries	0–0	1–1	0–0	0–0	1–0	6–5	0–0	0–0	8–6
Ovis/Capra	0–0	0–1	2–0	1–0	1–0	2–0	0–0	0–0	6–1
Sus cf. *scrofa*	0–0	0–0	0–0	0–0	0–0	4–1	0–0	1–1	5–2
Sus cf. *domesticus*	0–0	3–2	0–0	0–0	3–1	3–2	0–0	0–0	9–5
Sus sp.	2–2	1–0	0–0	0–0	4–4	0–0	0–0	0–0	7–6
Oryctolagus cuniculus	0–0	0–0	0–0	1–1	0–0	27–8	0–0	0–0	28–9

Tab. 5. Minimum number of individuals calculated distinguishing between stratigraphic units (MNI_{su}) and considering the entire assemblage (MNI_g). Legend:* IN *infant,* JU *juvenile,* SU *sub-adult,* AD *adult,* SE *senile.

mainly from small (20–100kg) animals, thus very small animals with tooth marks are almost uniquely leporids. Consumption indicators are present in appendicular (n=117, 71.8%) bones, and comparatively less in axial (n=12, 7.4%) or indeterminate bones (n=34, 20.9%). Among indicators of consumption, pits (n=48, 23–6%), punctures (n=46, 22.7%) and furrowing (n=37, 18.2%) are more frequent than crenulated edges (n=24, 11.8%), digestion (n=21, 10.3%), notches (n=18, 8–9%), scores (n=4, 2%), chipped back-edge (n=3, 1.5%), crushing (n=1, 0.5%) and shaft cylinders (n=1, 0.5%). Furrowing is mainly in heavy degrees (n=22, 59.5%) compared to moderate (n=11, 29.7%) and light (n=4, 10.8%) degrees.

The larger number of measurements obtained for pits/punctures are presented in Table 8. Not considering the data from very small animals (WG 1) due

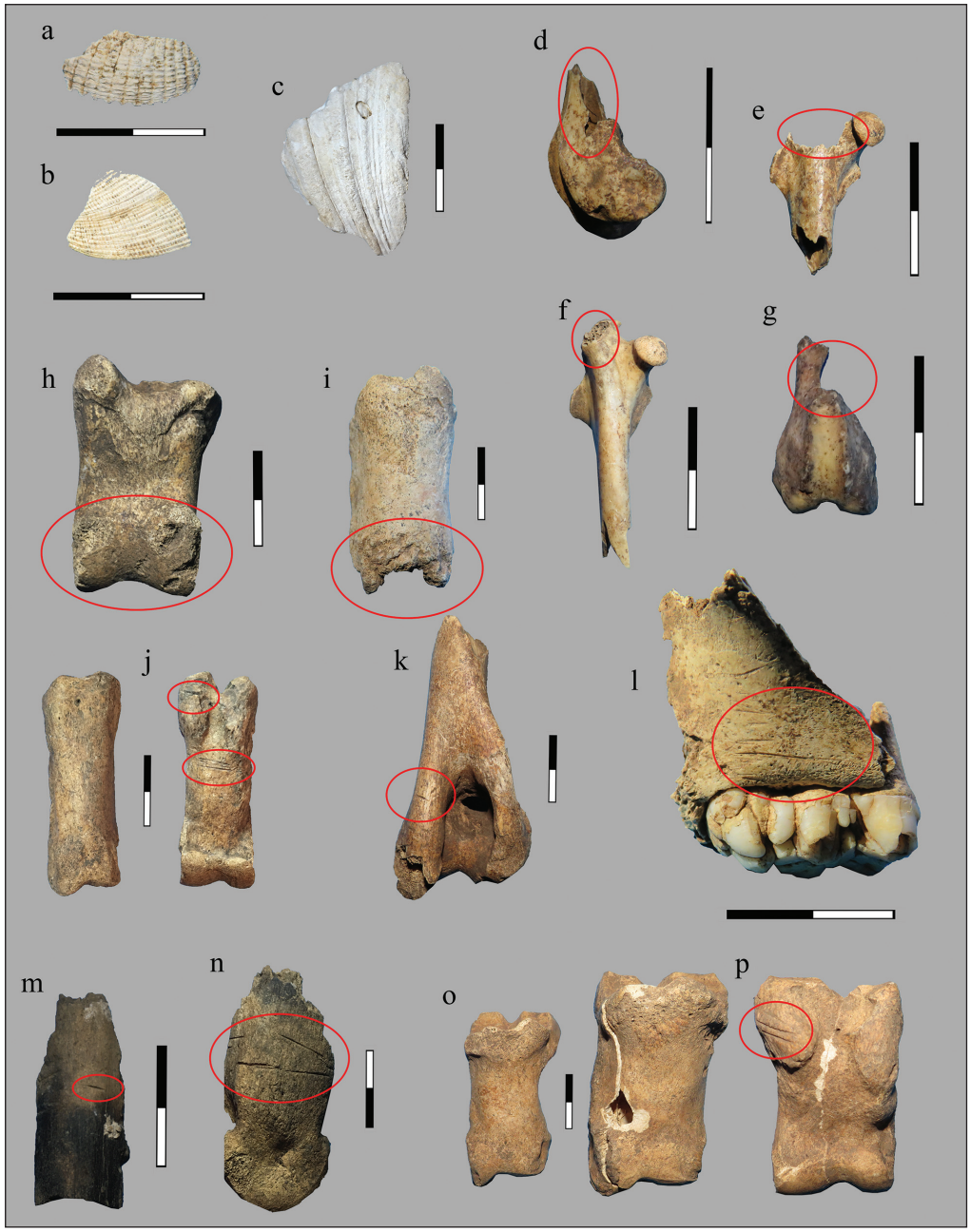

Fig. 6. Selection of materials from Ota: **a** ***shell fragments from common cockle,*** **b** ***grooved carpet shell and*** **c** ***scallop;*** **d, e, f, g** ***different rabbit long bones with mechanical damage in the form of notches in fracture planes and crenulated edges;*** **h, i** ***bovine proximal phalanges with mechanical damage by carnivores;*** **j** ***caprine proximal phalange;*** **k** ***swine humerus and*** **l** ***maxilla;*** **n** ***bovine distal metapodial and*** **p** ***proximal phalange with cutmarks;*** **m** ***bone fragment with burning damage and cutmarks;*** **o** ***proximal phalange from cattle and*** **p** ***auroch showing large size differences between specimens.***

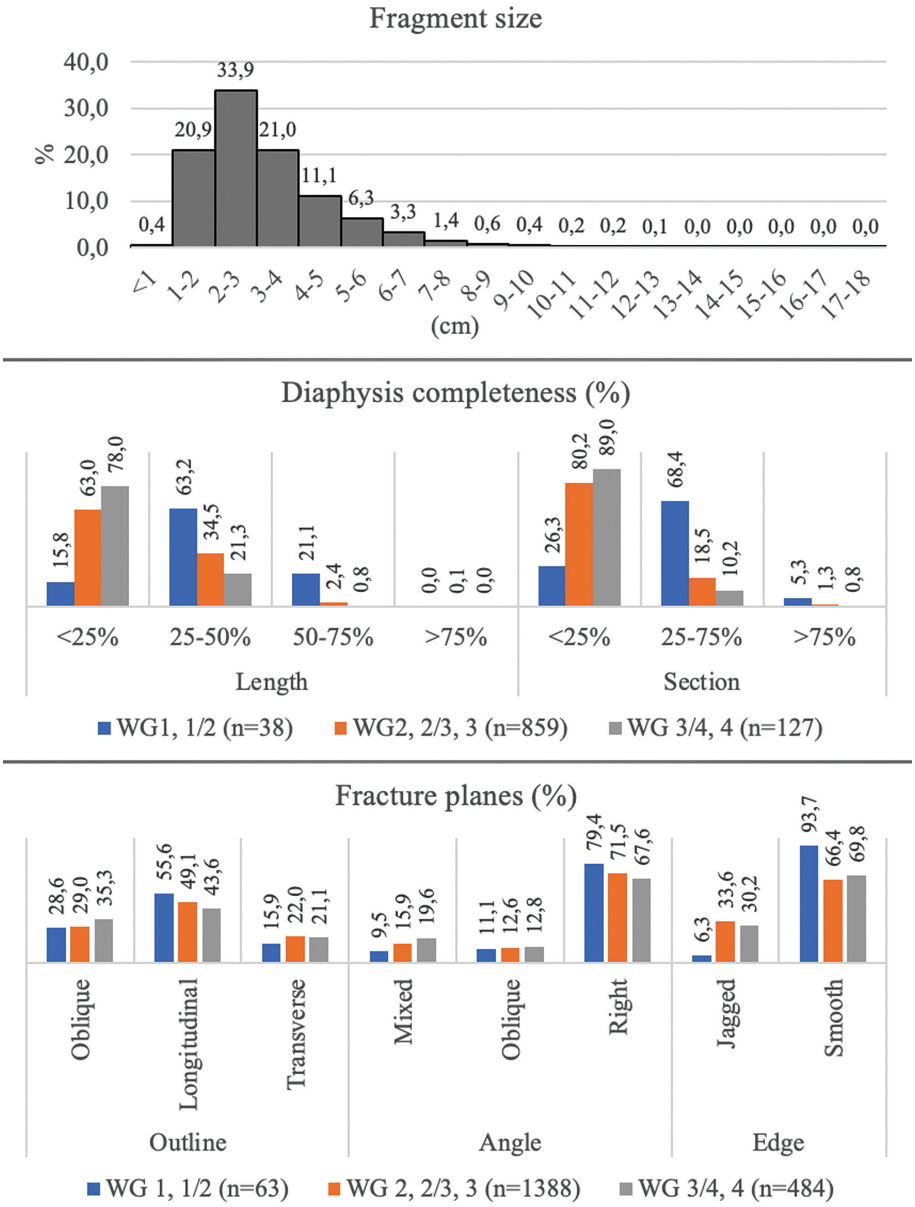

Fig. 7. Assessment of breakage per weight group in the assemblage considering:* a *fragment size*, b *diaphysis completeness, and* c *fracture planes.

to sample size, we present a comparison of the remaining results with published experimental and actualistic measurements obtained for wolf, dog, wild boar, pig and humans (*Delaney-Rivera* et al. *2009; Saladié 2009; Andrés* et al. *2012; Saladié* et al. *2013*). Results for cancellous tissues show similarities with canids, swine and humans, while cortical/thin cortical data is better framed within the variabilities of canids and swine (Fig. 8). We cannot discard the possibility that some smaller and shallow tooth marks could relate to human consumption. At the same time, the absence of the characteristic scores made by swine while feeding suggests that they were not preponderant in the modification of these remains. Canids, probably dogs, seem to fit better with the taphonomical patterning recorded and the different types of behavioural consumption indicators.

Finally, other indicators are present in the faunal assemblage. Trampling, chemical corrosion and concretions are scarce. The higher frequencies of weathering (10%), manganese oxide precipitation (10%) and vermiculations (10%) are noteworthy (Fig. 9). Weathering occurs mostly in initial degrees 1 and 2, but this together with the identification of degrees 3 and 4 suggests that while the exposition of the remains before sedimentation was small, some remains were subjected to larger exposure or at least some moments of re-exposure. Vermiculations are relat-

able with the provenance of remains from low-depth stratigraphy and/or high bioturbation areas, since these normally occur in the top horizons of the stratigraphy. The presence of manganese oxide in degrees 1 and 2 accompanied by some amount of degree 3 and the little degree 4 can relate to humidity and decomposition of organic matter. Overall, the low incidence of weathering, vermiculations and scarcity of trampling suggests that although the site shows important bioturbation and disturbance of deposits due to previous historical archaeological works, the faunal remains are fairly preserved.

Indicator	n	%
Cutmark	133	2.2
Anthropogenic breakage	126	2.1
Burning damage	172	2.9
Boiling	120	2.0
Tooth marks, digestion	170	2.8
Rodent marks	3	0.0
Vermiculations	624	10.4
Weathering	592	9.9
Trampling	9	0.1
Concretions	9	0.1
Manganese oxide	624	10.4
Chemical corrosion	5	0.1
Complete remains	193	3.2
Recent breakage	954	15.9

Tab. 6. Main taphonomical indicators identified in the Ota faunal assemblage.

Discussion

The faunal record in the Ota site during the Chalcolithic

The fauna profile identified so far in the Ota site shows the importance of swine in the economy of these groups during the Chalcolithic. Although it was impossible to further separate the majority of the remains due to the lack of metrical or morphological characteristics, wild boar and pig seem to have been present and, probably, hybrids. The generally small size of measurable and unmeasurable bone and teeth is suggestive of a small input from larger individuals, presumably wild boars. Caprines are also noteworthy in terms of NISP and MNE, with both goat and sheep present, and a majority of remains classified as goat/sheep. The triad of domesticated species is completed with the bovine, for which a small number of remains was classified as probable auroch due to their large size. Still, the majority of evidence is from smaller individuals of cattle and other bovines that probably correspond to cattle due to their small size.

Kill-off patterns among the main domesticated taxa show the prevalence of adult individuals indepen-

	Burning		Boiling		Cutmark		Breakage		Tooth mark		Digestion	
	n	%	n	%	n	%	n	%	n	%	n	%
Artiodactyla	0	0.0	0	0	0	0.0	0	0.0	2	2.6	0	0
Bos taurus	1	5.3	0	0	12	17.9	0	0.0	0	0.0	0	0
Bos primigenius	0	0.0	0	0	3	4.5	5	19.2	3	3.8	0	0
Bos sp.	3	15.8	0	0	6	9.0	10	38.5	2	2.6	0	0
Capra hircus	1	5.3	0	0	3	4.5	1	3.8	0	0.0	0	0
Ovis aries	0	0.0	0	0	3	4.5	0	0.0	0	0.0	0	0
Ovis/Capra	1	5.3	1	10	8	11.9	0	0.0	12	15.4	2	20
Cervus elaphus	1	5.3	1	10	7	10.4	3	11.5	4	5.1	0	0
Sus cf. *scrofa*	0	0.0	0	0	1	1.5	1	3.8	0	0.0	0	0
Sus cf. *domesticus*	0	0.0	0	0	5	7.5	0	0.0	4	5.1	0	0
Sus sp.	2	10.5	3	30	19	28.4	6	23.1	26	33.3	6	60
Herbivore	2	10.5	0	0	0	0.0	0	0.0	0	0.0	0	0
Oryctolagus cuniculus	7	36.8	4	40	0	0.0	0	0.0	23	29.5	1	10
Leporidae	0	0.0	1	10	0	0.0	0	0.0	2	2.6	1	10
Sub-total identified	*19*	*100*	*10*	*100*	*67*	*100*	*26*	*100*	*78*	*100*	*10*	*100*
Weight group 0 ind.	48	31.4	22	20.0	24	36.4	9	9	12	16.9	6	54.5
WG 1 (<20kg)	2	1.3	0	0.0	0	0.0	0	0	1	1.4	1	9.1
WG 1/2 (<100kg)	7	4.6	8	7.3	1	1.5	1	1	1	1.4	0	0.0
WG 2 (20-100kg)	62	40.5	55	50.0	14	21.2	54	54	37	52.1	4	36.4
WG 2/3 (<300kg)	10	6.5	8	7.3	8	12.1	6	6	8	11.3	0	0.0
WG 3 (100-300kg)	6	3.9	3	2.7	2	3.0	4	4	1	1.4	0	0.0
WG 3/4 (>100kg)	6	3.9	5	4.5	8	12.1	9	9	6	8.5	0	0.0
WG 4 (>300kg)	12	7.8	9	8.2	9	13.6	17	17	5	7.0	0	0.0
Sub-total indeterminate	*153*	*100*	*110*	*100*	*66*	*100*	*100*	*100*	*71*	*100*	*11*	*52*
Total	**172**		**120**		**133**		**126**		**149**		**21**	

Tab. 7. Different taphonomical indicators' absolute and relative values per species and weight groups.

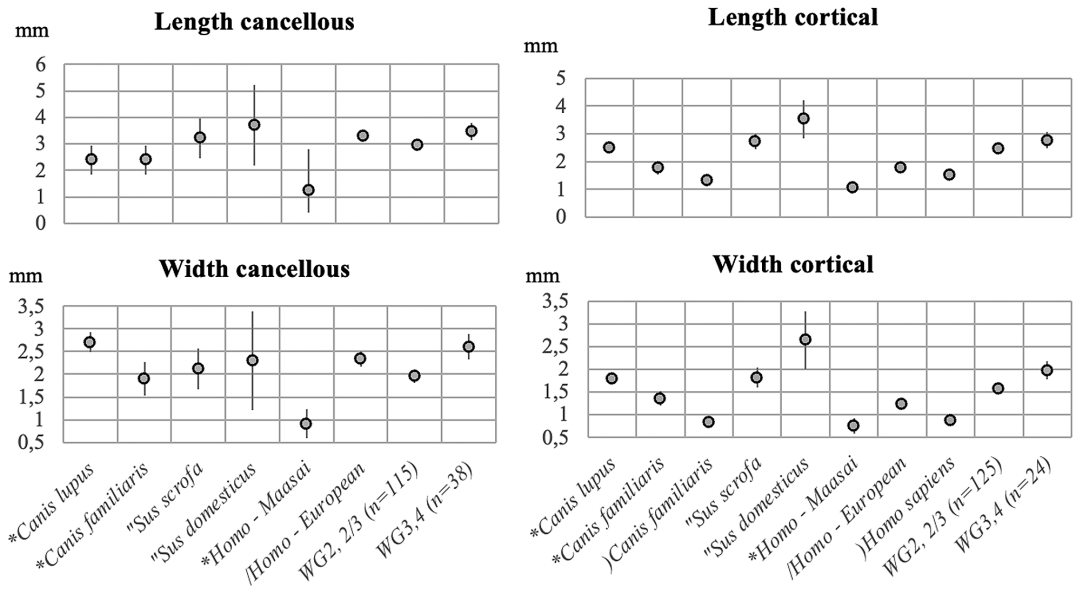

Fig. 8. Comparison of results (in mm) obtained for the maximum (length) and minimum (width) axis of pits/punctures recorded in the Ota assemblage according to the type of bone tissue. Values presented are the mean and CI 95%. Legend:* *Andrés *et al.* 2012; "Saladié 2009; /Saladié *et al.* 2013,)Delaney-Rivera *et al.* 2009.

dently of the MNI calculated. Considering swine, it is not easy to understand age patterns due to the superimposition of wild and domesticated specimens. All the larger size individuals identified as possible wild boar are adult or senile, with the possible pigs comprising juvenile, sub-adults/adults and adults, and the wild boar/pig adding infant/juvenile individuals. These omnivorous animals were being slaughtered while the meat was tender, but older individuals are also present and they could relate to reproductive purposes. Caprine are represented by different individuals, from juvenile to adult/senile individuals, with a clear higher proportion of adults and even one case of one adult/senile goat. More information is needed to better understand the kill-off pattern in caprine, but a focus on older individuals is clear. The large majority of the assemblage comes from contexts that were sieved so we do not expect a bias against small teeth (including deciduous teeth). An infant/juvenile cattle individual was identified based on the presence of scarce unfused elements and low ossification bones, but teeth that could allow for a better age estimate were not recovered. The presence of younger bovine can relate to the acquisition of primary and secondary products, since the slaughter of calves can relate to the need to reduce the amount of fodder needed and no further need for milk exploitation, or the use of one calf to stimulate several cows (*Vigne, Helmer 2007*). The slaughter of older cattle after they started to be

				C.I.	C.I.			
	N	Mean	SD	+95%	-95%	Min	Max	95%CI
length WG 1 cortical/thin cortical	2	4.89	0,45	5.50	4.27	4.57	5,20	0.62
length WG 2, 2/3 cortical/thin cortical	125	2.46	0,83	2.61	2.31	1.02	5,29	0.15
length WG 3, 4 cortical/thin cortical	24	2.77	0,74	3.06	2.47	1.67	4,27	0.30
width WG 1 cortical/thin cortical	2	2.59	0,60	3.42	1.75	2.16	3,01	0.83
width WG 2, 2/3 cortical/thin cortical	125	1.58	0,55	1.67	1.48	0.51	3,76	0.10
width WG 3,4 cortical/thin cortical	24	1.98	0,48	2.17	1.79	1.24	3,22	0.19
length WG 1 cancellous	7	2.52	0,86	3.15	1.88	1.64	4,25	0.64
length WG 2, 2/3 cancellous	115	2.95	1,21	3.17	2.73	1.31	7,49	0.22
length WG 3,4 cancellous	38	3.48	1,03	3.80	3.15	1.83	5,64	0.33
width WG 1 cancellous	7	1.89	0,48	2.25	1.53	1.32	2,73	0.36
width WG 2, 2/3 cancellous	115	1.96	0,75	2.10	1.82	0.59	4,83	0.14
width WG 3,4 cancellous	38	2.60	0,91	2.89	2.32	0.83	5,07	0.29

Tab. 8. Descriptive statistics for the length and width (in mm) of pits and punctures on cortical/thin cortical and cancellous tissues recorded on identified and indeterminate remains identified to weight group (*SD *standard deviation,* CI *confidence interval).

less productive is a common practice, especially if older individuals are not needed for use as traction (*Pérez Ripoll 1999*).

Clear hunting practices are recorded. Besides the smaller amount of red deer adult individuals, leporids, probably only consisting of the European rabbit and almost entirely adult individuals, show important NISP, MNE and MNI results. Other taxa comprise a possible equid bone, carnivores, Aves, amphibia ind. and Anura for which the scarcity of available data hinders further discussion. One must emphasize that sieving was implemented in Structure 3, corresponding to 97% of the total assemblage under study. Finally, some bivalves were recovered; the grooved carpet shell is more frequent, but the common cockle and scallop are present.

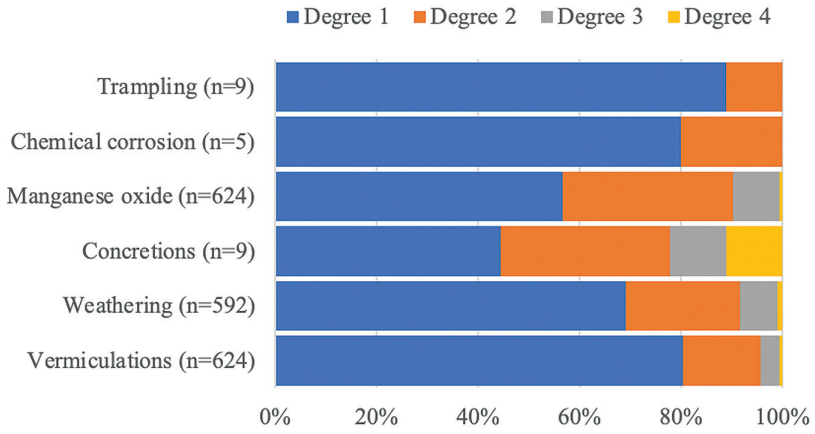

Fig. 9. Other indicators identified in the assemblage and their assessment based on degrees of modification.

The assemblage has several indicators of anthropogenic processing of animal body parts, with cutmarks related to the different stages of butchering and anthropogenic breakage indicators recognizable. Burned and possible boiled remains are present with similar frequencies and can potentially relate to the higher longitudinal outlines and right or mixed angles of the breakage planes in the small to large weight groups. The frequency of double colourations and the larger number of degrees 2 and 3 might result from the culinary practices, more than another type of natural or non-culinary anthropogenic action. Overall, the fragmentation as well as modern breakage that affected the collection is also evident.

Regarding leporids, they have higher preservation of diaphysis in comparison to other species. Nonetheless, complete long bones are absent – only isolated teeth and bones from the extremities are complete, and modern breakage is infrequent (n=9). At the same time, consumption indicators on leporid bones and burning are present. The former comprises notches and punctures in appendicular bones (n=16), and crenulated edges (n=12) in innominate (n=8), scapula (n=1), femur (n=2) and mandible (n=1). Morphologically, the majority of these remains seem to lack the typical characteristics of carnivore gnawing tooth marks, showing similarities with human consumption. One must consider the possibility that other carnivores, such as canids, could have had access to the remains. Wolfs, for example, are known to completely consume rabbit remains, thus this would result in a large, digested sample (*Lloveras* et al. *2020*) but this is not found in the assemblage, and the implementation of sieving certainly diminished recovery bias. The importance of dogs in Late Prehistory contexts is noteworthy, since they probably ate human-abandoned waste, resulting in a different patterning of body parts, besides distinguishable tooth marks and digestion degrees, but data is lacking for better comparison (*Almeida* et al. *2022*). Other carnivores, as is the case of foxes (*Sanchis 2000; Lloveras* et al. *2012*) and the Iberian-lynx (*Lloveras* et al. *2008a; Rodríguez-Hidalgo* et al. *2013; 2015*), have slightly different patterns of consumption, but leave tooth marks that can be distinguishable from human chewing. Beak/talon marks created by birds of prey (*e.g., Sanchis 2000; Lloveras* et al. *2008b; 2009*) are absent in the collection. Measurable tooth marks on leporid bones were scarce, because pits are less prevalent than crenulated edges and tooth notches. Moreover, a lower breakage of leporid bones compared to that seen with larger animals was observed. The lack of young leporids could relate to the natural dead's *latu senso*, or the lack of anatomical connections that could hint at predation, together with the abovementioned data, lead us to suggest a largely anthropogenic origin for the leporids in the assemblage. Hence, carnivores seem to not have contributed substantially to the faunal accumulation of the Ota site for smaller specimens, but we cannot entirely discard secondary access to them, for example, by dogs. The secondary access and modification of remains are well characterized regarding larger taxa. In these cases, it is not clear if all consumption damage should be related to carnivore action, because some smaller and more shallow tooth marks could be produced during human chew-

ing. While swine do not seem to be of relevance in the consumption due to a lack of diagnostic tooth marks, the morphologies, types and size of tooth marks are consistent with a large canid, also identified in the assemblage.

The presence of molluscs in Iberian Late Prehistory contexts is common and associated with merely economic or an ideological and symbolical dimension of their consumption or the use of shells. Regarding scallops, for example, the circulation of their shells is recurrent even in inland sites, while others, such as the grooved carpet shell, could be consumed or circulated in conditions that would allow their consumption in farther regions (*Valera, André 2016/2017*). The few bivalves identified do not allow for further considerations, since they were scattered in several stratigraphical units and not related to specific contexts that could further reveal their purpose. On the one hand, they could be consumed and thus represent a small portion of these groups' diet due to their bromatological value, on the other hand, they could be part of the existing interaction and circulation networks where shells are commonly interpreted (*e.g., Coelho 2006; 2008; 2013; Soares 2013; Delicado* et al. *2017; Valera, André 2016/2017; Almeida* et al. *2020a; Almeida, Valera 2021*).

The data from a wider perspective

An important amount of Chalcolithic faunal records is published for central and southern Portugal (Fig. 10). Focusing on Estremadura, it is clear that equids are almost absent from the assemblages and, when recovered, their NISP is <1%. Clear hunting strategies are represented by the presence of cervids, mainly red deer and the occasional roe deer, but besides Columbeira (14%) and Ota (9%), these species have values of <5% in Chibanes, Zambujal, and especially Leceia and Penedo do Lexim. Swine dominate the assemblages of Ota (39%) and Chibanes (48%), showing frequencies similar to caprine in Columbeira and Zambujal. Caprine are even more frequent than swine in Penedo do Lexim and Leceia. In all cases, bovines are proportionally less common than swine and caprine, although the values obtained in the Ota site (24%) are similar to Zambujal (25%) and a bit less to Leceia (20%). The small frequency of equids and cervids is maintained during the end of the Chalcolithic, even if Vila Nova da São Pedro shows 8% of cervids. This site is the only one where bovines have important values (30%), but are still lower than swine, which are prevalent in all these assemblages, even reaching 58% in the Chibanes IC collection. Further results are expected to be published for VNSP that could allow for a better understanding of this pattern and if it is fully representative of the site.

It is not clear how observed differences in proportions between the larger faunal groups for these sites relate to environmental and archaeological factors and how this change regarding chronology and context. The lack of contextual and fine-grain chronological information, especially for older studied and published collections, hinders the proper discussion and assessment of possible patterns that could help explain these differences.

These results have some disparities from the ones obtained for the Alentejo region with its peneplains that differ from the Estremadura region. The difference between these two regions is currently seen not only in the archaeological records themselves but also in the faunal spectra that have been recovered (*Valente, Carvalho 2014; Almeida, Valera 2021*). While equids are slightly more abundant than in the Estremadura, cervids have much higher values, reaching 3–12% during ~3000–2400 BCE, with one case of 36% in the S. Pedro site, in Redondo. Later, between ~2400–2000 BCE, the two ditched enclosures of Porto Torrão and Perdigões show that cervids were an important part of these economies with 23% and 29%, respectively. In the Alentejo, swine are the most frequent group in all sites with exception of the Perdigões collection dated to ~3000–2400 BCE from where caprine reaches 39%. Caprine has values similar to bovine in S. Pedro, but the latter is less frequent in Monte da Tumba, Perdigões, Mercador and the older Torrão study by Driesch in Arnaud (*1993*). During ~2400–2200 BCE, the rise in cervids is accompanied by a similarity in abundance between caprine and bovine, always between 14–19% to both groups, with a prevalence of swine.

The lower dependency on red deer hunting in the Estremadura compared to the Alentejo might relate to availability and the type of sites. The Estremadura records of larger settlements, more dependent on domesticated animals, could result in a higher anthropization of the surrounding areas leading to less availability of the large wild game. While the archaeological data (type of sites, material culture) can point in this direction, the scarce archaeobotanical data does not allow for further discussion of this hypothesis, a human impact on the landscape was already observable during the Chalcolithic (and previously) in several regions (*e.g., Lord* et al. *2011*).

Equids and mainly cervids are scarce in the Estremadura regional records with higher frequencies in the Alentejo, thus similar to other roughly contemporaneous records from Spanish Extremadura, such as Atalaya (*Rodríguez-Hidalgo, Cabezas 2011*), Hornachuelos (*Castaños 1998*), Cerro de la Horca (*Castaños 1992*), Cerro I (*Castaños 1991; 1997*) and Cerro II de Los Castillejos (*Castaños 1991*).

Conclusions

With its 170m AMSL and an occupational chronology ranging from the Neolithic to the Islamic period, Ota is exposed to various climatic actions that result in a generalized lack of sedimentation (*Texugo* et al. *in preparation*). This is a reality shared by its congeners in Estremadura, resulting in a cultural phenomenon – the walled enclosure– that is mainly based on palimpsests, very difficult to disentangle and securely study. These problems were taken into consideration during the excavation campaigns that occurred from 2019 up to 2021 at Ota (*Texugo* et al. *in preparation*). To reduce their impact and help in the excavation and interpretative process of the identified archaeological units, the taphonomical study of the faunal assemblage of this site was promptly

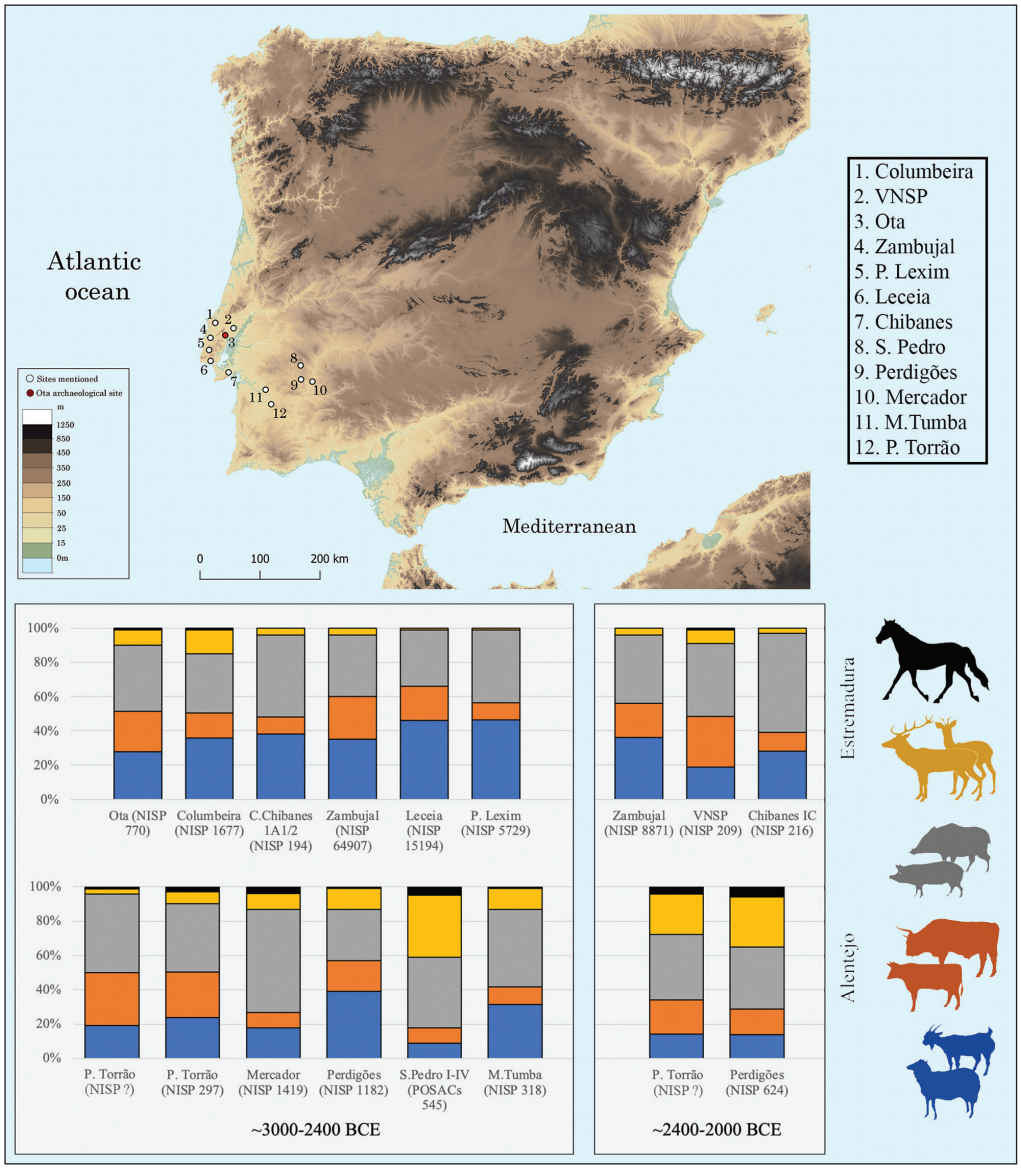

Fig. 10. Map with location of sites mentioned in the text and histogram comparing the %NISP of equids, cervids, swine, bovine, and caprine between the Portuguese Estremadura and Alentejo regions during the Chalcolithic (after* Antunes 1987; Arnaud 1993; Davis, Mataloto 2012; Costa 2013; Moreno-García 2013; Correia 2015; Pereira 2016; Pereira *et al.* 2017; Cardoso *et al.* 2021; Driesch, Boessneck 1976; Cardoso, Detry 2001/2002; Moreno-García, Sousa 2015; Valera *et al.* 2020a; Detry *et al.* 2020; Almeida, Valera 2021*). **VNSP *Vila Nova de São Pedro.* PoSACs *Parts of the Skeleton Always Counted.***

carried out. It allowed us to characterize the consumption patterns of these communities, which included both hunting and local production, and the networks to which they might have been connected, due to the presence of exogenous shells. However, it also allowed us to empirically corroborate the existence of paedogenic processes, to which the anthropic influence, through the intense architectonic reformulations, is added.

Nonetheless, and summing up, it seems that Ota replicates the patterns found in neighbouring regional sites, with a fauna profile highlighting the importance of domestic species, namely swine, goat/sheep and cattle. Hunting practices are complementary, as is suggested by the less common red deer, auroch and possibly wild boar. Of added interest are the leporids, mostly composed of rabbits, that after a taphonomical assessment seems to relate mainly to human consumption, even if occasional indicators of other predators are recorded. As noted earlier, we do not discard access to these remains by carnivores, which is also demonstrated in the larger animal remains. However, this would mainly have been secondary access to human food refuse. The assemblage has several indicators of anthropogenic processing, with cutmarks derived from butchering, anthropogenic breakage, and thermal alteration with culinary proposes. The kill-off patterns are suggestive of secondary product exploitation in caprine and bovine, possibly milk, to produce cheese, materialized in the presence of cheese makers in the archaeological record. The analysis of taphonomical indicators of the sedimentary environment reinforced the interpretation based on fieldwork observations concerning stratigraphies, further supported by new absolute dates. This allowed for the presentation and discussion of zooarchaeological information from a current perspective, one still uncommon for this region and period.

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Colonization dynamics of LBK farmers in Europe under geostatistics test

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ABSTRACT – *Exploiting a database developed during a previous research project, this study uses factor analyses, GIS techniques and basic geostatistics to evaluate in detail the agro-ecological determinants of the first Neolithic diffusion in continental temperate Europe (the Linearbandkeramik or LBK), as well as its underlying settlement dynamics around half a millennium (5550–4925 BCE). More than 6600 LBK site locations, spread from Moldavia to Normandy, are initially assessed for their informative coherence and ability to offer a unified perspective on the evidence established at more local and regional levels. Most of these data can be used to define the broad geo-pedological options involved in the location of sites across Europe; loess substrate was far from being an exclusive settlement choice and a variety of soils, typically of medium moisture, were exploited. LBK farmers thus had a great capacity to adapt to the different geographical contexts they encountered. With regard to settlement dynamics in Central and Western Europe, the data reveal a systemic interplay between creation, stability and abandonment of sites, supporting the diffusion of the LBK subsistence system. The progressive decline in the number of new sites was compensated by an increase in their stability until the last stage of the expansion process. At this point, abandonments became widespread without significant renewal, except in the westernmost regions. The easternmost parts of Europe could not be integrated in the large-scale temporal modelling, since the chronological data available in the database are insufficiently precise. Shedding new light on the systemic variability of the geo-environmental options followed by these early farmers and highlighting some modalities and spatial-temporal limits of the resilience of their agro-sylvo-pastoral system, our overall analysis confirms and somewhat clarifies current interpretations of the LBK phenomenon.*

KEY WORDS – *Neolithic; LBK; Europe; colonization; geo-environment; settlement dynamics*

Geostatistični test kolonizacijske dinamike LTK kmetov v Evropi

IZVLEČEK – *S pomočjo podatkovne baze, vzpostavljene v prejšnjem raziskovalnem projektu, v tej študiji predstavljamo rezultate faktorskih analiz, tehnik GIS in osnovne geostatistike, s katerimi natančneje vrednotimo agro-ekološke dejavnike med prvo neolitsko difuzijo v Evropo z zmernim celinskim podnebjem (področje kulture linearno trakaste keramike ali LTK) in poselitveno dinamiko v pol tisočletnem obdobju med 5550–4925 pr. n. št. Več kot 6000 LTK lokacij, ki se raztezajo od Moldavije do Normandije, smo najprej ocenili glede na njihovo informativno koherentnost in sposobnost ponuditi poenoten pogled na podatke, razvidne na lokalni in regionalni ravni. Večino teh podatkov je mogoče uporabiti za določanje širokega nabora geo-pedoloških danosti na lokacijah po vsej Evropi; puhlica še zdaleč ni bila izključna poselitvena izbira, raznolika, srednje vlažna tla so bila pogosta izbira. LTK kmetje so se bili sposobni prilagoditi različnemu okolju, s katerim so se srečevali. Glede*

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na poselitveno dinamiko v srednji in zahodni Evropi podatki kažejo sistemsko povezanost postavitve, stabilnosti in opustitve naselij, skladno z difuzijo LTK preživetvenega sistema. Postopno zmanjševanje števila novih naselij je nadomestila njihova stabilnost, ki se je ohranila do zadnje stopnje procesa širjenja. V njej so opustitve naselij brez obnove postale, razen v najbolj zahodnih področjih, zelo pogoste. V časovno modeliranje nismo vključili najvzhodnejših delov Evrope, saj so kronološki podatki, ki so na voljo, premalo natančni. Z analizo smo osvetlili sistemsko geo-okoljsko variabilnost in modalitete ter prostorsko-časovne omejitve odpornosti agro-gozdno-pašnega sistema prvih kmetovalcev ter potrdili oz. pojasnili veljavne interpretacije LTK fenomena.

KLJUČNE BESEDE – *neolitik; LTK; Evropa; kolonizacija; geo-okolje; poselitvene dinamike*

Introduction

This paper discusses the settlement dynamics of the LBK (Linearbandkeramik), from Hungarian Transdanubia to the shores of the English Channel and the Black Sea, between 5550–5500 and 4950–4900 BCE (Figs. 1.a and 2). The origin of this large cultural complex is to be sought in the peripheral areas of the Painted Pottery cultures of the Carpathian-Balkan regions, most notably the Starčevo/Körös-Criş which extended during the first half of the 6th millennium from Serbia to the lower Danube basin. In its early phase of development, the LBK is characterized by the low variability of its ceramics, house types and more generally settlement and food production systems (*Bánffy, Oross 2010; Czekaj-Zastawny 2009; Kreuz* et al. *2005; Kulczycka-Leciejewiczowa 2000; Lenneis 2001; 2003; 2010; Lenneis, Pieler 2016; Lichardus* et al. *1985; Lüning 2005; Oross, Bánffy 2009; Quitta 1960; Pavlů 2000; Salavert 2017*). Recent bioarchaeological and palaeogenetic research supports the migration hypothesis developed as early as the 1920s (*Childe 1929*) and describes a process of direct population movement (*Brandt* et al. *2013; 2015; Lipson* et al. *2017; Mathieson* et al. *2015*), in addition to the internal mobility of individuals, particularly women (*Price* et al. *2001; 2002; Bentley* et al. *2012*). Current palaeogenomic analyses point to an incipient genetic admixture from local hunter-gatherers during the LBK period, further developing through the succeeding centuries (*Brunel* et al. *2020; Rivollat* et al. *2020*). Prior to these new insights, a pure migration hypothesis formed the basis of a multi-agent modelling approach (ANR-09-CEP-004-01/OBRESOC project), exploring multiple socio-environmental interactions (*Bocquet-Appel* et al. *2015; in prep.; Dubouloz* et al. *2017*). Following this experimental approach and based on the archaeological data collected on this occasion (*Dubouloz, Gauvry, in prep.*), our objective here is to carry out a detailed evaluation of the site database and its capacity to account for settlement dynamics. In order to address this issue and refine our understanding of its geography, a planimetric dataset was built around this archaeological database, inspired by the GIS approaches developed in the '*ArcheoMedes*' and '*ArchaeDyn*' programmes (*van der Leeuw* et al. *2003; Gandini* et al. *2012; Gauthier* et al. *2022*).

After a general analysis of the archaeological and environmental data, we will address the question of the dynamics of archaeological settlements based on measures of geographical distribution.

An in-depth exploration of the agro-ecological relationships involved in this archaeological distribution will be the subject of another paper developing a space-time model of the LBK expansion process. Finally, to bring this research to a close, a third contribution will focus on the role of salt resources in the overall LBK process, in relation to this ecological modelling.

The archaeological data

The analysis includes 6639 sites, spread over 14 countries and eight major river basins (Danube, Dniestr, Elbe, Oder, Rhine-Meuse, Seine, Vistula, Weser). The database (BD_LBK) is informed by various descriptors presented in sections 1.1 and 2.1 and Appendix 6. The initial 'OBRESOC' database, with 6566 units, was corrected and reorganized to enable SQL queries, and then amended by including data from Romanian Moldavia (Robin Brigand, Oliver Weller) and the Republic of Moldova (Madalin-Cornel Văleanu, Brigand, Weller). The study window was extended by a buffer zone of 70km around outlying LBK sites. This measurement corresponds to half the observed maximum inter-site distance, which is theoretically possible to cover in two days' walk. This brings the total study area to 1 211 807km^2. For some regions, the BD_LBK contains fewer sites than those recorded in the literature. This is principally the case

in the Kraichgau and Middle/Upper Neckar (Baden-Württemberg), where the number of known sites is much higher than in the database (*Bogaard* et al. *2016*). As the latter was designed as an inventory of fully identified sites, many locations on published maps without precise bibliographic and geographical references have been ignored. Additional work to identify all the available sites will be necessary here in order to address these gaps. The question will arise later of the impact of these deficits (~5%) on our overall results (see section Brief synthesis and perspectives).

Archaeological descriptors

Each site is recorded by several descriptors of a strictly archaeological nature or linked to a brief geographical description (countries, rivers watershed). They are presented below in increasing order of relevance.

❶ The 'Country' variable is coded by two letters (ISO 3166-1 alpha-2). It reflects the general effects of history and research policies in major political regions.

❷ The 'Basin' variable is derived from a simplified map of rivers drawn up by the European Commission Environment Agency (Catchments and Rivers Network System, 2012). It shows the apparent structuring role of river basins in the geography of LBK diffusion. After verification of its operational value, it will not be used in the multivariate analyses.

❸ The 'Nature of the intervention' variable is a means of assessing the primary quality of the archaeological data, mostly derived from random collection (Collect., 50.7%), organized survey (Survey, 23.9%) and partial excavation (F.Part., 22%); extensive excavations are very much in the minority (F.Ext., <4%). This variable makes it possible to modulate the results according to the uncertainties of the database.

❹ The variable 'Category' of sites (settlement, enclosure, shelter/cave, cemetery, *etc*.) is mostly not filled in (67.5%). Therefore, on a European scale, all the entries in the database are integrated under the neutral term 'site'.

❺ 'Spatial accuracy' is of uneven quality: 39.6% of the coordinates of the sites are very well to fairly well positioned (Loc ++ ≤100m and Loc +– ≤500m), while 60.4% are more poorly located (Loc –– ≥1000m). But this range of uncertainty usually coincides with the resolution of the geo-environmental data.

❻ The 'Area' of a settlement should be a relevant criterion for describing its importance, but the low occurrence of documented instances (18.4%) rules out statistical analysis.

❼ The 'Dating' variable (see section Chronology of settlements and Appendix 13 for more details) describes the dating evidence in Boolean coding. Sites dated by major chrono-cultural stage are characterized by a 'first settlement' variable (St. x) and a 'duration of occupation' variable in years of continuous occupation (D. x00); the absence of information is coded 'nr' in both cases. The mapping of dating precision (Precise = St. x Loose = St. nr) reveals a very strong dichotomy (Fig. 1.a) between Western Europe (France, Belgium), where sites are more often well dated, and Eastern Europe (Ukraine, Romania, Republic of Moldova). Central Europe (Fig. 1.b) is intermediate in this respect, with some well-documented sectors (Hungary, Austria, Slovakia and Germany to a lesser extent) and others that are often more limited (Poland, Czech Republic).

❽ 'Reliability' is a synthetic variable which describes the overall quality of the archaeological map. It combines the values of three variables: geography (accuracy of location), chronology (accuracy of dating) and contextual expertise (type of fieldwork). The mapping of this index is carried out through a transformation of the point entity into a raster information with 5km sides, from the most reliable to the least reliable. This mode of representation offers a general view of the state of research on the data (Fiab.A = 3 positive variables; Fiab.B = 2 positive variables including chronology; Fiab.C ≥ 2/3 negative variables = 80.2% of sites). There is a strong heterogeneity in the database (Fig. 2), very similar to that produced by the 'Dating' variable. The western and southern 'half' (Seine, Meuse and Moselle basins, Rhine and Weser basins, Hesse and Württemberg, Danube valley, Austria) is generally well documented. The other 'half', in the centre and the east of the map (Thuringia/Saxony-Anhalt/Saxony, Bohemia, Moravia, Slovakia, Hungary, Poland, Romania, Moldova and the Ukraine) often shows a more limited documentary quality.

Multiple Correspondence Analysis (MCA)

A multiple correspondence analysis (MCA) was applied to the complete disjunctive table of most of the BD_LBK's discrete data (*Benzecri 1973; Escofier, Pagès 1990*). This analysis will characterize the documentation in its suitability for addressing the issues of the determinants and rhythms of the LBK

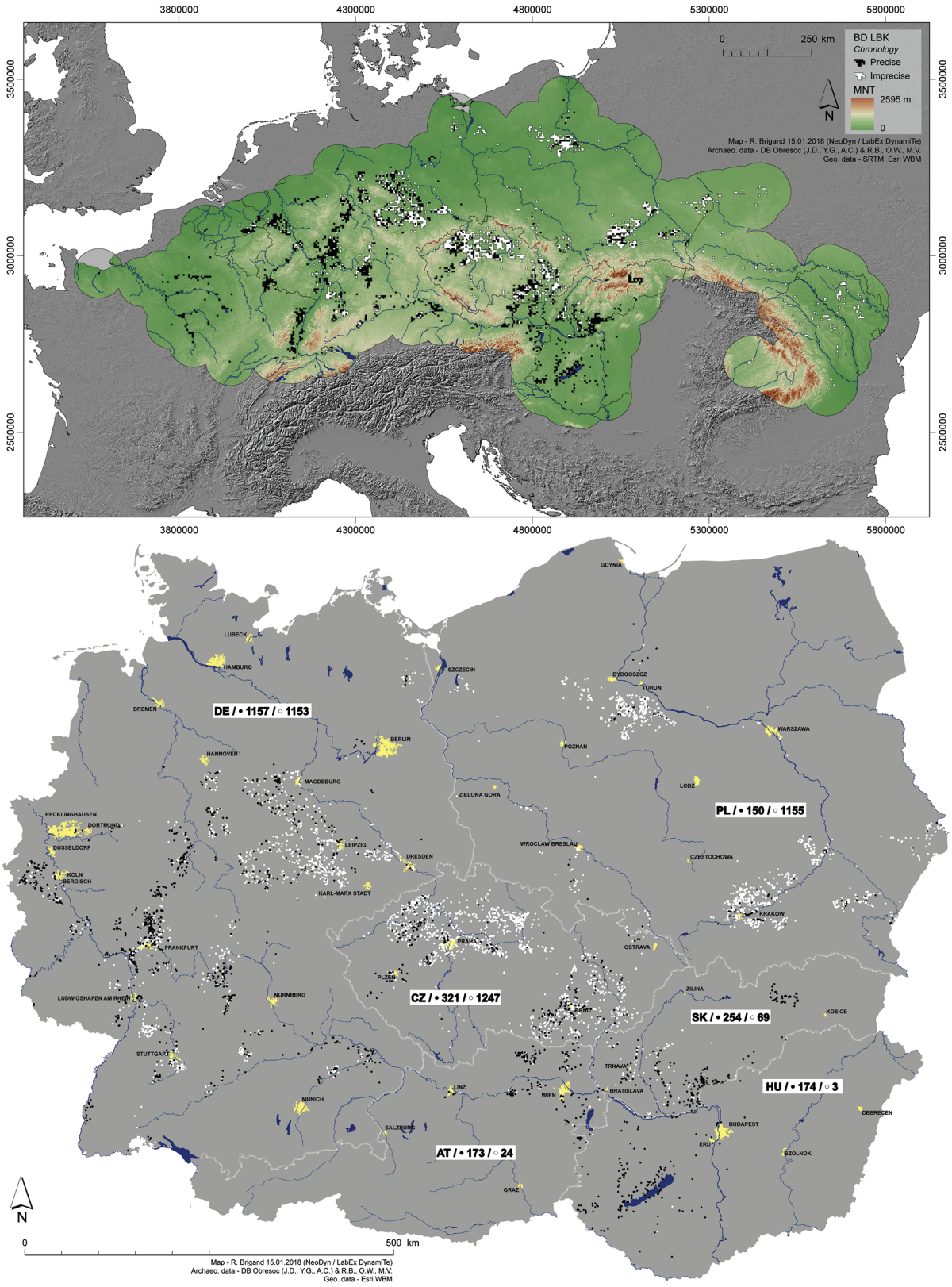

Fig. 1. Upper: LBK settlement map (6639 features) and chronological accuracy (each site – or group of sites – is represented by a pixel of 25km²). Bottom: map of LBK sites in Central Europe (Poland, Slovakia, Hungary, Czech Republic, Austria, Germany) precisely dated (black dots) and simply dated LBK (white dots).

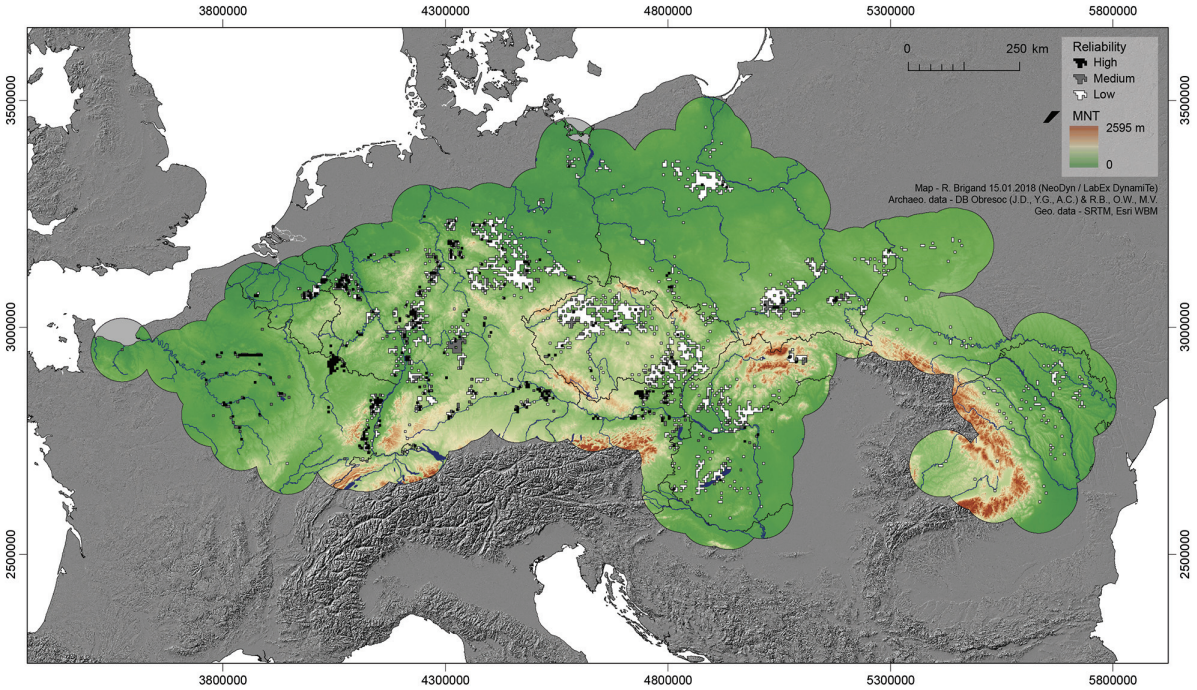

Fig. 2. LBK settlement map (6639 features) and overall reliability of the archaeological information (each site, or group of sites = 25km²/pixel). Hydronyms are abbreviated: Bu. Bug, Da. Danube, Dn. Dniestr, Dr. Drava, El. Elbe, Is. Isar, Ma. Main, Ma. Marne (Fr.), Me. Meuse, Mo. Moravia, Mo. Moselle, Od. Oder, Pr. Prut, Rh. Rhine, Sa. San, Se. Seine, Va. Vah, Vi. Vistula, Vl. Vltava, Wa. Warta, We. Weser, Yo. Yonne.

agro-sylvo-pastoral system in its continental development. Six variables are mobilised for 38 active modalities: the variables 'Category', 'Area' and 'Basin' were excluded from the analysis because of the insufficient quality of the available information or because they were too general.

A preliminary reading of the relative contributions of the six variables themselves provides a framework for the following detailed analysis of their modalities involved in the MCA (Fig. 3).

This first approach shows that five variables out of six contribute, through some of their modalities analysed below, to explaining the intrinsic variability of the data recorded in the inventory. The 'Country' variable does not seem to play a particular explanatory role in the overall construction, which is reassuring. The 'Reliability' variable, despite its polythetic dimension (*cf.* 1.1–8), does not sum up the patterning of the data alone: its statistical weight is only significant on the first factor. We shall see below that different modalities of its own descriptors are particularly discriminating throughout the analysis. The other four variables do not show very strong correlations: for example, 'Duration' is not strictly related to the age of the installation ('Chronology') nor to the research intensity ('Fieldwork'); in the same way, geographical precision seems only partially related to 'Fieldwork'. These general observations suggest that a rather complex dispersion characterizes the variability of the data, which are therefore not univocally determined.

Description of the factors or components (Appendices 2–4)

The detailed analysis of the first three factors of the MCA, then of the factorial maps of their 38 modalities, makes it possible to specify the previous observations (Appendices 2–4, 7 and Figs. 4 and 5).

The first factor (original eigenvalue of F1 = 10.69% or 77.79% in Benzecri correction) is detailed in Appendix 2. It contrasts the sites well documented by excavations, dating to different stages of the LBK (especially St. 2 and 4) and of rather limited duration, with the less well-documented and therefore less reliable sites: France and Poland/Czech Republic respectively embody these two opposing poles which, not surprisingly, dominate the structuring of the data.

The second factor (F2 = 5.55% or 8.45% Benzecri, Appendix 3) mainly articulates the temporal variability around the differential documentary effects of 'Survey' and the 'Collect'.

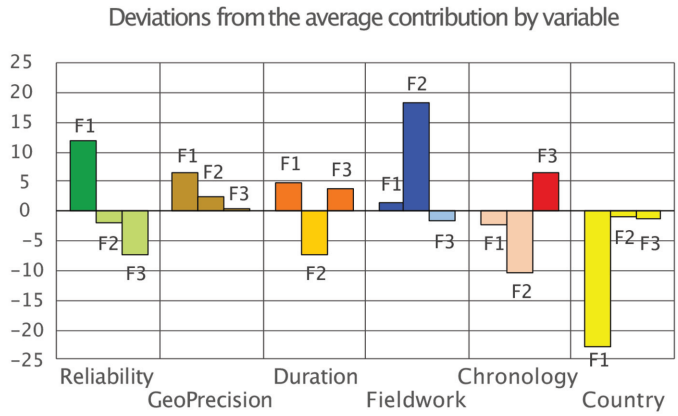

Fig. 3. Relative contributions of the six variables to the characterization of the first three components of the MCA (colours shown in Annexes 2 to 4)

The third factor (F3 = 5.07% or, 5.53% Benzecri, Appendix 4) specifies the variability of the borders of the time sequence, by underlining the opposition of older and long-lived Central European sites, resulting from 'Survey' prospection (52.1% of the inertia), to westernmost sites dating to the later stages of the LBK and correctly located (31.2%). It also shows that some countries linked to 'Collect' in F2 (Slovakia, Hungary) are additionally associated with 'Survey'.

Analysis of maps F1/F2, F1/F3 and F2/F3 (Figures 4–5 and Appendices 5–7)

● Map F1/F2 (Figure 4 and Appendix 5) shows a qualitative and chronological structure in the data and reveals three main groups of modality associations. It contrasts extreme documentary situations, between France/Netherlands (best information) and Poland/Czech Republic (worst information). In addition, it defines for part of Central Europe an intermediate group of sites with variable documentation and often 'average' quality. Germany and Belgium, at the centre of the scatterplot, are linked to all qualities of documentation, but with only a small proportion of the best; Austria has a significant rate of good quality information; Hungary and Slovakia are isolated from the other countries mainly because of their stronger ties to the early stages of the LBK.

● Map F1/F3 (Figure 5 and Appendix 6) identifies, in addition to the extremes already identified in F1, a central cluster of medium to high level modalities; this indicates a fair to good reliability shared by many sites in central-western Europe belonging to the main part of the LBK sequence and of all durations. It also confirms the better documentation of the western trio (Netherlands, Luxembourg, France), and the more varied documentary quality in Germany, Belgium and Slovakia. The cluster of countries gathered around the least positive modalities confirms the singularity of Poland, linked to 'Survey'.

● Map F2/F3 (Appendix 7) characterizes the database without the influence of poor documentary situations; it shows links masked by the hyper-structuring weight in F1 of the strong correlation of qualitatively weaker or undefined modalities. Hence it confirms the existence of the same poorly or badly characterized sites in the BD_LBK (here centrally positioned and therefore not very significant in describing this additional variability) and their distinction with the very well-characterized group in France and the Netherlands in the later stages of the LBK. In addition, this plot underlines a significant and favourable situation with Poland and its systematic 'Survey' practices. It also confirms that, at the time of database completion, Hungary and Slovakia stand out strongly from the other European countries in terms of the relative weight of their older, long-term and partially documented sites.

A synthesis of these successive and complementary analyses is quite easy to make, as they provide fairly similar results on the variability of the documentation. Three major poles emerge: first, the group with the best possible combination of documentation, in Western Europe, with sites in France, the Netherlands and Luxemburg; second, the group with lowest quality information, around the Czech Republic and partly Poland; third, the combination of intermediate quality information in Hungary, Slovakia, Germany, and Belgium. The remaining five 'Country' modalities are divided between the poor-quality combinations (Moldova, Romania, Ukraine, Switzerland) and the medium-quality ones (Austria).

Apart from the western trio, Poland and Hungary/Slovakia both present a complex situation. They can be regarded as specific versions of poor and moderate documentation. Thus, Poland shares with the western part of Europe a significant proportion of sound documentation (Fig. 4, map F2/F3), thanks to its affinity for high-quality 'Survey'. In the group of medium quality documentation, Hungary and Slovakia stand apart from others (see Figs. 4–5 and Appendix 7). This may be related to their greater connection to the earlier stages of the LBK. The mid-quality group is also well represented by Germany and Belgium, which possess all the variety of docu-

mentation in significant proportions. Some is rather poor and broadly similar to the qualitatively under-documented Eastern Europe and Czech Republic, where the huge number of entries in the database statistically overshadows the well-documented sites in Bohemia and Moravia. Finally, Austria's documentation lies between the good and medium quality groups, quite close to that of the western countries.

Quality of the BD_LBK and overall heuristic validity.

The overall impact of the observed heterogeneity (Appendix 1) in the BD_LBK on the investigation of geo-environmental aspects and LBK settlement dynamics will now be assessed.

From the point of view of geography, this diversity is arranged quite clearly along an east-west transect; our information thus gains in quality along this axis and its suitability for interpretation increases at the same time. Apart from language barriers (for Ukraine and Moldova), three logically related constraints contribute to this overall European pattern: the number of sites recorded, the temporal depth of the research and the underlying types of archaeological intervention. Thus, three countries which are major contributors to the database (Germany, Czech Republic, Poland) are characterized by an overall documentary situation of average to mediocre quality; and three other countries, lesser contributors to the database (France, Netherlands, Austria), present much more favourable situations. This dichotomy, which is somewhat counter-intuitive, is probably due to a mass effect. For the first countries mentioned, the temporal and spatial extent of research has produced a high proportion of sites identified 'in the past', while settlements that are well documented by more recent research have in this case relatively less weight than in countries where more recent, more proactive and/or more localized research will have accumulated fewer poorly documented sites.

Several intermediate situations are obviously present. For example, Hungary and Slovakia each illus-

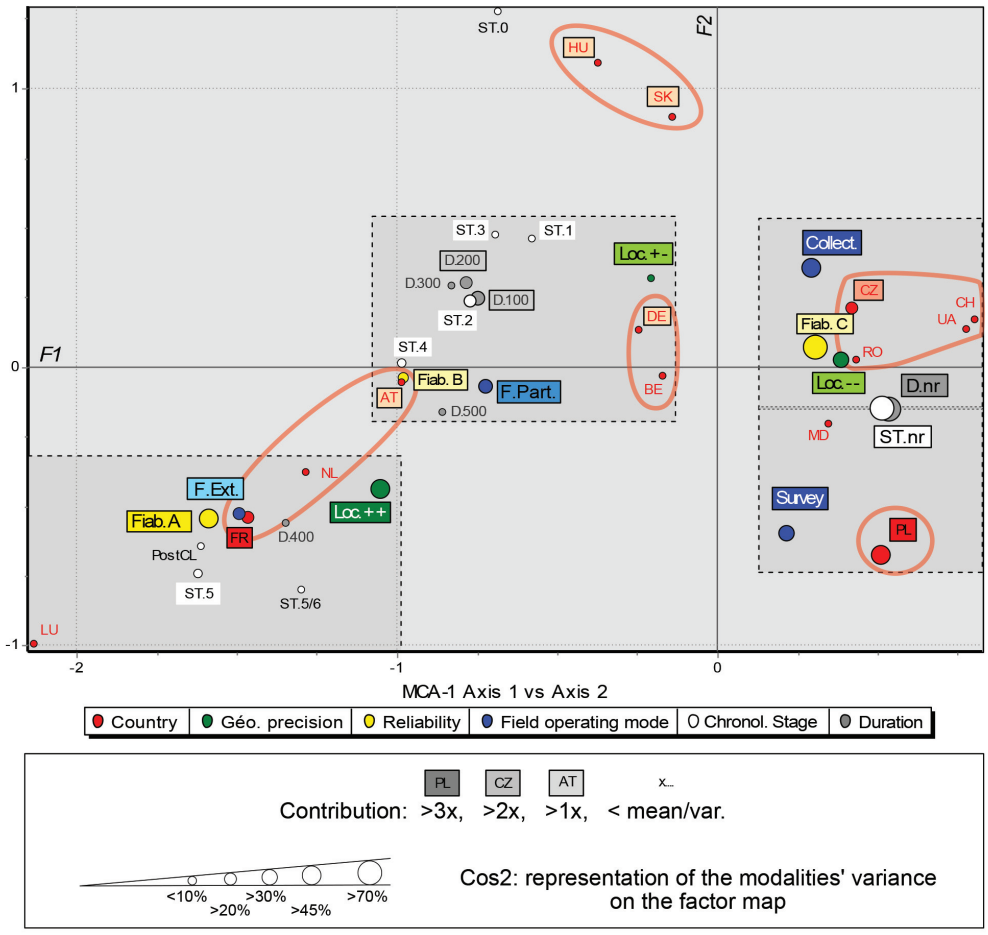

Fig. 4. F1/F2 map of the MCA showing the archaeological descriptors. Size and coloured highlighting of the fonts symbolize the level of the modalities' contribution; radius of the circles shows their representation's rate; red contours underline the particular distribution of the countries.

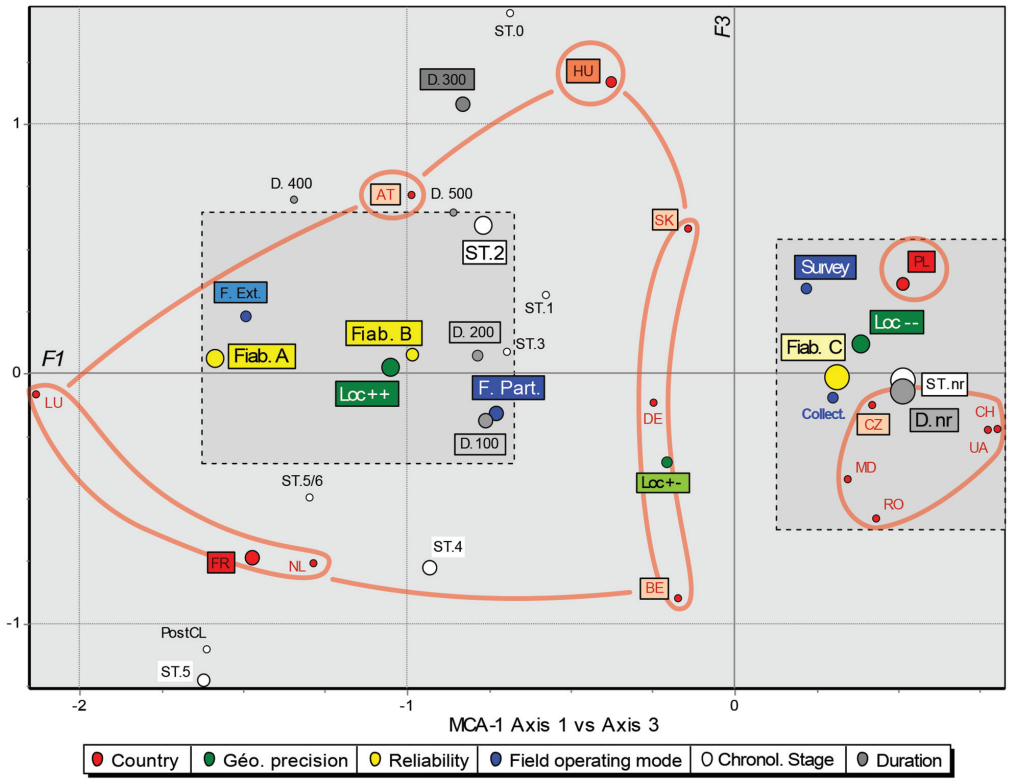

Fig. 5. Graph of the 1/3 factorial map (F3 inertia: 5.07% or, 5.53% in Benzecri correction). Same legend as Figure 4.

trate their specificity, and their close positioning seems as much related to the broad trends that structure LBK data as to their own similarity. Thus, their convergence is probably mainly due to the distribution of the chronological variable: these two countries have relatively few well-documented sites and comparable proportions of moderately to poorly documented sites, but their share of later LBK sites, lower than in the other countries, may explain their joint isolation in the results of this analysis.

Finally, at the geographical margins of the phenomenon under study, the situations are broadly opposed. One, in the east, appears to be mediocre overall, no doubt due to shortcomings in the collection of information, but also possibly due to a very different history of research and more limited funding. The other situation, in the west, generally appears to be good, probably due to the geographical limitation of the areas concerned (the Netherlands and Luxembourg) and/or significant and earlier funding of rescue archaeology.

Thus, as was to be expected, the 'Country' variable is not an explanatory descriptor, but is only relevant in highlighting contextual trends. These can be summarized by five fairly well-differentiated classes and sub-classes: (i) the class with little information, mainly comprising eastern sites; (ii) the sub-class 'Poland', which has limited information in general, but is often well documented by 'Survey' or extended excavations ('F.Ext.'); (iii) the class of mixed situations, comprising Belgium, Germany, Slovakia and Hungary, with comparable proportions of poorly and moderately documented sites, together with some large to huge archaeological investigations; (iv) the sub-class 'Austria', which has fairly good information overall; (v) finally, the class of the most favourable situations, mainly associated with the Netherlands, Luxembourg and France: Austria participates to a certain extent in this last group (F1/2).

This extensive information variability could have a negative impact on the use of the database for research, by restricting the number of comparable sites available in different regions and by blurring the conclusions to a greater or lesser extent, depending on the regional representativeness of the available samples. However, in the broad analysis of the agro-ecological determinants of LBK settlement, it emerges that these documentary limitations have only a marginal impact. Indeed, such an approach mainly requires geolocation in line with the resolution used for the geo-environmental space, and this is often enough to provide a good summary of the main characteristics of the LBK point-pattern. Basic geostatis-

tical techniques such as low-pass filtering will be able to overcome the main documentary weaknesses. On the same geo-environmental level, the characterization by stages of LBK expansion will be more uncertain, particularly in Eastern Europe, a region that will have to be excluded from detailed analyses. But for the large contributors in Central Europe, with considerable medium- to poor-quality documentation, the problem is mitigated by the significant number of available sites and their varied spatial distribution.

The projected research on settlement dynamics is in turn dependent on the quality of information on the chronology and continuity of occupations. The MCA presented in this section has highlighted the weight of the undetermined modalities in the structuring of the data: thus 60% of the sites in the BD_LBK do not meet the fine chronological aspects. The majority of these sites belong to the eastern regions of Europe, which again cannot be compared with other regions (although there are some pioneering studies such as Dmytro Kiosak (*2017*) and Thomas Saile (*2020*)). Among the latter, the three largest contributors to the database (Germany, Czech Republic, Poland) certainly present a significant rate of negative responses (in Thuringia/Saxony/Saxony-Anhalt (Thüringen/Sachsen/Sachsen-Anhalt in graphs), Bohemia (Čechy in graphs), Little Poland (Mało-Polska in graphs) and Kuyavia (Kujawy in graphs)), undoubtedly challenging the representativeness of these samples with regard to the regional temporal variability of LBK occupation; but the distribution of correctly to very well-informed sites overlaps quite regularly with the general pattern of known sites (Fig. 1), giving reason to hope for good spatial representativeness. Unless we can correct these biases, our forthcoming historical-anthropological interpretations will have to take this uncertainty into account.

Topographical and agro-ecological data

In this section we will focus on site locations (point coordinates) in order to characterize their geo-contexts. The set of variables integrated in the analysis is presented in Appendix 8. Each archaeological site is thus documented by two topographic and six agro-ecological variables for a total of 38 descriptors out of 41 (two descriptors and one modality, not represented in the data, were deleted).

Data classification

❶ Slopes. The slope map is classified into four map units: SL1 (flat) = from 0 to 3; SL2 (low slope) = from 3 to 9; SL3 (medium slope) = from 9 to 20; SL4 (steep slope) = from 20 to 65; in the analysis, the SL4 modality was grouped with SL3.

❷ Landscape openness. Classified into three sets, this measure is a morphometric indicator that determines the degree of concavity and convexity of the landform (*Yokoyama* et al. *2002*). It considers for each pixel a line of sight over 8 azimuths (r=10km) which may be redundant with the visibility indicators (total visibility): OP1 (closed); OP2 (open); OP3 (very open).

❸ Moisture. This is the variable deduced from the low-resolution (1km) surface water saturation map. The map is classified into four map units: HY1 (low); HY2 (medium); HY3 (high); HY4 (very high).

❹ Soil texture. This document, originally classified into seven classes, is simplified into six classes (by combining the <no data> and <organic layer> fields): TX0 (n/a); TX1 (coarse, clay<18% and sand>65%); TX2 (medium, clay<35% and sands>15% or clay <18% and 15%<sands<65%); TX3 (medium, fine, clay<35% and sand<15%); TX4 (fine, 35%<clay <60%); TX5 (very fine, clay>60%).

❺ Soil thickness. The original five-class classification is retained: PR0 (n/a); PR1 (shallow, <40cm); PR2 (moderate, 40–80cm); PR3 (deep, 80–120cm); PR4 (very deep, >120cm).

❻ Loess. The European loess map (*Haase* et al. *2007*), produced at a scale of 1:2 500 000, contains nine classes distinguished according to their thickness and degree of alteration; this document has been simplified to the extreme to retain only the existence or not of loess in the substrate: LO1 (presence); LO2 (absence)

❼ Soil group. The 1:1 000 000 Soil Geographical Database of Europe (SGDBE v4) initially presented in 27 classes according to the 1985 FAO classification has been simplified to 11 classes (European Soil Data Centre (ESDAC), esdac.jrc.ec.europa.eu, European Commission, Joint Research Centre): SO1 (Cambisols = brown soils with little typing or differentiation); SO2 (Chernozems, Greyzems and Phaenozems = soils with a high content of organic matter in their upper horizons, clinohumic soils); SO3 (Fluvisols = alluvial soils); SO4 (no data = glaciers, city, rivers, destroyed soils, n/a); SO5 (Gleysols, Histosols, Marshes, Planosols, Vertisols); SO6 (Podzol = soils marked by a true podzolization process); SO7 (Luvisols, Pozoluvisols =

degraded and leached soils characterized by eluvial upper horizons); SO8 (Lithosols, Regosols, Rankers, Rendzinas, Outcrops = thin soils, limited in depth by a coherent and hard material (bedrock or hardened horizons); SO9 (Arenosols = soils with sandy granulometry, not differentiated); SO10 (Salinosols = saline soils of Solonetz or Solonchaks type); SO11 (Andosols = soils of volcanic origin).

❽ Fertility. The fertility map produced as part of the ANR 'Obresoc' project (*Schwartz* et al. *in prep.*) was used without regrouping or modification. The simplification of the soil cover carried out by the authors is dictated by an attempt to reconstitute Neolithic soils. As such, this work differs from classic studies – and from those presented here – which are based on the current state of the soil. Nevertheless, the scale (1:5 000 000) means there is great simplification and often arbitrary cartographic limits: FR0 (n/a); FR1 (very fertile); FR2 (fertile); FR3 (medium fertility); FR4 (low fertility); FR5 (not fertile).

Statistical analyses (MCA and HAC)

All statistical analyses performed on the LBK settlement data are based on the cross-referencing of the point attributes with the set of environmental descriptors operated in matrix form. The characteristics of the locations are at pixel level (100m), but include the very close environment since a low-pass filter has been applied to the raster data. The value of each cell is calculated from the eight surrounding pixels, thus obtaining a smoothed raster where the maximum and minimum values of each neighbour are averaged and local variations are reduced.

A multiple correspondence analysis (MCA) of the topographic and agro-ecological modalities and a hierarchical ascending classification (HAC) on the factorial coordinates (factor scores) enables a description of the settlement choices of LBK populations.

Description of the factors (Appendices 9–11)

● The strongest contributions to factor 1 (~85% of its total variance or inertia) mainly separate sites in poorly defined or rare contexts from all other sites (Appendix 9). Its relevance to our research questions is therefore very limited.

● The second factor (Appendix 10) is mainly based (~84% of its inertia) on the opposition between leached (Luvisols) or degraded soils, very deep, with a medium-fine texture and good fertility, and brown soils with moderate to deep depth, fine texture, very good or medium fertility, in a closed landscape. This second statistical summary thus distinguishes two kinds of favourable agro-ecological environments.

● The third factor (Appendix 11) is mainly based (~81% of its inertia) on the predictable opposition between deep and very fertile soils of Chernozem, Greyzem and Phaenozem types and very thin soils or soils with a tendency to waterlogging.

Analysis of map F2/F3 (Fig. 6)

Because factor 1 is defined by modalities that mainly describe the absence of information, it is more relevant to focus on factors 2 and 3 of the MCA (Fig. 6), despite a reduced inertia (total = 14.3%, 35.7% in Benzecri correction). With the results of the HAC conducted on the factor coordinates of the modalities, it reveals four main classes (Cl.1 to 4).

● Class 1 (Cl.1), with 2,916 sites (44% of the total), is predominately determined (>90%) by sites located on very deep (PR4), degraded (SO7) or alluvial (SO3) soils; then (> 50%) on medium-fine textured soils (TX3), fertile (FR2), humid and tending to hydric saturation (HY3); to a lesser extent (35–50%) by sites located on flat (SL1), open (OP2) to very open (OP3) landforms and medium hydromorphic soils (HY2). Two poles of association of agro-ecological modalities constitute class 1: the first one is very specific, around degraded, very deep, moderately fine-textured soils, and the second one around the most shared modalities, including good fertility, average waterlogging, and flat or very slightly sloping land in an open landscape. The presence of loessic substrates does not seem to be very discriminating, since their absence also contributes to defining this subgroup of CL.1.

● Class 2 (Cl.2) is composed of 132 sites (2%) located on soils for which the depth (PR0) and nature (SO4) are not given. This very marginal class of uncharacterized sites is not very relevant.

● Class 3 (Cl.3) concerns 1414 sites (21.3%) located primarily (>90%) on clinohumic (SO2) or sandy (SO9) soils; then (>50%) on very fertile soils (FR1), or soils marked by a process of true podzolization (SO6) and to a lesser extent (35–50%) on deep soils (PR3), with low surface hydromorphy (HY1) and sometimes with a coarse texture (TX1). Two preferred associations of agro-ecological modalities are also visible in class 3. The first one, very characteristic, concerns sites on clinohumic soils, very fertile, and the second one sites on deep soils with low waterlogging.

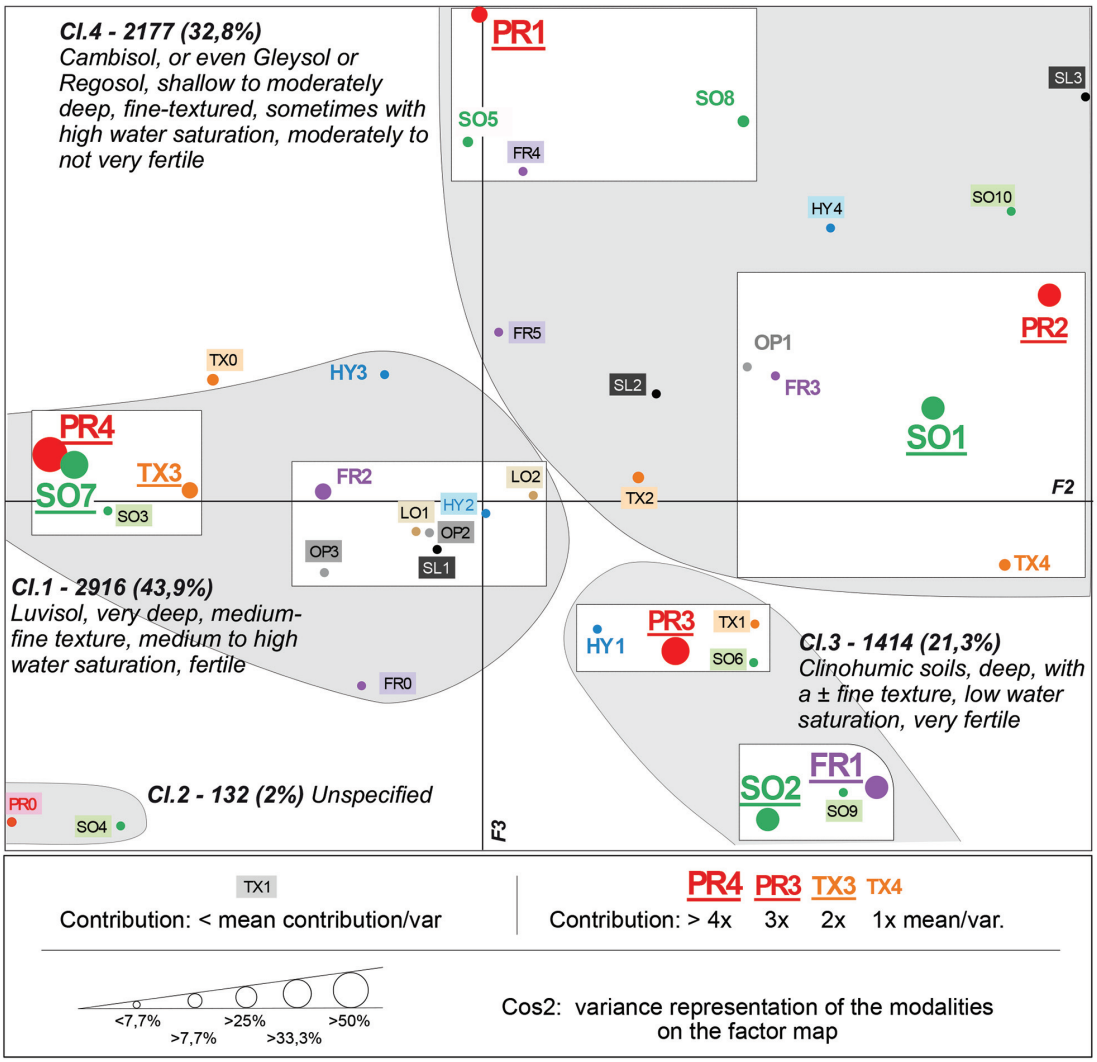

Fig. 6. Plot of the MCA showing topographic and agro-ecological traits (map F2/F3, inertia F2: 7.69% – 22.95 in Benzecri correction; F3: 6.58% – 12.74% in Benzecri correction) and arrangement of the classes from the HAC. The class boundaries are indicative; they do not exclude other under-represented modalities.

● Class 4 is made up of 2177 sites (32.8%), located primarily (>90%) on moderate depth soils (PR2) or shallow soils (PR1), waterlogged (SO5) or thin soils (SO8) or even saline (SO10); then (>50%) on brown (SO1), moderately fertile (FR3) to poorly fertile (FR4), fine-textured (TX2) soils located in topographic environments marked by a steep slope (SL3) and a closed landscape (OP1); and to a lesser extent (35 to 50%) on slightly sloping (SL2), non-fertile (FR5) and moderately textured (TX3) soils. This very heterogeneous class is structured around two very significant groups of modalities: the first concerns sites on brown soils of moderate depth, fine texture and, in part, average fertility in a rather closed landscape; the second group, very characteristic, but much less represented, is made up of shallow soils of low fertility, such as Gleysols, Vertisols, Rendzinas and Regosols.

Intermediate conclusions

The broad analysis of the agro-ecological data thus highlights the great variety of contexts in which LBK settlements are found. Rather than, as has often been assumed, a simple constraint by loess (47.6% of the total number of sites are strictly located on a loessic substrate), it is a set of characteristics favourable to sustainable farming that conditions the most frequent location of these sites: *very good to average fertility, very great to average depth, not too pronounced waterlogging, fine to average textures*. Many different soil types (SO1, SO2, SO7, even SO3 and SO6), whether on loessic or non-loessic substrates and widely present throughout Central Europe, seem to have been acceptable compromises for these early farmers. It is thus clear that they had an ancestral practical knowledge of the agrological properties of the soils, including their natural vegetation and

associated fauna. This background will have successfully guided their settlement choices in the Central European landscape.

Additional analyses

As regards the importance of loess and major soil types in the choices of location, further analysis can be made on a continental scale in order to identify interregional and/or temporal variability. Uncertainties related to soil evolution over the last 7000 years will be addressed in the course of the analysis and in the conclusions that can be drawn from the current soil cover.

The loess issue

Loess substrates make up more than a quarter of the surface area occupied by the LBK as a whole (26.2%). This share is greater if one excludes the mountain ranges, largely avoided by LBK agro-pastoralists. Loess is fairly evenly distributed (see Appendix 12), with a particularly marked presence to the northeast and east of the Carpathians, as well as in Hungary, around the Harz mountains and in Belgium/the northern Paris Basin. It is therefore expected that in most of these regions, loess may have been a major substrate for the establishment of LBK settlement.

Two approaches have been followed to specify the archaeological impact of these formations. One is based on the geographical coordinates of the sites and the other on a buffer zone of 2.5km around each site. This second approach partly reduces some of the imprecision in locating the sites and mapping the loess areas.

According to the first approach, the general trend between the Black Sea and the English Channel shows (Fig. 7.A) an almost equal number of locations on loess or other substrates (47.5% of occupations and 47.6% of localities). At a more precise temporal scale (Fig. 7.A and B), and therefore at a varying geographical scale, a trend can be seen towards a lesser dependence on Loess (Chi2: df 4, p. 0.001) between the beginning and the end of the LBK (from 55% to 42.4%), well expressed by the deviation from the mean of the occupations. This overall development thus underlines the importance of loess, but mostly at the beginning of the process, as well as increasing adaptation to the varied geo-pedological contexts encountered.

This space-time trend, identified on the basis of the present-day distribution of loess across Europe, motivated a second approach and further investigations of the geo-pedological composition of the terroir within a radius of 2.5km around each site, by major settlement region. In order to evaluate loess dependence, three surface thresholds in the buffer zone were established: (1) with 80% of loess in the buffer area, the site is considered to be located to maximize the presence of this formation, or has simply benefited from its extensive availability in the area; (2) conversely, with between 0 and 20% of loess in the buffer area the site is considered to be located with no particular interest in the presence of this substrate or has simply suffered from its low availability; (3) an intermediate threshold at 40% of the buffer area is also tested to define a proximity of the site to loess (<1km), but without excluding other substrates. According to this analysis, approximately 30% of all LBK sites are loess-independent, 34% have predominantly a loessic substrate, and 20% have a broad access to other types of geology. The remaining 16% (between 20 and 40% loess surface) represent sites with little attraction to this loess. At this level of geographic and temporal resolution, the importance of loess in the location of LBK sites is clearly variable.

The distribution of this differential access to loess according to major settlement regions (98% of sites), reveals a number of different patterns of settlement (Fig. 8.A-B).

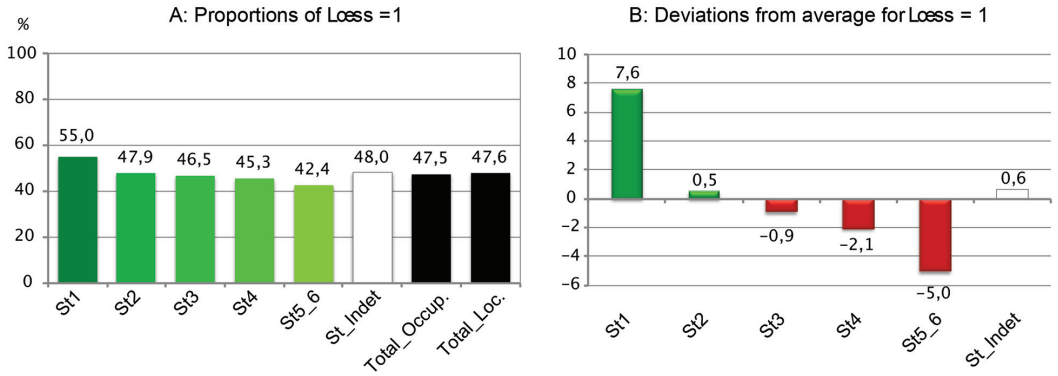

Fig. 7.* A *proportions of sites punctual location on a loess substratum;* B *deviations from average

❶ The opposition of the extreme situations (80% *vs* 20% of the buffer area) creates four groups (Fig. 8.A):

● A first group (green) with 42–64% of sites with over 80% loess and 15–34% of sites loess-independent (0–20% of their buffer area), occurring in regions where the spatial distribution of loess corresponds to large, compact sectors (Niederrhein-Westph./Maas (NWM), Wetterau/Main, Franken, Elbe-Saale, Austria (Österreich in graphs), Southern Vistula, Romania/ Moldova).

● A second group (yellow) with only 12–30% of sites with over 80% loess and 30–48% of sites loess-independent, occurring in regions with smaller and more discontinuous loess sectors (Alsace-Middle Rhine (Alsace-Mittel-Rhein in graphs), Neckar, Lower Saxony/Fulda-Weser (BSFW), South Bavaria/ Schwabia (Süd-Bayern/Schwaben in graphs (SBS)), Bohemia, Moravia, Slovakia-Hungary and South-Eastern Poland-Ukraine (SPK)).

● A third group (orange), far western [Paris Basin/ Hainaut, Franco-Luxembourg Moselle (BPHM)], where only 5–8% of sites have over 80% loess (mainly the nine sites in Belgian Hainaut) and 67–78% are loess-independent;

● The fourth and last 'group' (dark red) is made up of the Kuyavia/Chelmno area (KUJ), where 100% of sites are not located on loess.

❷ At the threshold of 40% loess in their buffer area (Fig. 8.B), the sites fall into almost the same four groups as above:

● The fourth and third groups (red and orange) are formed by the same regions (KUJ, BPHM), where the attraction of loess concerns only 0% and 11–15% of sites, respectively, except in the small Belgian Hainaut region. This overall statistic confirms the weak association of the LBK with loess in these regions.

● The second group identified above concerns 40–62% of the sites in the same regions, to which are added the Moldavian-Romanian and Southern Vistula regions. By doubling or even tripling the proportion of sites concerned, the 'mixed' terroirs thus represent a considerable weight in these regions and reveal a fairly strong link between the LBK and loess (50% ± 10).

● The first group retains five of the seven regions with 80% loess, and now includes 72–83% of the sites in NWM, Franken, Wetterau/Main, Austria and Elbe-Saale, which is only a slight increase (1.3 to 1.7 more cases). This weak progression is due to the high spatial availability of loess, which 'mechanically' attracts a large number of sites (42–64%). But, by increasing this proportion of sites to 72% and more, the 'mixed' sites contribute to the dominant view of the crucial importance of loess for the LBK. This observation remains true for some regions of Germany and Austria, where Eva Lenneis (*2001*) notes that about three quarters of the settlements are located on loess, from the earliest phase onwards. But in other important regions of Central Europe (Hungarian Transdanubia (Magyar-Dunántúl in graphs), Morava, Bohemia, South Bavaria/Schwabia (Südbayern/ Schwaben in graphs), Middle Rhine/Alsace (Mittel-Rhein/Alsace in graphs), the dominance of loess

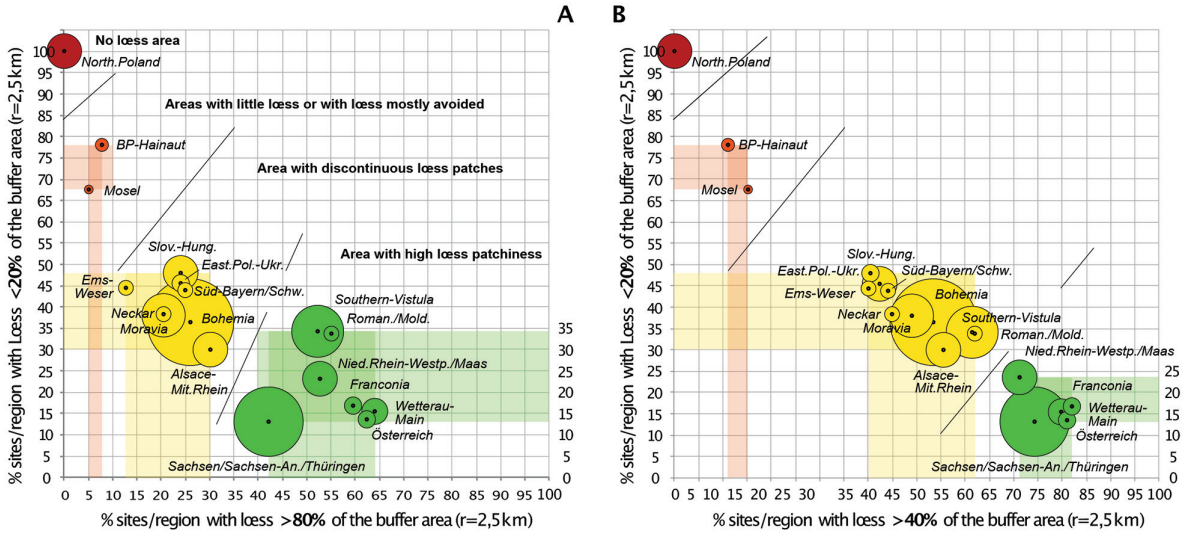

Fig. 8. Geographical distribution of sites according to the proportion of loess area in their 2.5km buffer zone: A <20% vs. >80%; B <20% vs. >40%.

must be tempered by a significant proportion of 'mixed' configurations associating proximity of loess and other substrates.

Intermediate conclusions

The analyses at supra-regional and regional levels of site position and buffer areas both confirms and moderates the importance of loess in the choice of LBK site location, as already revealed by the MCA (Fig. 6): only 52.3% of the large sample of sites examined (Fig. 8) have over 40% of loess in their buffer areas. As the results show many alternatives, the study indicates a certain independence of the LBK system from loess, even in regions where its presence is high, such as the eastern Carpathians or the Transdanubian Hungary. However, there is a slightly stronger link at the beginning of the sequence (St1) than at the end (St4 and 5–6). These figures suggest that starting from a subsidiary exploitation of non-loessic substrates by the earliest farmers (St1), the LBK's subsistence system has been increasingly adapted to this kind of substrate.

LBK and present-day soil groups

The geographical distribution of present-day soil groups shows the predominance of Cambisols and Luvi-Podzoluvisols (57% of the total area), far ahead of Clinohumic soils (Chernozems, Phaenozems, Greyzems), Podzols, Fluvisols, Gleysols and Renzine-Regosols (Fig. 9 and Appendix 12).

Cambisols develop in large continuous areas in the heart of the LBK territory and particularly in the central and central-western parts. Luvisols (and Podzoluvisols) generally border these Cambisols, in rather fragmented patches, and dominate in Poland, as well as in the north-western and western parts of the study area. Clinohumic soils are distributed mainly in the east and south-central regions, on the periphery of the above soils, with some other good patches in the Elbe-Saale region and more modestly in southern Poland and Bohemia. Gleysols occur between the previous groups, mainly in the northern periphery, like the Podzols, and more in connection with Fluvisols. The latter are distributed throughout the study area, particularly in Moldova/Romania, Poland, Belgium and France. Lastly, Rendzinas essentially show the opposite distribution to Podzols, in the southern half of the LBK occupation zone, with important areas along the Paris Basin, the Austrian Danube and in Hungary, Slovakia and Ukraine: the LBK largely avoided these soils.

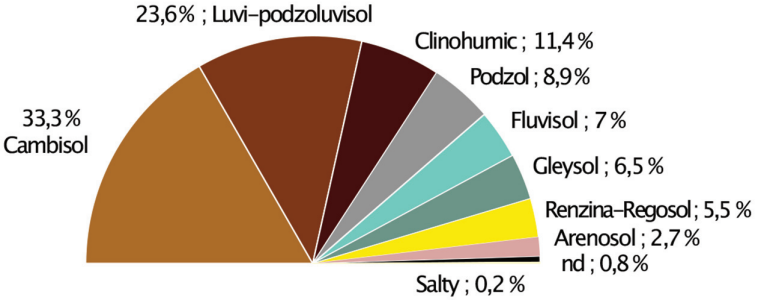

Fig. 9. Distribution of the main types of soils in the geographical area of the LBK.

This current distribution of the main soil groups, expressing major topographical, geological and morphological factors, appears to be a significant geographical determinant for LBK settlement location. We can nevertheless expect considerable variability, as has been shown for the loess.

Available soils/selected soils

The distribution of soils at LBK sites shows a good overall correlation with the distribution of soils currently available in the study area (Pearson (0.866) and Spearman (0.7381): p. <0.05). This indicates that the early Neolithic farmers made use of most of the possibilities offered by the environment. But the observation of the deviations from the relative distribution of these soil groups in the study area as a whole and at the sites (Fig. 10) shows a stronger relationship (Chi2, df 7, p. <0.01) with Luvi-Podzoluvisols (+51.7%), Clinohumic soils (+45.6 %) and Fluvisols (+28.6%). The best represented group in the study area, Cambisol (33.3%) is a bit under-represented (–20.4%), and Renzinas-Regosols, Gleysols, Arenosols and Podzols (between 2.7 and 8.9%) are clearly under-represented at LBK sites compared to current geographical availability (between –34.5 and –88.8%).

The importance of Luvi-Podzoluvisols could be at least partly due to soil developments over the last 7000 years (*Lorz, Saile 2011*) and could reflect the higher availability of Chernozems (here with Clinohumic soils) at the time of the LBK. This hypothesis can be applied especially around the Harz mountains, as well as in Bohemia and Moravia, judging by the present-day intermingling of Luvisols in the Chernozemic areas and their immediate surroundings. However, Carsten Lorz and Thomas Saile (*O.c.*) also point out that such a proposal can only be based on detailed pedo-

logical studies. The question of Cambisols is even more complex, since this notion covers very diverse soils whose main common feature is an incipient pedological differentiation, and their age is therefore questionable. We will simply note here that more than 80% of the sites located on these formations, very often close to areas where Chernozems and Luvisols are concentrated, avoid their most acidic forms. This is the case in the regions noted above, especially along the secondary, or lesser, watercourses. Here, the 'absolute' quality of the soils would have weighed less than the proximity of densely settled areas and site networks.

Loess and selected soils

Together with these apparent connections, there are significant differences in numbers by substrate for the four main occupied soils (Fig. 11). A Chi-square test confirms (df 3, p. <0.001) that the presence of a loessic substrate at the site coordinates tends to favour Luvi-Podzoluvisols and Clinohumic soils in the establishment of LBK sites, especially in the early LBK; conversely, the absence of loess tends to favour Fluvisols and marginally Cambisols, especially towards the end of the LBK.

The weighting of these archaeological observations by the geographical patterns of the three main soil groups attested on loess provides a complementary conclusion (Tab. 1):

● Clinohumic soils, preferred on loess more than on other substrates (18.7 *vs.* 14.6%), have apparently been exploited in proportions lower than their availability on loess (18.7 *vs.* 28%), except in their two main distribution zones east of the Carpathians, as well as in Slovakia and more partially in Moravia and Kuyavia (see Fig. 12).

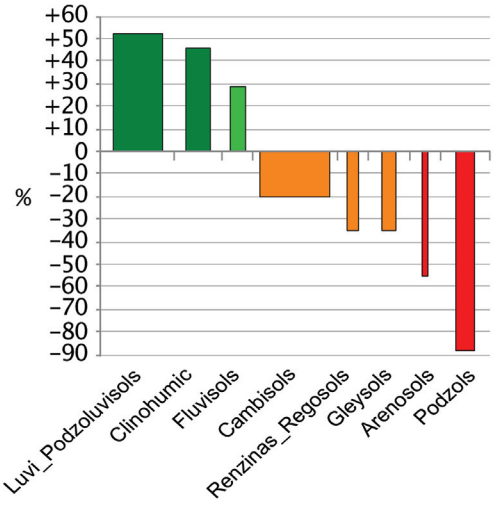

Fig. 10. Relative deviations in the proportions of the selected soil types from those of the available soils (horizontal values proportional to the overall availability).

● Luvisols appear to be the main beneficiary of the apparent choices of LBK settlement location, especially on loess (> 42% of sites).

● Despite the lower overall availability on loess, Cambisols also seem to be readily chosen, and in higher proportions than their overall availability on loess. This trend may reflect an environmental and/or social determinant, *i.e.* a pull of the loessic substrate on the location of LBK sites, irrespective of the soil itself, and/or a desire to be close to a site network occupying the best soils.

Thus, according to these non-exclusive preferential connections, the locational choices of LBK sites as a whole reveal several major alternatives. The 'Chernozem on loess' archetype would have been only one of the LBK settlement modes, valid in certain regions and/or at the beginning of the sequence. Elsewhere, according to the gradual spatial variation of environmental availability, LBK settlements seem to have largely found other geo-pedological contexts that were suitable for their farming requirements (Figs. 12 and 13).

Regional variability

An analysis by major settlement zone (Fig. 12) illustrates this variety of situations in seven main classes:

● Romania-Moldova is distinguished by a preponderance of clinohumic soils (> 80% of cases).

● Slovakia, Moravia (Chernozem) and Kuyavia/Chelmno region (Phaenozem) show a preference for both Luvisols and Clinohumic soils (>66% combined).

● In a large part of Germany Luvisols dominate Cambisols (>70% combined).

● In contrast, in the west and southwest of Germany, Cambisols predominate over Luvisols (>70% combined); in Austria, Clinohumic soils take second place (=89% combined), as already observed by Lenneis (*2001.Fig. 6*) for LBK 1 in Austria, where present-day Brown soils are preferred to present-day Chernozemic soils.

● Bohemia, Southern Vistula and Silesia show a more balanced distribution of Cambisols, Luvisols and Clinohumic or Fluvisol (>67% combined).

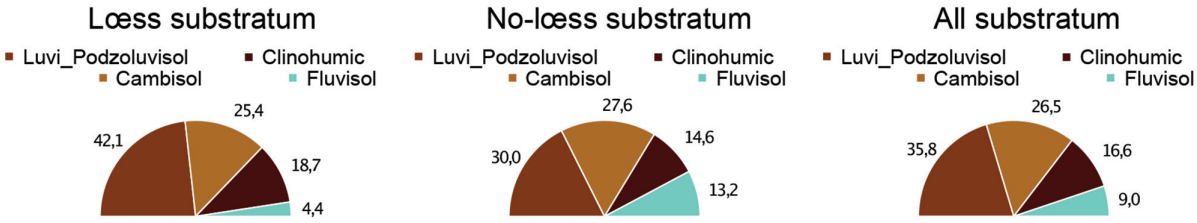

Fig. 11. Archaeological proportions of the four main soil types according to the presence/absence of loess.

Soil groups (%)	% area	% soil on loess/ soil group area	% soil/loess area	% soil-sites on loess
Clinohumics (11.4)		66	28	**18.7**
Luvi-Podzoluvisols (23.6)		34	27	**42.1**
Cambisols (33.3)		14	17	**25.4**

Tab. 1. Proportions of various loess configurations/major soil groups.

● On the periphery, Hungary, Mecklenburg-Pomerania, south-eastern Poland and the Ukrainian borders show a wide variety of soils, including a type that has been encountered rarely until now (only in Kuyavia): Gleysols, associated with Luvisols and Cambisols or Fluvisols (>68% combined).

● In the west, except for Belgian Hainaut (nine sites), Fluvisols dominate, associated with Cambisols (>75% combined) and a variety of other soils.

The cartography of these major classes (Fig. 13 and Appendix 12) shows that, during its spread, the LBK farming system did not focus on a specific geo-pedological niche, but adapted to changing local and regional conditions. In view of this general strategy, the Paris Basin sites appear somewhat distinct, since they underuse the soils developed on the large loess patches occurring in this region. Mainly dated here to the end of the LBK sequence but locally pioneer, the occupation initially tied to the main floodplains was extended, during the early 5th millennium (BVSG group), to the loessic plateaus now largely covered by luvisols (*Dubouloz* et al. *2005; Bostyn* et al. *2019*). The BVSG farmers seem therefore to have returned to the predilections followed during the European expansion process from which they ultimately resulted.

Overall weighting of results

Beyond issues of loess and soils, the distribution of LBK sites highlights their relationship to highly significant sedimentary characteristics. The MCA/HAC (Fig. 6) identifies groupings that are largely defined around variations in water saturation, texture and soil depth (Tab. 2). And it should be remembered here that soil quality not only affects agricultural potential, but also natural plant communities. The influence of these sedimentary characteristics on tree and herbaceous formations implies that the associated vegetation and fauna were most likely important parameters in site location, although such factors remain hidden in our strictly geo-pedological analysis.

Medium-fine to fine-textured soils thus characterize more than 82% of the sites (Tab. 2.A), and of these about 71% have low to medium water saturation. In the same way, a great to very great thickness of the soils characterizes nearly 80% of the sites, of which nearly 72% have low to medium water saturation. These very high proportions identify the main soil characterization of LBK locations and indicate the skills of already expert farmers. However, a significant proportion of the occurrences (<30%) combines the same characteristics of depth and texture with high water saturation, thus showing that alternative choices were made. This option may have been related to a particular interest in the proximity of specific vegetational areas such as riparian zones or marshes. Concerning the other soil types (Tab. 2.B) on which a minority of LBK settlements are located (≤20%), low to medium water saturation also dominates (more than 70% of the cases), thus restating the critical value of this characteristic for LBK agriculture.

From all these observations it can be inferred that, beyond particular types of soil, LBK farmers first sought and found geo-soil formations that were not water saturated, rather fine-textured and quite deep: in other words, a range of situations favourable to their agricultural and gathering needs and widely represented in the territory they explored. These general characteristics provide a better definition than present-day soil types of LBK farmers' main criteria for establishing settlements. According to the statistical study, we must add to this major trend the complementary and less common search for waterlogged soils and their particular vegetation and fauna.

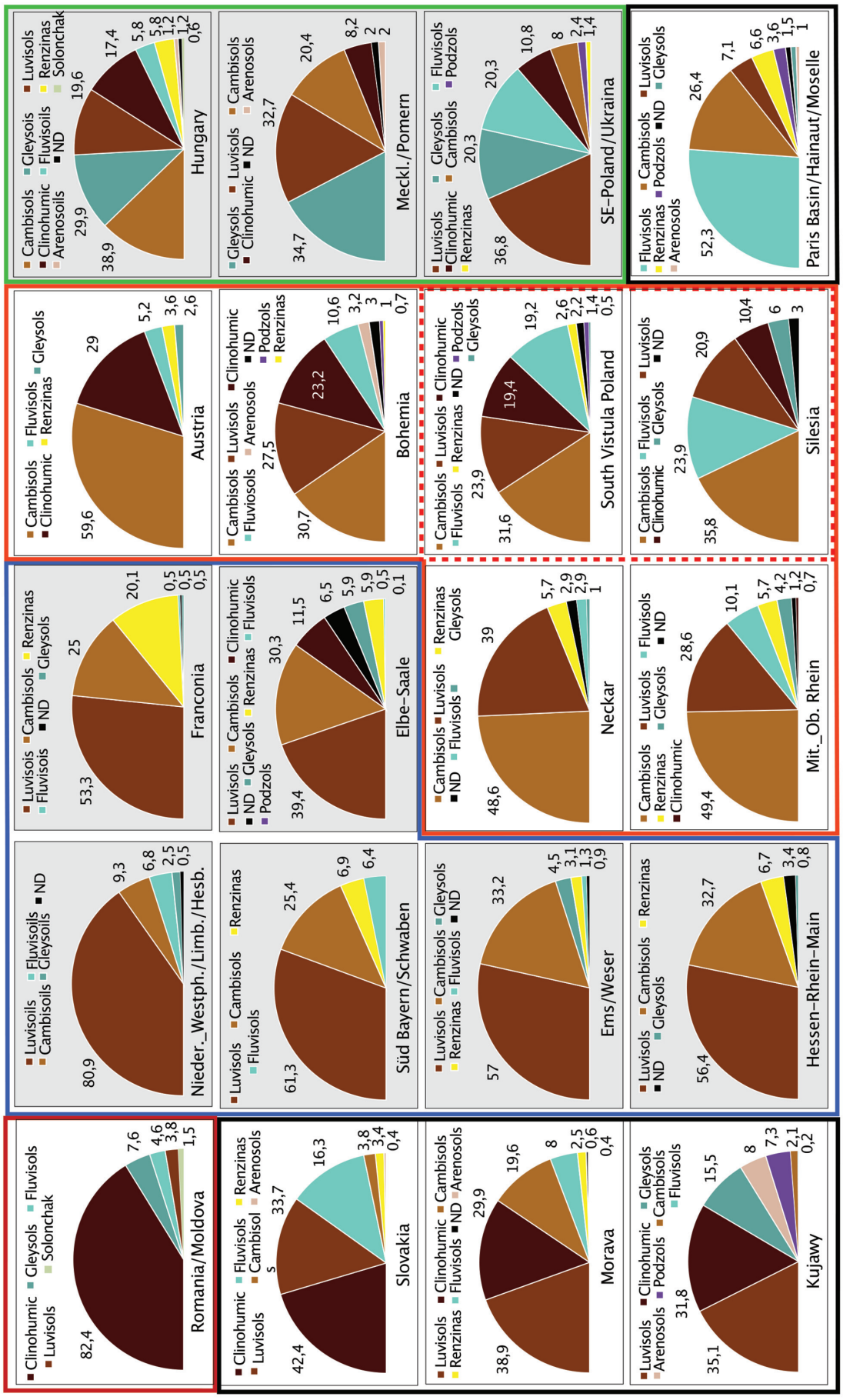

Fig. 12. Proportions of the different types of soil for the LBK sites of twenty settlement areas.

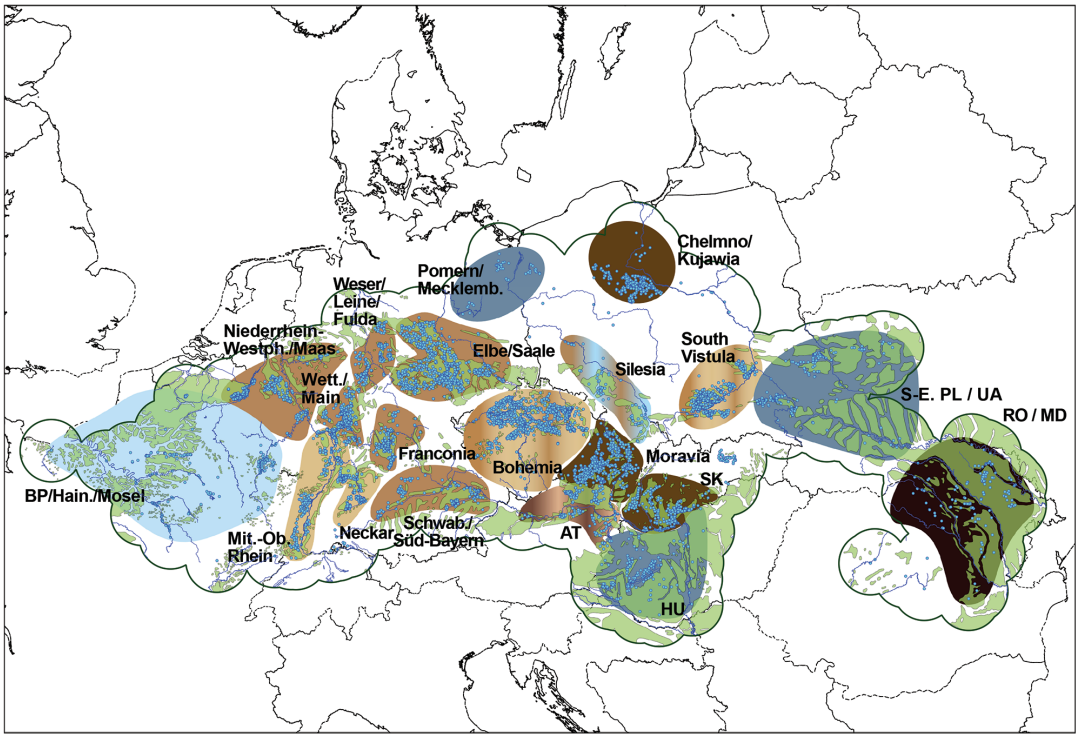

Fig. 13. Geographical distribution of the dominant soil configurations of twenty LBK settlement areas: very dark brown: predominance of Clinohumic soils; dark brown: predominance of Luvisols/Clinohumic soils; medium brown: predominance of Luvi Podzoluvisols/Cambisols; beige: predominance of Cambisols/Luvisols or Clinohumic soils; blue-gray: importance of Gleysols; light blue: importance of Fluvisols; light green: Loess.

These findings are at least partially in line with the conclusions of Michael Kempf (*2020a*), whose research is not really comparable to that developed here, as differences in spatial scale, temporal perspective, size of the samples examined, resolution of the basic environmental data and the descriptive system of the geo-pedological units make this comparison rather impractical. However, we note a convergence of our observations with some results of his analysis, especially the importance of low-medium water saturation in the choice of settlement location.

On the other hand, the study by Lorz and Saile (*2011*) on the genesis of the Chernozems, restricted to southern Lower Saxony, also reaches some conclusions compatible with those produced here on a continental scale. This is the case for the partial disconnection that can be observed between site location, loess and the presence of Chernozems, which has already been proposed by various researchers cited by these two authors. Thus, their database clearly shows the major importance in LBK site location of contact zones between geo-pedological ensembles, recalling our definition of 'mixed terroirs' (section 2.3.1 and Fig. 8). Due to the fine resolution of their environmental data, they ultimately draw the conclusion, unattainable at the resolution of our own study, "*[...] that LBK settlers preferred highly productive and light soils* ***with easy access to water courses*** *(*Sabel 1983*). These conditions are provided in the dry Loess landscape of the investigated* ***region with a distinctly incised, dense drainage network****.*" (*op. cit. p. 278*, underlined by authors). This specific environmental configuration might be the actual source of our observations (section 2.3.2a) concerning site distribution in the intertwined Chernozems-Luvisols-Cambisols of the loessic region around the

A	% of total (N)	Low-medium sat. (N)	Strong and more sat. (N)
Txt. fine to medium-fine	**82.2 (5455)**	**70.7 (3832)**	29.8 (1623)
Depth + and depth ++	**79.8 (5200)**	**71.7 (3730)**	28.3 (1470)
B			
Other textures (very fine, medium, coarse)	17.8 (1184)	79.5 (941)	20.5 (243)
Moderate and shallow depth	20.2 (1317)	70.1 (923)	29.9 (394)

Tab. 2. Overall statistics of site distribution by soil water saturation, texture and depth (NB: 1.8% of soils are not characterized by depth).

Harz or in Moravia. As much as the search for a dense and socio-economically supporting neighbourhood, the need for easy access to water, identified at the meso-regional scale and at higher spatial resolution (see also *Končelová 2005*), appears to be a strong complementary determinant of this site distribution that is partly disconnected from the best soils.

Settlement dynamics

Much has already been written on settlement dynamics and no attempt is made here to challenge the interpretations and conclusions drawn from previous research. Rather, we will try to show how large-scale geo-spatial statistical analysis can identify and weigh the different factors underlying this space-time phenomenon.

Chronology of settlements

The phasing of the overall extension of the LBK, at least in broad stages, is a necessity for this research project, as it enables continuities and discontinuities across time and space to be considered together. But this ambition is particularly sensitive when the western and central-eastern zones are compared. Despite the predictable discomfort of many specialists, we have nevertheless attempted such a chronological standardization, according to a six-stages (St. 0 to 5) sequence (Appendix 13).

The information in the archaeological database can then be used to reconstruct probable settlement dynamics on a continental scale. This first approach is based on the 2559 locations with LBK occupations that can be dated to a stage (4535 different occupations), excluding both extremities of the sequence (St. 0 and St. 5–6) as the occurrences are very low and/or their definition very specific. Indeed, the '5–6' and 'Post CL' (or '6') stages only appear in the database as marginal information that we did not want to lose at first. The '5–6' stage is related to the Paris Basin where it extends the LBK occupation (early BVSG) and the 'Post-CL' stage was taken into consideration only for subsequent occupations on LBK sites: this stage is therefore not really listed as such and cannot be considered here. The total sample thus represents about 39% of the database, but is unevenly distributed among the different regions. In addition to far Eastern Europe, this limitation is likely to be noticeable for Poland, the Czech Republic and Belgium, for example (Appendix 1).

Several elaborations of the database are necessary, in the form of simple aggregations by major stage: (1) the total number of occupations; (2) the number of newly created sites, *i.e.* without immediately preceding occupation; (3) the number of enduring occupations (total number of occupations excluding site creations); and lastly (4) the number of abandoned sites during stage 't', previously occupied during stage 't -1'.

In order to compare settlement trends over similar time periods, these values have been weighted by the approximate duration of the different stages (Appendix 13). Each is split into 'n' periods of twenty-five years (a human generation), according to the following division (the cut-off effect remains unavoidable): St. 1 ≈ 7 x 25 y., St. 2 ≈ 6 x 25 y., St. 3 = 2 x 25 years, St. 4 ≈ 4 x 25 y., St. 5 ≈ 4 x 25 y. Lastly, a renewal rate is calculated (ratio of new creations to total numbers) that allows an overall summary of settlement dynamics.

The resulting curves (Figs. 14 and 15) reveal singularly different dynamics, depending on which of the parameters is considered.

Apart from the few settlements of the formative LBK stage (St. 0), the number of creations is similar during St. 1 and St. 3, around 19% for each stage. However, almost 39% of the dated sites (Fig. 14, red curve: Creation) are established during St. 2. Creations then decline and fall to about 5% during St. 5.

At first glance, settlement density is relatively stable between St. 2 and St. 4 (Fig. 14, black curve: Total), with the latter appearing as a clear stage of equilibrium, in view of the highest number of enduring sites (Fig. 14, yellow curve: Stability). The process that emerges, already well identified, is one of an expanding pioneer front that was particularly marked for stages 1 and 2.

However, these trends as perceived through the numbers of occupations per 25-year period offers a different reading (Fig. 15). The curves highlight the St. 3 stage, where the density (black curve) is clearly higher here than in the St. 2 and St. 4 stages, despite a significantly decreasing renewal rate (in green, 42.9 *vs.* 87.6%) and an increase in abandonments (in light blue, 215 *vs.* 61 per 25 years). New creations and a great stability of previously existing sites (in red and yellow) explain this counter-intuitive result. At the 25-year generation rate, St. 3 probably represents, at the mid 52nd century BCE, the climax of the expansion process, before a pause at St. 4 which remains at a high level of settlement density.

At St. 5, all factors considered except 'abandonment' reach unprecedentedly low values and indicate the exhaustion of the LBK.

As stated earlier in this chapter, this overall reading of the chronological processes is obviously related to the state of the basic information in the database and its representativeness. It is therefore still fragile in terms of detail and should be considered with a margin of error that cannot be easily assessed.

Geocentres and standard deviation ellipses

First, a method is applied to assess the overall dispersion of sites and analyse the similarities at each chronological stage: the measurement of centroids (barycentres or geocentres) and deviation ellipses. This approach has long been used in spatial geostatistics (*Lefever 1926; Pumain, Saint-Julien 2001*) and in spatial archaeology (*Hodder, Orton 1976; Gauthier 2004; Poirier 2010; Nuninger* et al. *2012*). It enables the comparison of distributions based on a number of indicators:

(i) The geocentre corresponds to the average coordinates of the dispersion by period and the distance between each of these centroids is a way to assess the rates of population movement (Tab. 3).

(ii) The deviation ellipse encompasses sites whose location shifts by no more than one standard deviation from the centroid and therefore allows a measurement of dispersion at each stage of the LBK culture (Fig. 16). For the reasons mentioned in the conclusions of section I.3, the eastern expansion in Moldova and Romania has not been included in these analyses.

The centroid of the LBK formative stage (St. 0, <5500 BCE), located on the shores of Lake Balaton, involves only a very small set of settlements. The orientation of the deviation ellipse (in white) shows the dispersion gradient along a SE-NW axis. Then, a shift in polarities is very marked in the next stage St. 1: the roughly 350km distance between the two geocentres (Tab. 3 and Fig. 16) undeniably evokes territorial expansion during this founding stage of the colonization of Central Europe (in yellow). Indeed, between *c.* 5500 and *c.* 5325 BCE settlement extended from Transdanubia to the Rhine (nearly 900km of maximum extension) and the upper Vistula valley, then towards the end of this stage Kuyavia and northwest Ukraine (nearly 800km). This settlement expansion, with standard deviation ellipses increasingly orientated east-west, remains at least until St. 3 (*c.* 5175–5125 BCE, in blue) very close to that of St. 2 (in purple), with a small extension to the west (lower Rhine/Meuse region, the Moselle and eastern Champagne).

The westward expansion restarts with St. 4 (*c.* 5125–5025 BCE) during which further parts of the Seine Basin and the Belgian Hainaut are colonized. Nevertheless, the geocentre shifts less than a hundred ki-

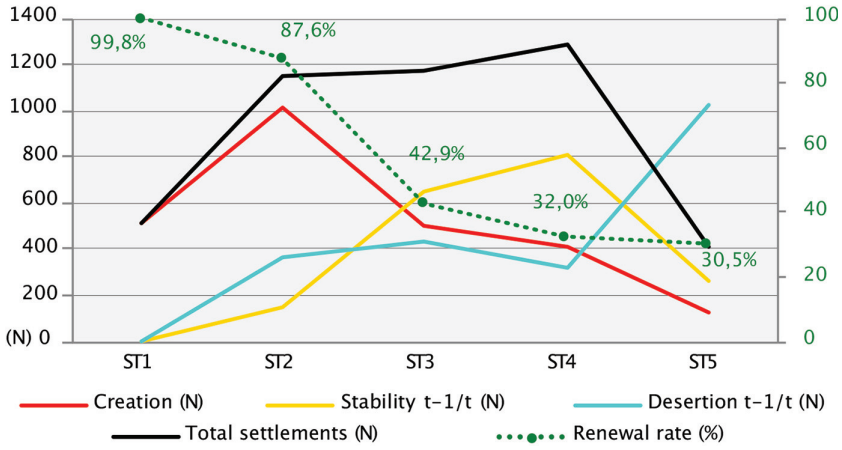

Fig. 14. Summary of the population dynamics (excluding the reoccupations after hiatus as Creation), combined with the renewal rate (right-hand scale); colours are the same as in Figure 22 (maps).

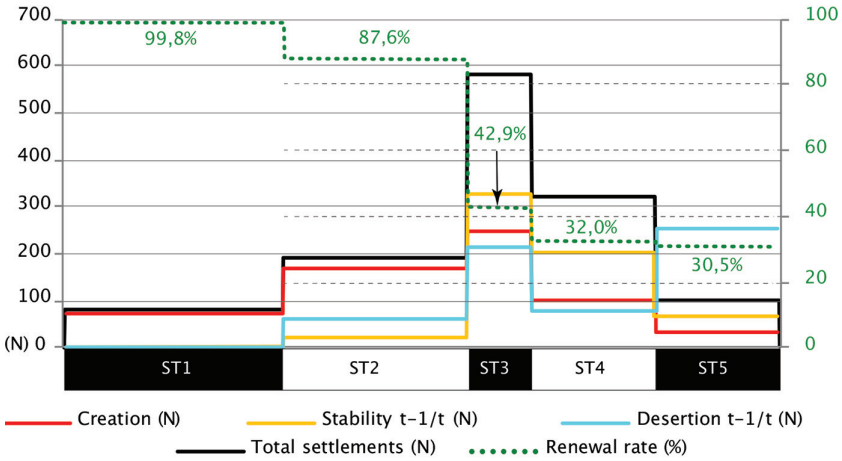

Fig. 15. Summary of the settlement dynamics by 25-year period.

lometres (Tab. 3), settlement being largely maintained in the former foci of Central Europe. The situation changes radically in St. 5, at the very end of the 6th millennium and the beginning of the 5th, with the weakening of the Transdanubian and central-eastern LBK foci. This is clearly underlined by a 308km shift of the barycentre (Tab. 3) and by the change in orientation of the deviation ellipse towards a NE-SW axis. It can be assumed that a rather similar process would be observed in Eastern Europe when the dating is better established there, and it will be interesting to compare the rates and average distances of progression there with those measured for the western expansion.

Stages	ST. 0/ST. 1	ST. 1/ST. 2	ST. 2/ST. 3	ST. 3/ST. 4	ST. 4/ST. 5
Inter-centroid distance (km)	350	75	28	92	308

Tab. 3. Spacing of centroids over successive stages (in km).

Density and transition maps

In order to go beyond the point distribution of sites, the 'kernel density estimation' tool (KDE) analyses the data in a continuous surface, reflecting the intensity of the occupation of the space. This method provides an estimate of the density of sites in a moving window and the resulting values include the situation in the neighbourhood. Thus, an area surrounded by other densely populated areas will have its own density increased. This method has been well known to geographers since the 1980s (*Silverman 1978; 1986; Wand, Jones 1995; Zaninetti 2005*), and widely used by archaeologists working at site scale (*Baxter, Beardah 1997; Beardah 1999*).

The results depend on two parameters: (i) h, the value of the radius, fundamental since it determines the degree of smoothness of the data that offers the best representativeness, between the point scatter and a non-discriminating mesh (*Silverman 1978*); (ii) k, the chosen function, here a quadratic function. In our study, a graphical approach inspired by the ArchaeDyn program (*Nuninger* et al. *2012*) and already proven (*Brigand, Weller 2018a*) is exploited. This involves plotting the maximum values obtained from a series of calculations according to a given interval, here 5000m. The inflection point of the curve corresponds to the best window size, which in our situation is 12.5km, a value between 10 and 15km (Fig. 17) corresponding to about half a day's walk.

At a radius of 12.5km, the KDE density value (in km²) is therefore calculated for each stage and compared with another relevant indicator: the average observed distance (AOD) (Fig. 18). These values are considered from stages 1 to 5 (formative St. 0 AOD = 51km and KDE = 0). In the graph combining these two parameters, the values of AOD and KDE are respectively very high and very low for stages 1 and 5. It is clear that during these two periods the occupation is the least dense. Conversely, the occupation is more concentrated during stages 2 to 4, with the

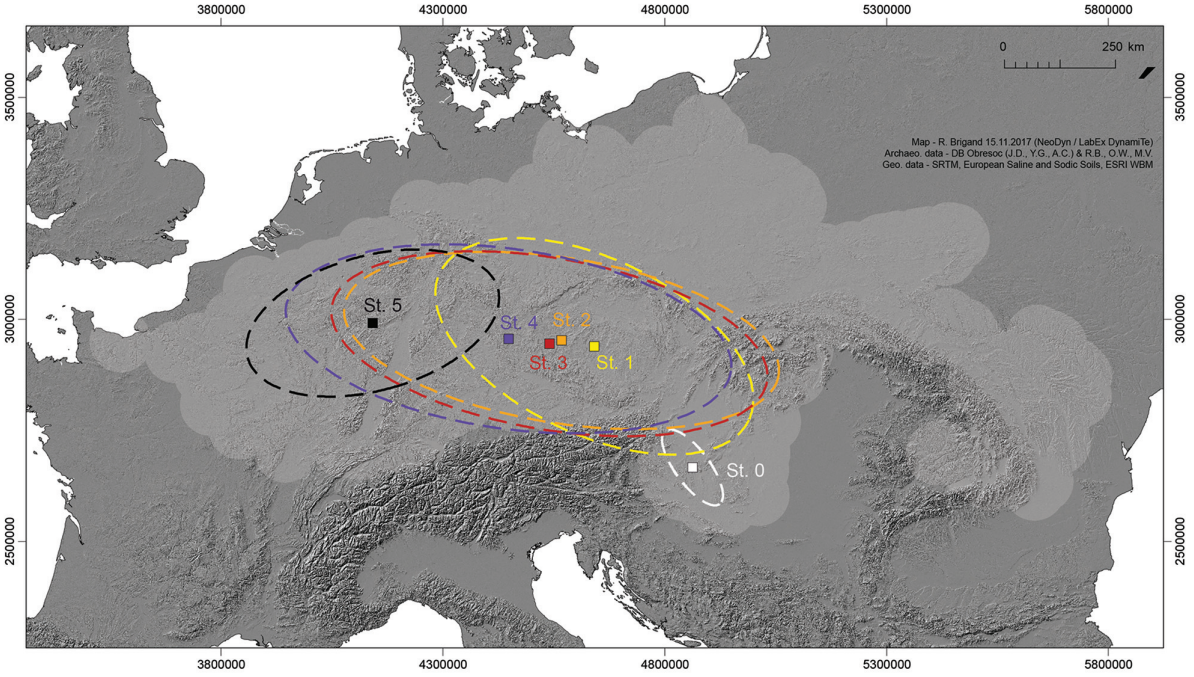

Fig. 16. Geocentre and standard deviation ellipse of the LBK settlement (stage-dated sites, 39%).

average distance being lowest and the maximum density being higher: the values of stage 4 show a slightly higher AOD, reminiscent of the situation highlighted in Figure 14.

In order to evaluate the differences between periods following the density curves and maps (Figs. 19–20), an approach based once again on methodological advances from the *ArchaeDyn* program (*Nuninger* et al. *2012*) is proposed. This method exploits the relative difference in density between two periods through the use of the Normalized Differential Ratio (NDR), defined in the same way as the Normalized Difference Vegetation Index, namely: NDR= (T1–T0)/(T1+T0). This calculation makes it possible to visualize the dynamics of settlement between two chronological sequences, and thus to distinguish the newly created sectors from those more stable or in disuse. A precise example of such a protocol is proposed in Appendix 14.

This *modus operandi* was thus implemented on a European scale (excluding Romania, Moldova and a large part of Ukraine), and a synthesis of the proportions and areas relative to the created, stable or abandoned sites by stage is presented in an analytical diagram (Fig. 19) and five maps (Fig. 20).

● Between St. 0 and St. 1, the newly colonized areas (Figs. 19 and 20.a, red) are the most extensive, since the LBK leaves its initial focus to reach Moravia, Bohemia, Saxony/Thuringia and the Rhine valley in the west, Little Poland, Transcarpathian Ukraine and the upper Bug valley in the north and northeast.

● Between St. 1 and St. 2 spatial expansion remains substantial both outside and inside the previous occupied areas (Figs. 19 and 20.b, red or orange). The main features are: expansion or densification of settlement in the Rhine-Meuse-Moselle valleys (Fig. 20.b, red-orange), colonization of the hilly areas of the western Carpathians (Fig. 20b, red), and a decline in southern Transdanubia and the Elbe-Saale area (Fig. 20.b, light blue). In Saxony, Saxony-Anhalt and Thuringia, for example, the small number of very 'reliable' and well-dated sites (Figs. 1 and 2) relativizes the significance of the results proposed here, especially for the abandonments.

● Between St. 2 and St. 3, the dynamics of colonization decrease and stability dominates (Figs. 19 and 20.c, yellow), in spite of some mobility of settlement in the occupied spaces (orange) and limited expansion out of the already colonized zones (red), such as the southern foothills of the Western Beskids up to the confluence of the Vah and the Danube (Slovakia). This is the beginning of a stability that will be strengthened with the passage to St. 4 (Figs. 19 and 20.d), especially north of Lake Balaton, during which the internal and external 'conquests' are weak.

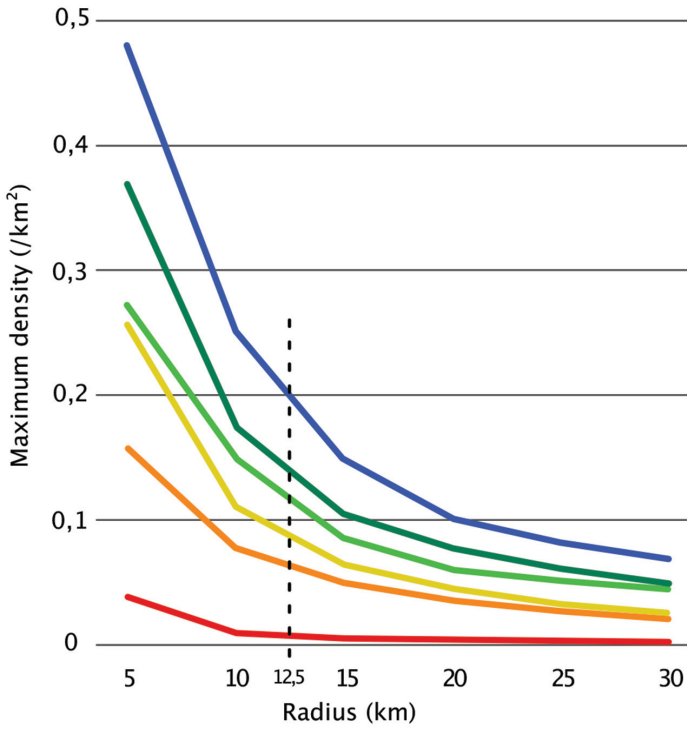

Fig. 17. Evaluation of optimal radius

● The dynamics between St. 4 and St. 5 (Figs. 19 and 20.e, light blue) have already been observed in sections 3.1 and 3.2 (Figs. 14–16) and indicate a massive decline in Central Europe and a refocusing on western Germany, Benelux and the Paris Basin, whose centre is now occupied.

Brief synthesis and perspectives

Although many meso- to macro-regional studies have already been carried out on both the settlement dynamics and land-use patterns of the LBK, our study is the first to tackle these questions on a continental scale using a large geo-referenced database and GIS.

As archaeologists, we are well aware that understanding the outputs of such an analysis depends largely on analytical studies at the lower scales. Due to the higher spatial and temporal resolution of the available

information, these more localized studies can often produce a better description and understanding of particular situations. Fortunately, much of this kind of research has already been done so that it is possible to adjust some of the results of our broader approach using these more specific cases and observations (among many others: *Bakels 1978; Bogaard 2004; Bogaard* et al. *2016; Ebersbach, Schade 2005; Koncelova 2005; Kreuz 1990; 2008; Lenneis 2001; 2003; 2010; Lenneis, Pieler 2016; Pieler 2010; Saile 2009; 2010; 2020; Tóth* et al. *2011*; but see also *Kempf 2020b*). It is also notable that our results are essentially an estimation of the processes underlying the current distribution maps, as were most of the synthetic narratives already proposed. It is to be hoped that the overall approach and methodological tools applied here will provide a more comprehensive basis for drawing conclusions. One of the main limitations of this approach, which is difficult to quantify globally, lies in the importance of the natural and anthropic phenomena which, since the 6th millennium BCE, might have masked and caused the disappearance of numerous settlements: direct erosion and colluvial cover and burial. These types of processes can appear, when analysed at a local scale, to be of considerable importance and therefore constitute one of the most problematic biases of the available spatial distributions. The overall assessment of this impact on the archaeological record remains to be made through further detailed local research. Nevertheless, at this stage of our general knowledge of the LBK phenomenon, the analysis proposed in these pages can represent a satisfactory framework for future improvements.

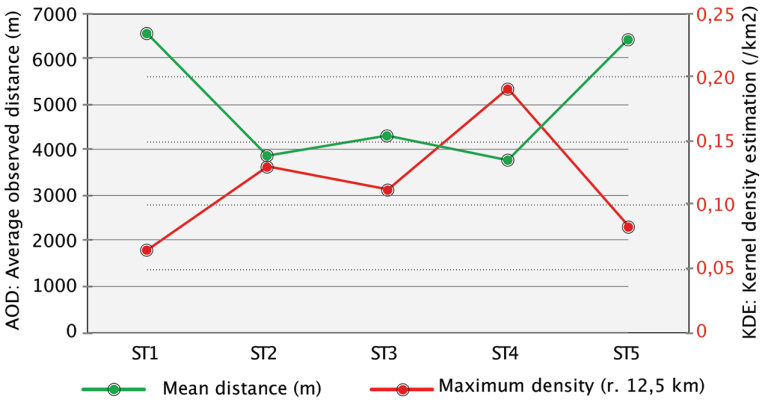

Fig. 18. Comparison of the observed average distance and density.

Three main topics were thus addressed for testing the overall capacity of archaeological research, as reflected in our database, to deal with some important issues: (1) the homogeneity, quality and limitations of the archaeological data; (2) the definition of agro-ecological determinants, if any, in the expansion process of this culture; (3) the highlighting of settlement dynamics that will have affected a significant part of temperate Europe between mid 6th and early 5th millennia BCE.

❶ The evaluation of the archaeological documentation gathered here delivers a rather complex verdict regarding its potential for description on a continental scale. The easternmost part of LBK Europe can only partially answer the questions raised and cannot be fully incorporated into an overall synthesis, mainly because of the lack of chronological precision on the occupations (see sections Archaeological descriptors and Quality of the BD_LBK and overall heuristic validity). The other settlement areas of the BD_LBK seem to be suitable for joint analysis; some of these are less well-documented, but still have sufficiently detailed samples in terms of number and space-time distribution. In this respect, the effect of the information deficit in the Neckar Basin on our results (see section The archaeological data) can be briefly mentioned here. First it can be assumed that the analyses are not really affected in their chronological dimension, since most of the non-selected sites are 'Survey-' or 'Collect'-sites probably lacking reliable chronological information. Conversely, there is a concern that the regional statistics on agro-ecological determinants may be affected. Yet on a continental scale this impact can be assessed as marginal, without signifi-

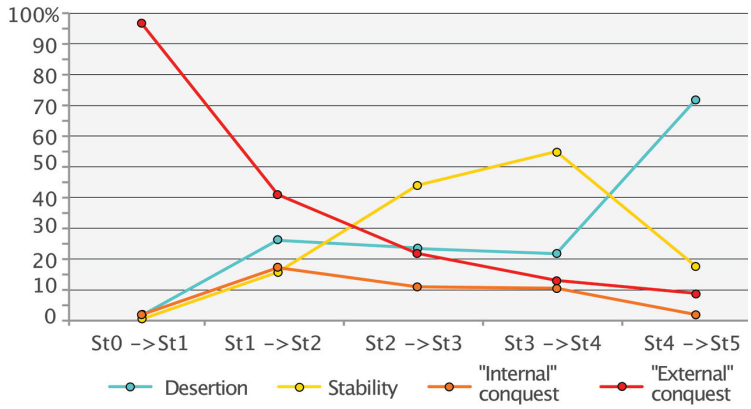

Fig. 19. Percentage representation of the areas concerned by the transition maps.

cant impacts on the robustness of the overall observations (see below).

❷ The analysis proposed in this article does not seek to describe the exact variability of LBK settlement agro-ecology in each region, but rather the dominant trends that have ruled it across Europe. And the general conclusions of our study appear to be supported by some higher resolution research: the importance of ecological transition zones (ecotones), the only relative relevance of the presence of loess, and the targeting of favourable soil characteristics, with no exclusive focus on their exact soil type. By examining the LBK settlement process in terms of the current geo-pedology, we can show that a major characteristic was the absence of exclusive preferences for particular formations. Thus, the LBK system was adaptive to the changing conditions available across temperate Europe, proof of a farming culture honed by centuries of practice. Here again, evalua-

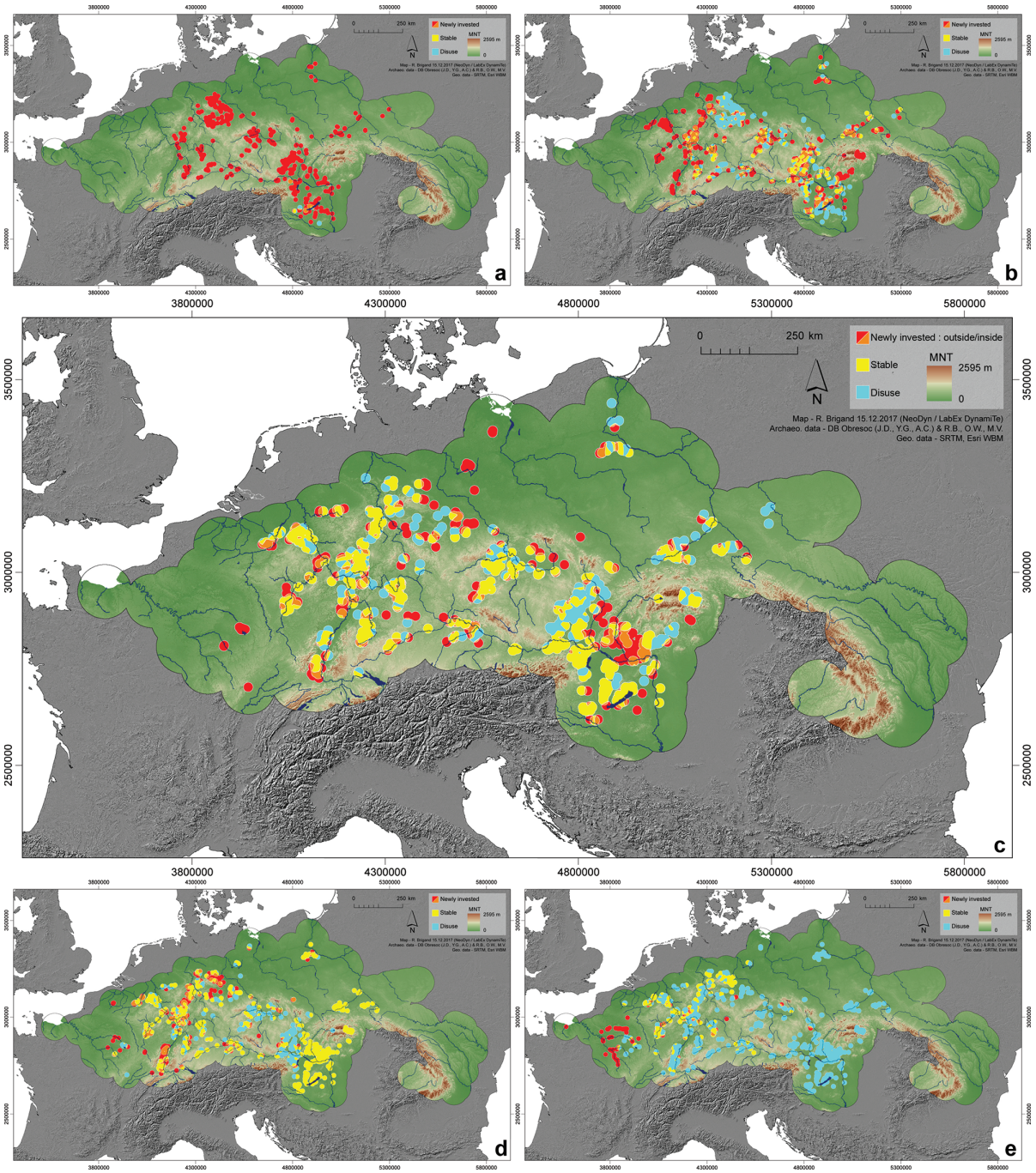

Fig. 20. Transition maps between developmental stages: **a** ***St. 0* (c. 5550–5500 BCE)/*St. 1* (c. 5500–5325 BCE);** **b** ***St. 1/St. 2* (c. 5325–5175 BCE);** **c** ***St. 2/St. 3* (c. 5175–5125 BCE);** **d** ***St. 3/St. 4* (c. 5125–5025 BCE);** **e** ***St. 4/St. 5* (c. 5025–4925 BCE).**

tion of the documentary bias in the Neckar region suggests that our rejection of many sites there, equivalent to about 5% of the current database, has only slightly weakened the rate of loessic substrates and of Luvisols and Cambisols in LBK's settlement system. This situation does not therefore profoundly affect the validity of our general observations, nor their relevance in describing the overall expansion process. Better still, their presence in the statistics would support the highly variable and adaptive character of the LBK agro-sylvo-pastoral system as a whole. It therefore appears that the current database, despite its limitations noted in the first part (section 1), is indeed a suitable sample for a reliable analysis of the geo-pedological components of the LBK expansion.

❸ In the light of different geo-statistic approaches, the LBK expansion dynamics ultimately appear as a combination of two major quantitative trends distributed over time. From stage 1 to stage 4, there is a rapid and steady decrease in the creation of sites beyond the previous colonization front, at the same time as an ever-stronger growth in the stabilization of places already occupied. The second trend is the fairly regular process of site abandonment, partially balanced by a roughly stabilized rate of creation within already occupied areas. Then, with stage 5, the number of site abandonments soars while the other settlement dynamics further decline, clearly demonstrating the weakening and increasing scarcity of the LBK cultural expression on a continental scale. The analyses also showed that stage 3 of our chronological framework (centred around 5150 BCE) may be considered as the climax of LBK expansion. This composite stage, formed, as noted in section 3.1, by compilation of an identified stage 3 in the west and a reconstructed middle/late transitional stage in the east, determines a state of equilibrium in stage 4 (and in the late LBK/post-Notenkopf in general). Then in stage 5 (or the latest LBK) a gradual dissolution occurs, as if the driving forces of expansion (demography, networks of socio-cultural exchange, sense of common identity) had after four centuries reached the limit of their capacity to maintain basic unity at such a large spatial scale. Thus, in our view, this overall trajectory is firstly and mainly indicative of a socio-cultural process.

It might be tempting to relate this trajectory to the 'boom and bust' pattern identified by Stephen Shennan *et al.* (*2013*) and Adrian Timpson *et al.* (*2014*) in their analysis of ^{14}C data covering the whole European Neolithic. Yet, for several major reasons, it seems clear that our LBK trajectory cannot be strictly linked to the pattern proposed by Shennan and colleagues, and in fact does not really match it at all. The authors of the population model under consideration themselves state that their results can only have a good statistical significance on a multi-millennial scale, with a time step of more than two centuries (*Timpson* et al. *2014.550*). However, the time scale analysed in the two cases is very different, with the duration of the LBK representing a small fraction (10–13%) of the span envisaged for Neolithic Western Europe, and occurring very close to its onset. Thus, the LBK trajectory alone (400–500 years, depending on the regions considered) cannot corroborate a model built according to other methodological requirements and with a much more general aim. In fact, it would not be logical to seek in the LBK trajectory highlighted by our own work confirmation of a model developed for a process that was taking place over about two millennia.

At the same time, it can be observed that the ^{14}C data of the eight European regions involved in the LBK expansion do not clearly illustrate the pattern. Indeed, on closer inspection of the curves proposed by Shennan *et al.* (*2013*) and Timpson *et al.* (*2014*) in their respective Figure 3, we can see considerable heterogeneity of the results and three different patterns. (i) The Paris Basin, Rhineland-Hesse and Moravia-Austria show a statistically valid start of a pronounced 'boom' approximately concomitant with the onset of LBK. However, this 'boom' lasts for about one millennium, *i.e.* twice the duration of the LBK itself. (ii) South Germany and Kujavia show a short and slight LBK-related 'boom', then two bigger ones many centuries later. (iii) The third pattern is represented by central Germany, Little Poland and Bohemia, where there is no LBK-related 'boom' but a few short 'booms' occurring 1500 to 2000 years after the end of the LBK itself. Curiously, these three regions have some of the most numerous LBK occupations known, so that these results appear very counter-intuitive. As for the 'bust', it appears statistically very significant in only three out of the eight regions, yet around 1700 to 2200 years after the end of an initial LBK-related 'boom' (Paris Basin, Rhineland-Hesse, South Germany). A fourth region (Moravia) displays a very short and slight 'bust', occurring at the same pace of time. This regressive phenomenon is therefore not directly related to the disappearance of the LBK. Moreover, in central Germany, a 'bust' seems to occur about 750 years after the end of a flourishing LBK that did not produce the signal of a 'boom', though logically predictable. Lastly, in two

regions where the strong settlement dynamics of the LBK are very apparent (Bohemia and Little Poland), we observe the absence not only of any 'boom', but also of any 'bust' over the four millennia considered.

In short, the overall heterogeneity of these results, where one would expect a good coherence, does not provide firm support for the population model defended by Shennan and colleagues and in our view raises doubts about the real adequacy of the proxy used in their study. Such an approach using a category of information that has become an expensive standard in scientific protocols is undoubtedly legitimate for defining new hypotheses, but it is up to researchers to confront them fully with the basic data, which should themselves be critically evaluated. The least that can be concluded, from the point of view of our work, is that the trajectory identified by our approach to the LBK cannot provide solid evidence for the population model promoted by Shennan *et al.*, at both methodological and factual levels.

In this respect, the final LBK dissolution should probably not be directly interpreted as an overall population collapse without an assessment at the same time of post-LBK cultural developments. Indeed, the trajectory identified here on the basis of the distribution of LBK sites alone cannot say much about the subsequent situations in the same regions (Stichbandkeramik (Stroke-ornamented ware), Lengyel, Hinkelstein/Grossgartach, BVSG). It is clear that the spatiality of these cultural developments must also be analysed in detail, as closely as possible to what is proposed here for the LBK. This is one of the reasons why it seems to us that the attempt to create demographic scenarios on the basis of radiocarbon dates alone is probably only a stopgap measure of very relative reliability. Indeed, such an approach cannot easily escape the heterogeneity of research focuses and their intensity, nor the varying archaeological visibility of different settlement modes; it cannot therefore guarantee a comparable representation of the different chrono-cultural aspects at stake. Under these conditions, statistical corrections, however rational and sophisticated they may be, cannot in our opinion replace basic archaeological information of the same reliability as that provided by the LBK. Since we have found that even the LBK data may be deficient for some specific analyses and interpretations, the results of radiocarbon analysis alone, disconnected from more or less uniform knowledge of chrono-spatial dynamics, are likely to be somewhat illusory with regard to long-term population dynamics (see *Crombé, Robinson 2014*).

For reasons of limited space here, we are developing elsewhere a complementary study- about the agro- ecological factors and their related settlement dynamics, through a spatial-temporal modelling (*Brigand* et al., *in prep.*). In a third contribution, special attention will be paid to the distribution of salt resources, the importance of which for Neolithic communities is now well identified (*Munteanu* et al. *2007; Weller, Dumitroaia 2005*), especially for the relatively more complex societies of the 5th and 4th millennia (*Weller 2015; Brigand, Weller 2018b*). While some salt production centres have been studied in Eastern Europe (*Sordoillet* et al. *2018*), we know much less about the early LBK farmers in Western and Central Europe. And as already raised in the literature for several geographical areas (*Bánffy 2013; Geschwendt 1958; Pyzel 2016; Saile 2012; Weller 2015*), to what extent did salt resources contribute to the rapid LBK expansion and the development of its main settlement areas throughout Europe? As we can see, there is still a lot of research to be done on this famous LBK culture, both on a local and European scale, in order to understand this unprecedented phenomenon.

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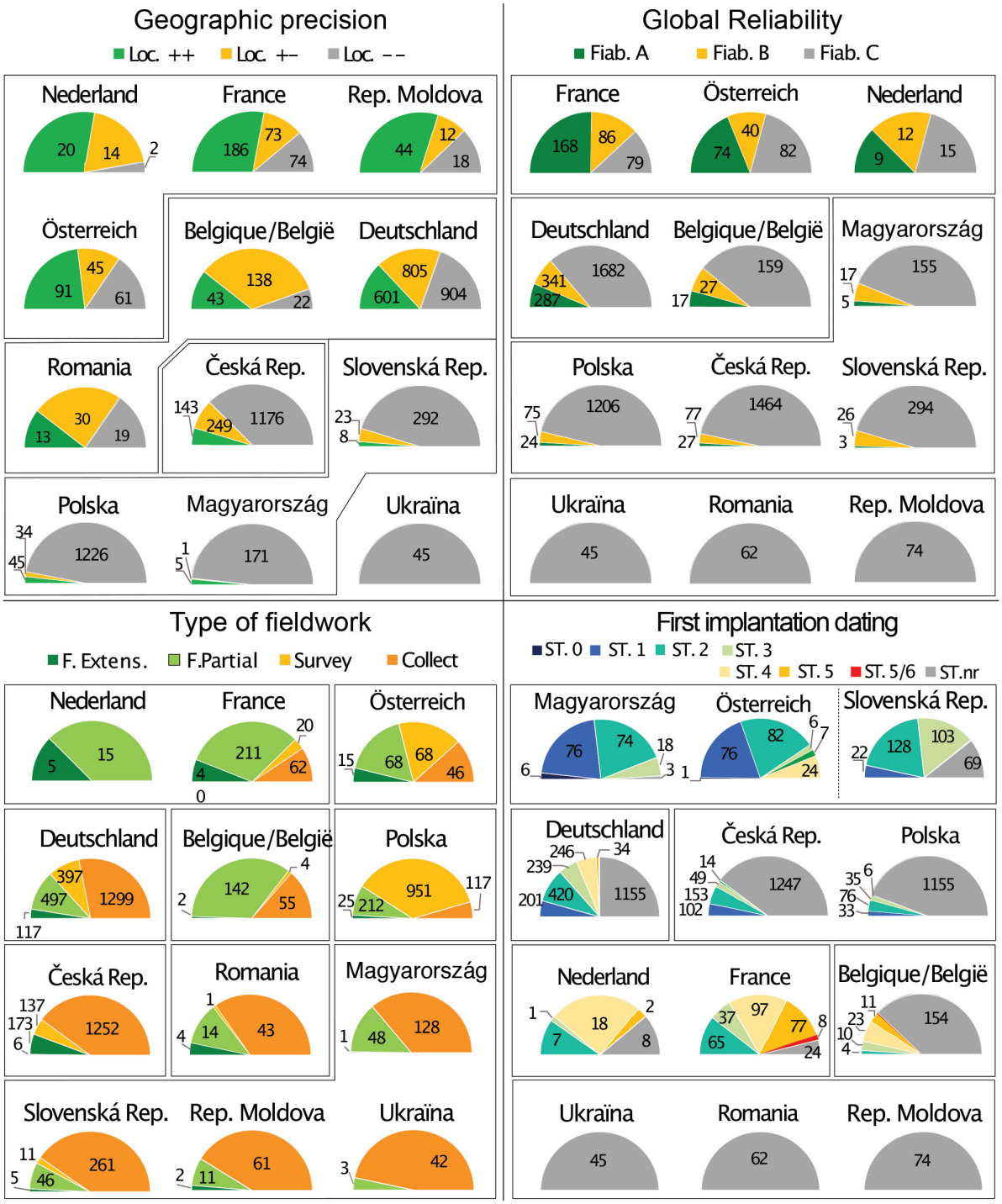
Appendices

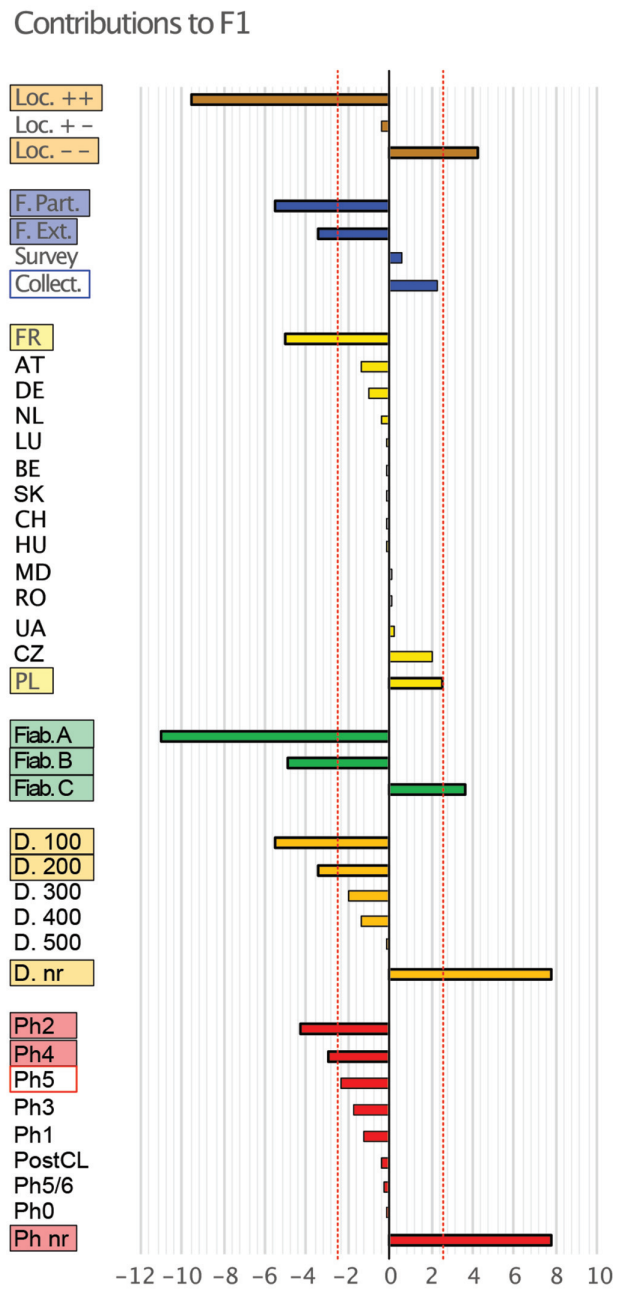
Appendix 1. Variability of site data (BD_LBK) across major countries.



Appendix 2. Contributions of the modalities to the first component (F1) of the MCA on the archaeological information of the database. The vertical dotted lines represent the average theoretical contribution.

The first factor (F1) is based on 15 modalities at or above the average theoretical contribution (81.7% of the total inertia). Five of these (positive, 26.2%) belonging to 5 out of 6 different variables define a weakly documented cluster; it is significantly represented in Poland and even in the Czech Republic. Ten other modalities characterise the opposite pole (negative, 55.6%); they belong to all the variables and combine geographical precision, extensive and partial excavations, short/medium duration of occupation, datation at LBK stages 2, 4, 5, and as a whole, good to very good documentary reliability: France contributes more than the other countries to this configuration, due to its strong link with the modalities 'Loc. ++', 'Fiab. A' and 'D. 100'.

F1 thus reveals a maximum and not very surprising variability of the data around documentary reliability and precision. There is a clear correlation between the most superficial types of intervention (prospecting, collecting), imprecise location (Loc −−), undefined chronology and duration of occupation (St.nr and D.nr).

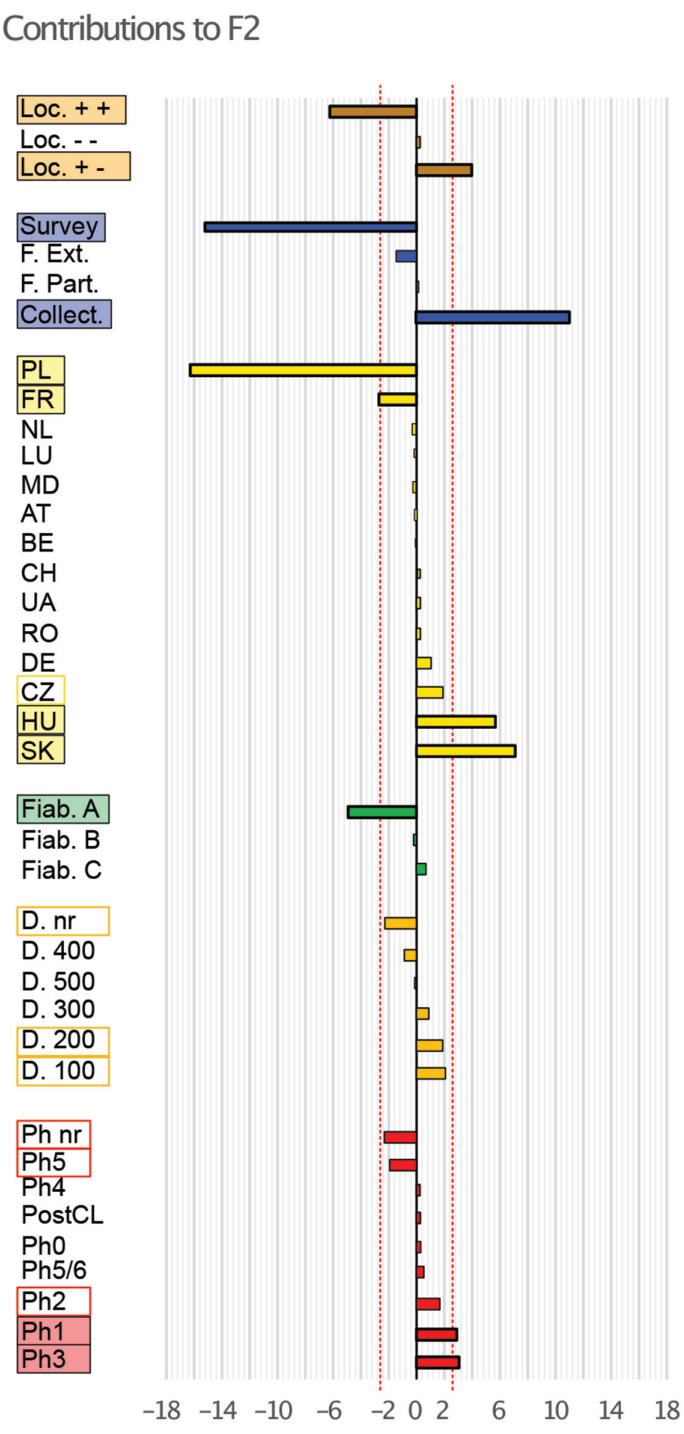


Appendix 3. Contributions of the modalities to the second component (F2) of the AFCM.

The second factor (F2) is based on 11 modalities at or above the average contribution (79.2% of the residual inertia). Of these, six are positive (33.6%) and belong to four out of six different variables. They define a pole representing early and middle LBK sites (Ph.1–3) from surface collections, with short/medium duration, correctly located and on the whole limited in reliability. Two countries contribute particularly to this cluster: Slovakia and Hungary.

Five other negative modalities (45.5%) characterise the opposite pole; they belong to four of the six variables analysed and combine geographical accuracy, surveys and good to very good documentary reliability. Only two countries determine this configuration, Poland in particular and France more slightly.

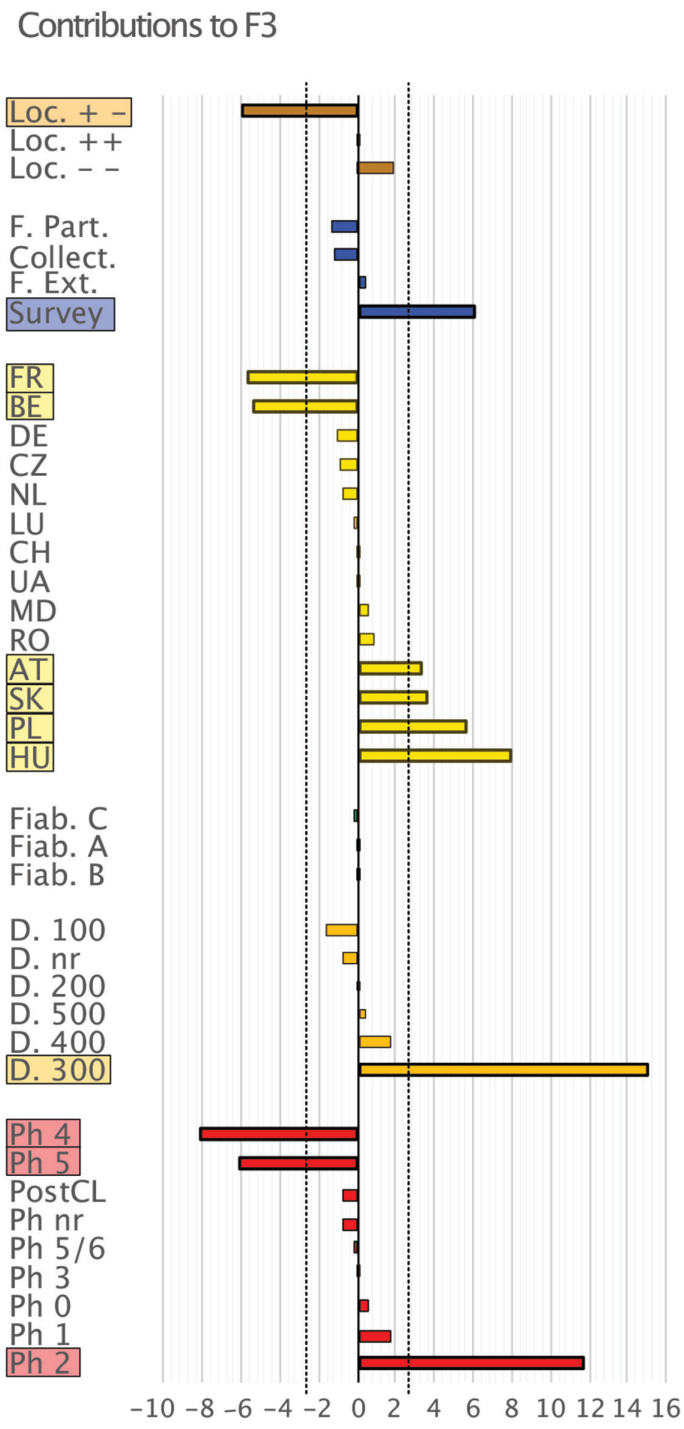
This second summary on the remainders of variability not described by F1, therefore reveals the contributions of four new descriptors: two modalities of the variable 'Type of intervention' (Survey and Collect.) and two of the variable 'Country' (Slovakia, Hungary). It contrasts sites mainly Northern and Western sites with good documentary reliability, resulting from 'Surveys' and very well located, with a group of early sites in the chronology from southern central Europe, resulting from more or less random collections ('Collect'), but correctly located.



Appendix 4. Contributions of the modalities to the third component (F3) of the MCA.

Finally, the third factor (F3) sumarize a residual fraction of the total inertia of the data, not yet taken into account. In this way, it adds complementary components to the global design of the data variability. It is constructed by 12 modalities at or above the average contribution (83.3% of the residual inertia). Seven of these are positive (52.1%) and belong to 4 out of 6 variables. They define a cluster of central-eastern sites (Hungary, Poland, Slovakia, Austria) resulting from 'Survey', belonging rather to stage 2 of the LBK (Ph.2) and showng a long duration (D. 300). Five other negative modalities (31.2%) define the opposite pole; they belong to only half of the variables analysed and combine late LBK stages with a correct location: this configuration is found mainly in France and Belgium.

This third complementary synthesis thus marginally contrasts early and long-lived Central European sites, not very well located and resulting from 'Collect', with Far-Western sites belonging to the recent stages of the LBK and correctly located. It also tells us that the main countries concerned in F2 by the 'Collect' modality are also concerned in F3 by the 'Survey' modality (Poland, Slovakia, Hungary).



Appendix 5 (see Figure 4, Map F1/F2)

The analytical data set is displayed in the factorial space around the most discriminating modalities of the first two summaries of the MCA. They oppose, in a ternary system, Poland, Hungary/Slovakia, and France.

● To the right of axis 1, are grouped the modalities representing sites which are relatively poorly documented (Fiab. C), both chronologically (St.nr and D. nr) and geographically (Loc --). Among them are those resulting from the lightest archaeological investigations (Collect. and Survey). Many Polish, Czech, Swiss, Ukrainian, Romanian and Moldovan sites share these characteristics: the first ones particularly linked to the 'Surveys' and all the others rather to the 'Collect' variable. It is therefore a large group of mostly central-eastern and eastern sites, which are generally less well documented than those in other regions of LBK Europe.

● In contrast, to the left of axis 1 and at the bottom of axis 2, are the well documented sites (Fiab. A), with good geographical precision (Loc ++), resulting from extensive excavations (F. Ext) and dated to the latest stage of the LBK (St.5). The countries concerned by this high-quality documentation are mainly France, the Netherlands and Luxembourg.

● As an intermediate to the previous clusters but still to the left of axis 1, meaning not being dominated by low quality documentation, the average archaeological information from Germany, Belgium, Slovakia, Hungary and Austria seems to be relatively well documented and localised (Fiab. B and Loc +-); it appears to be linked particularly to partial excavations (F. Part.), to the main stages of the LBK (St.1 to St.4) and to the most common occupation duration modalities (D. 100 to D. 300). This average position applies thus to countries that present in moderate proportions the whole spectrum of research types and a great variety of documentary realities. Austria is rather better documented than Belgium and Germany, where there is a significant proportion of less well-informed sites. These are therefore similar to those widely encountered further east, notably in the Czech Republic. Finally, Hungary and Slovakia, linked to partial rather than extensive excavations and to the early stages of the LBK, are isolated from the other regions of Europe and particularly from Poland with its particular link to 'Survey'.

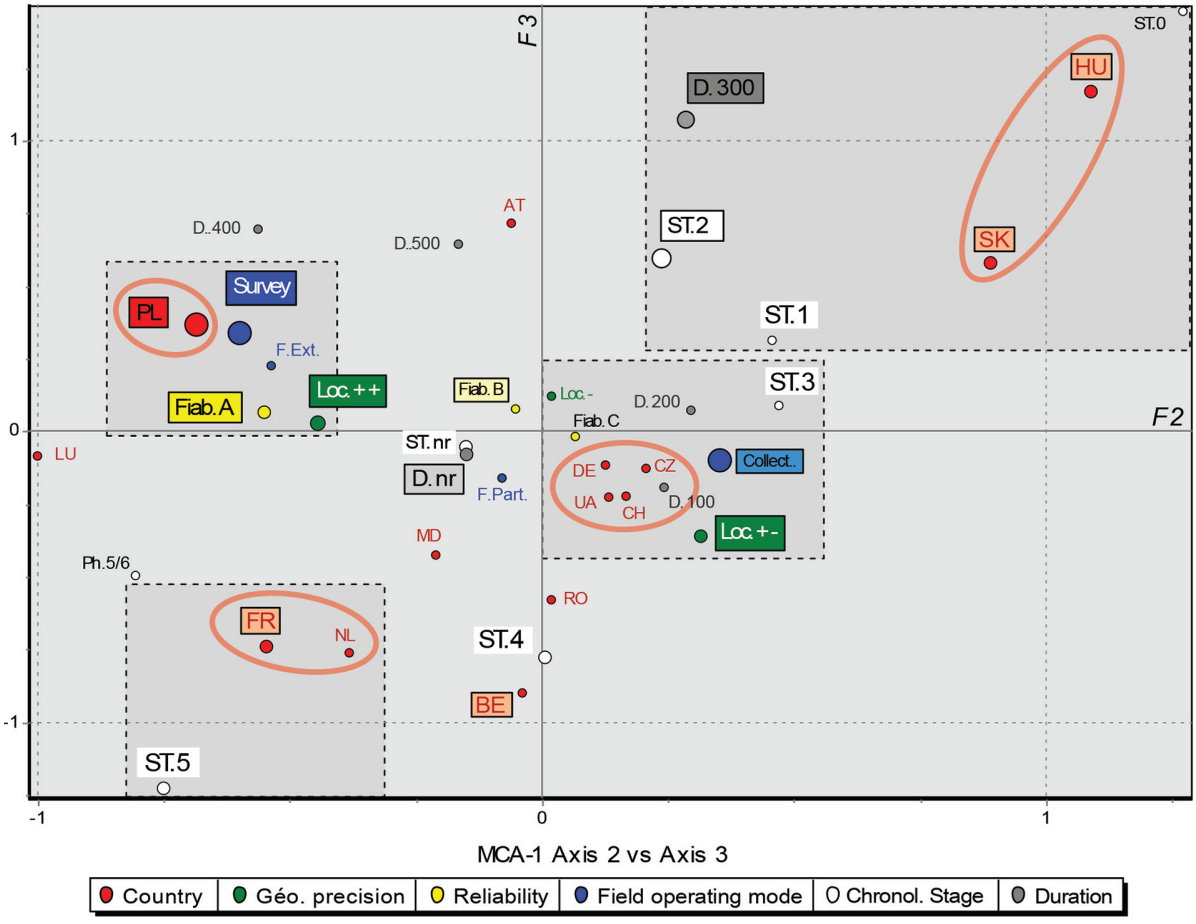
Actually, the structuring of the data revealed by this first and most distinctive synthesis of the data, is not surprising at all. Main opposition between poorly documented groups of sites and others is a kind of truism; similarly, the correlations between location accuracy, chronological characteristics and type of investigation are also predictable. But it was not taken for granted that all these possible variations should be organized in coherent sequences, evident for almost all the descriptors together. Under these appearances, the ordering of the countries on the factorial map draws an almost perfect east-west progression, which we believe is related to the temporal depth of research on the one hand and its funding on the other. Such a spatial configuration could rapidly change under an unlikely common elevation of the economic and technic standards of archaeological research in Europe. Poland, Hungary, eastern Lands of Germany, for example, have finally implemented effective and promising practices (rigorous survey programs, broad scientific Rescue Archaeology) that show a way forward. But at the same time West Germany has been slowly regressing in these respects, while other regions (Belgium, Slovakia, Romania) have remained behind. We cannot yet be sure whether the recent evolution of practices in France will impact the results upwards or downwards. Therefore, the harmonisation of data on a continental scale is still a long way off, or could be achieved at a frustrating intermediate standard.

Appendix 6 (see Figure 5, Map F1/F3)

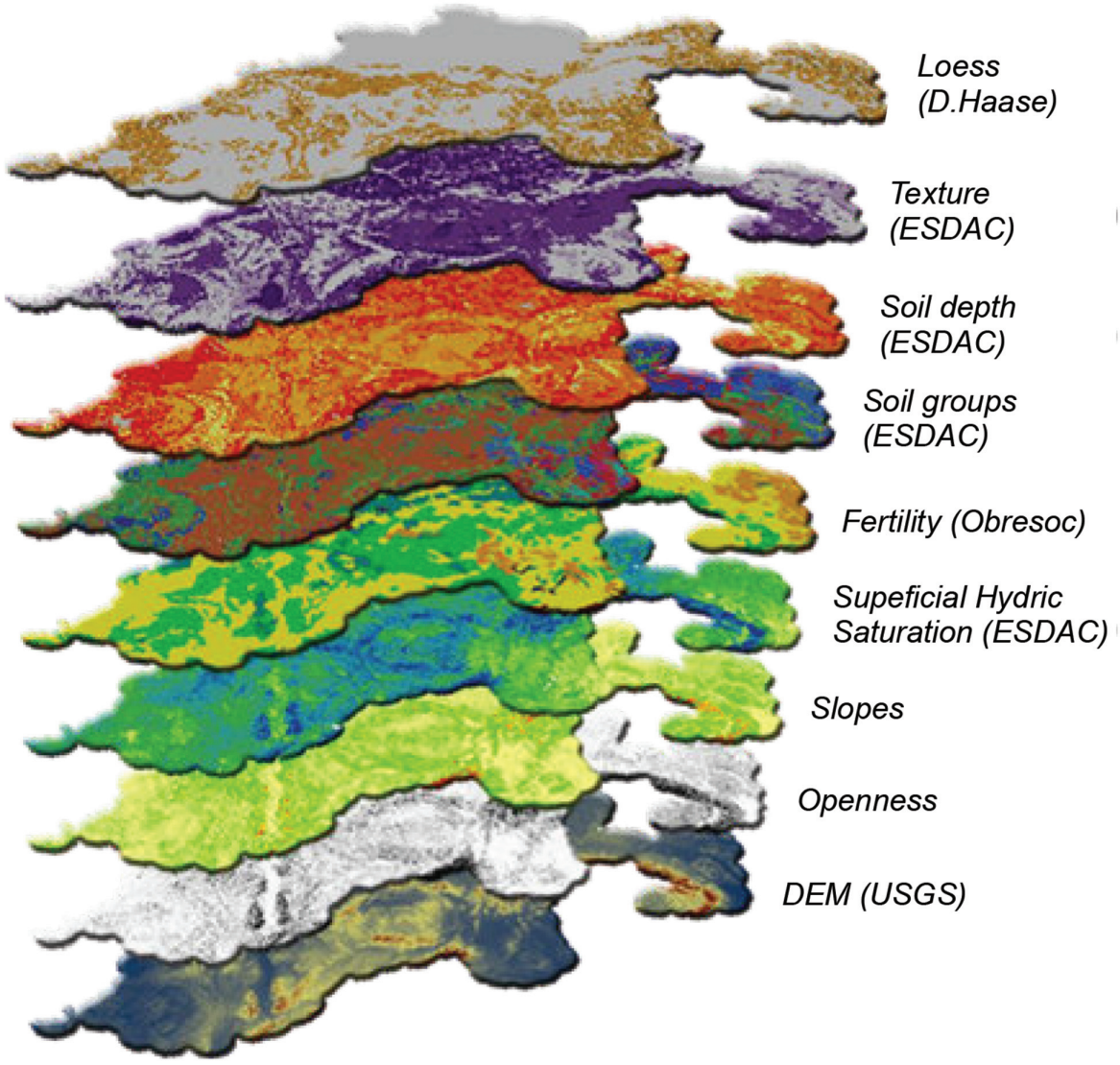
Following the methodological principles of MCA, map F1/F3 (Fig. 5) modulates the previous conclusions. It presents only two groups of opposite modalities: to the right of axis 1, the same set as before is shown again, due to the decisive weight of their modalities in the characterization of the first factor, and confirms the singularity of Poland; but it redistributes the other modalities in a single second group around which gravitate the other modalities of 'countries' and those, extreme, of the LBK 'chronology' (St.0 and 4-5): this map confirms Austria, linked to the long-lived durations (D.300 500), in a positive situation; France and the Netherlands, around late chronological stages and short durations, appear again as more often better informed and the Belgium-Germany-Slovakia trio still show their intermediate quality.

Appendix 7 (map F2/F3)

The F2/F3 map characterises the database without the influence of poor documentary situations; it can thus show some secondary links previously masked by the hyper-structuring weight, in F1, of weaker or undefined modality values. The main point of this map is, on the one hand, a significant and favourable configuration around Poland and its systematic 'Survey' practices; on the other hand, a clear highlighting of the Hungary and Slovakia's specificity related to the weight of their older and long-lived sites. The group of sites of the BD_LBK with limited or scarce documentation is logically in a central position and therefore not very significant in this secondary statistical summary. But interestingly, a part of the German sites belongs to this group, as already suggested by the previous diagrams. At last, the western trio (FR, NL, LU) remains linked to the best modality values, while part of the excavated Belgian sites are close to them, probably because of their links with the late stages of the chronology.

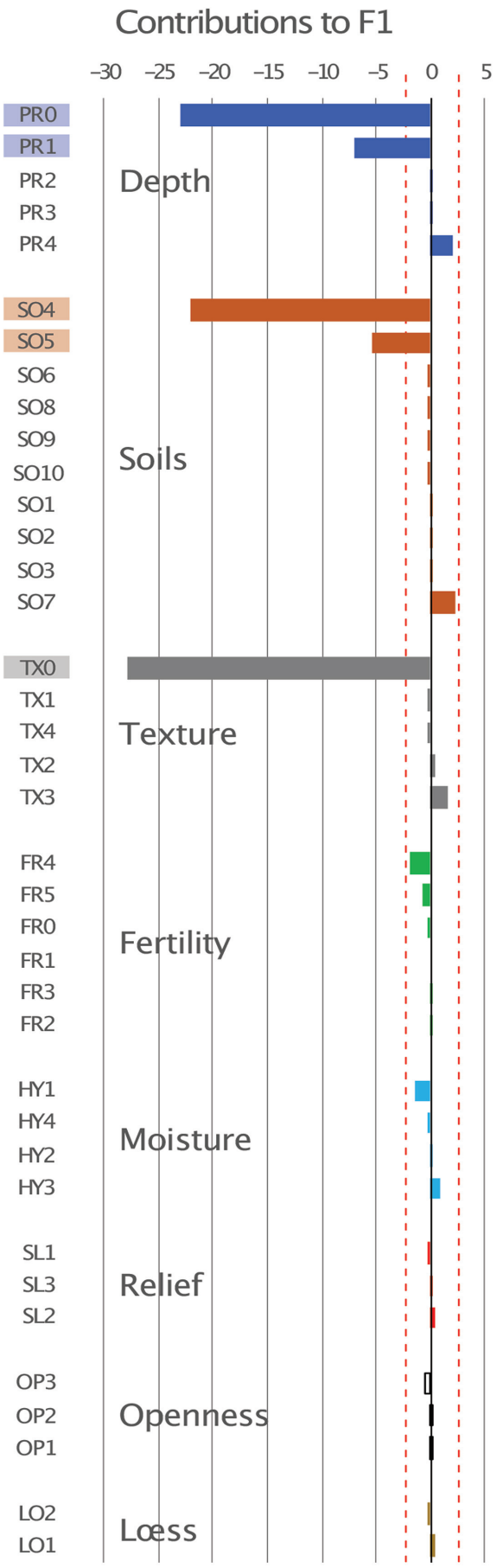


Appendix 8. Topographic and agro-ecological data of the GIS.



Appendix 9. Contributions of the agro-environmental modalities to factor 1 of the MCA. Vertical dotted red lines show the average theoretical contribution.

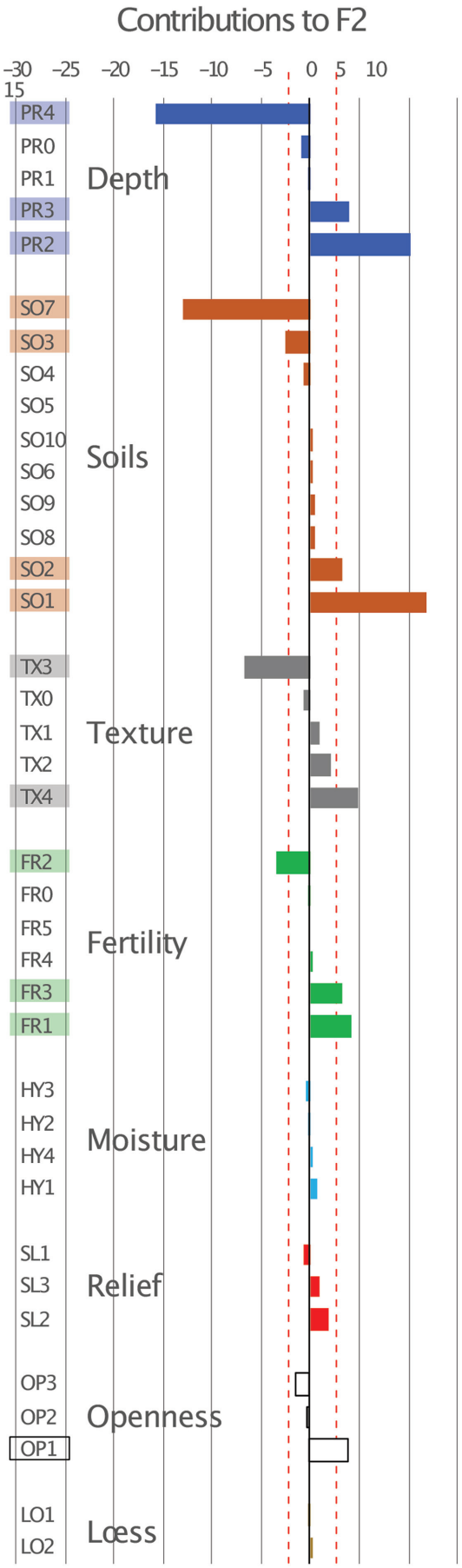
The highest contributions to Factor 1 (~85% of its inertia) are all negative. They relate to the 'undefined' modalities PR0 (n.r.), SO4 (no data) and TX0 (n.r.) which almost exclusively construct this first statistical summary (respective contributions of 22.9%, 22%, 27.8%, *i.e.* ~73% of the variability summarised by this factor). The other negative modalities PR1 (7%) and SO5 (5.3%), *i.e.* shallow soils and Gleysols or Vertisols, contribute only a little. The first factor therefore mainly separates sites in poorly defined or rare contexts from all other sites. Its relevance to our questions is therefore very limited.



Appendix 10. Contributions to F2 of the MCA.

The second factor is mainly built (~84% of its inertia) upon the opposition between negative PR4/very deep soil (15.7%), SO7/degraded and leached soil (13%) and also, very moderately, TX3/medium-fine texture (6.7%) and FR2/fairly good fertility (3.4%), for a total of ~38% of the factor's inertia; facing the positive modalities PR2/moderate depth (10.3%), SO1/Cambisol (11.9%), and very moderately TX4/fine texture (4.8%), FR1/very good fertility (4.2%), OP1/closed landscape (3.9%), PR3/deep depth (3.9%), FR3/medium fertility (3.2%) and SO2/clinohumic soil (3.2%) for a total of ~40%.

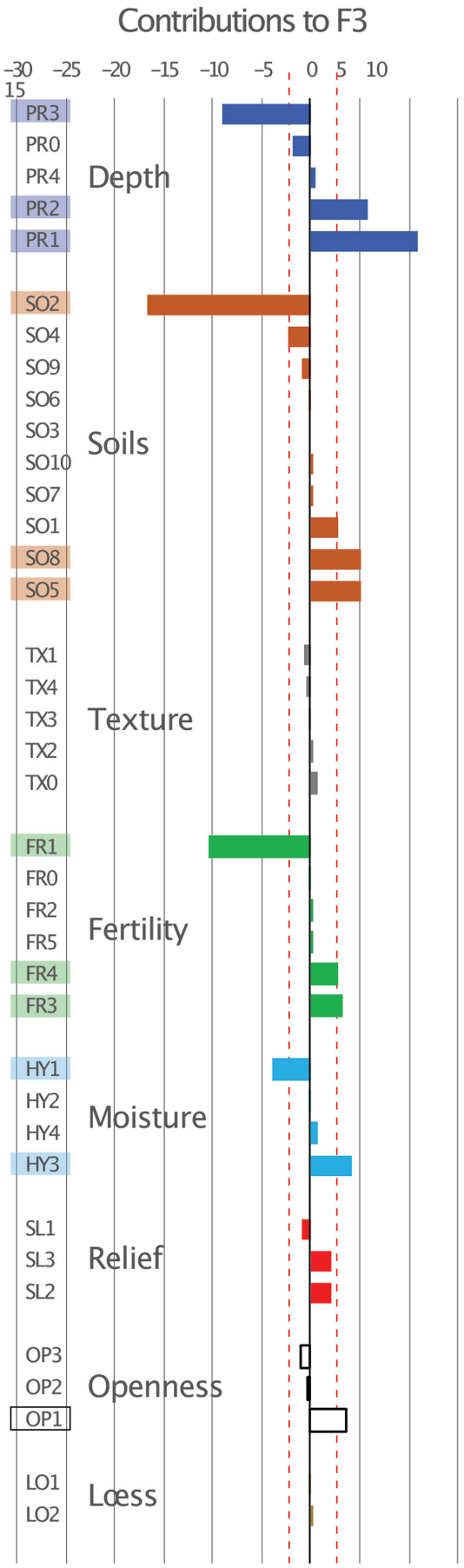
That is to say, an overall opposition between settlements on leached (Luvisols) or degraded soils, very deep, with medium-fine texture and good fertility; and those on brown soils slightly evolved or even clinohumic, with moderate to deep depth, fine texture, very good or medium fertility and in a closed landscape.



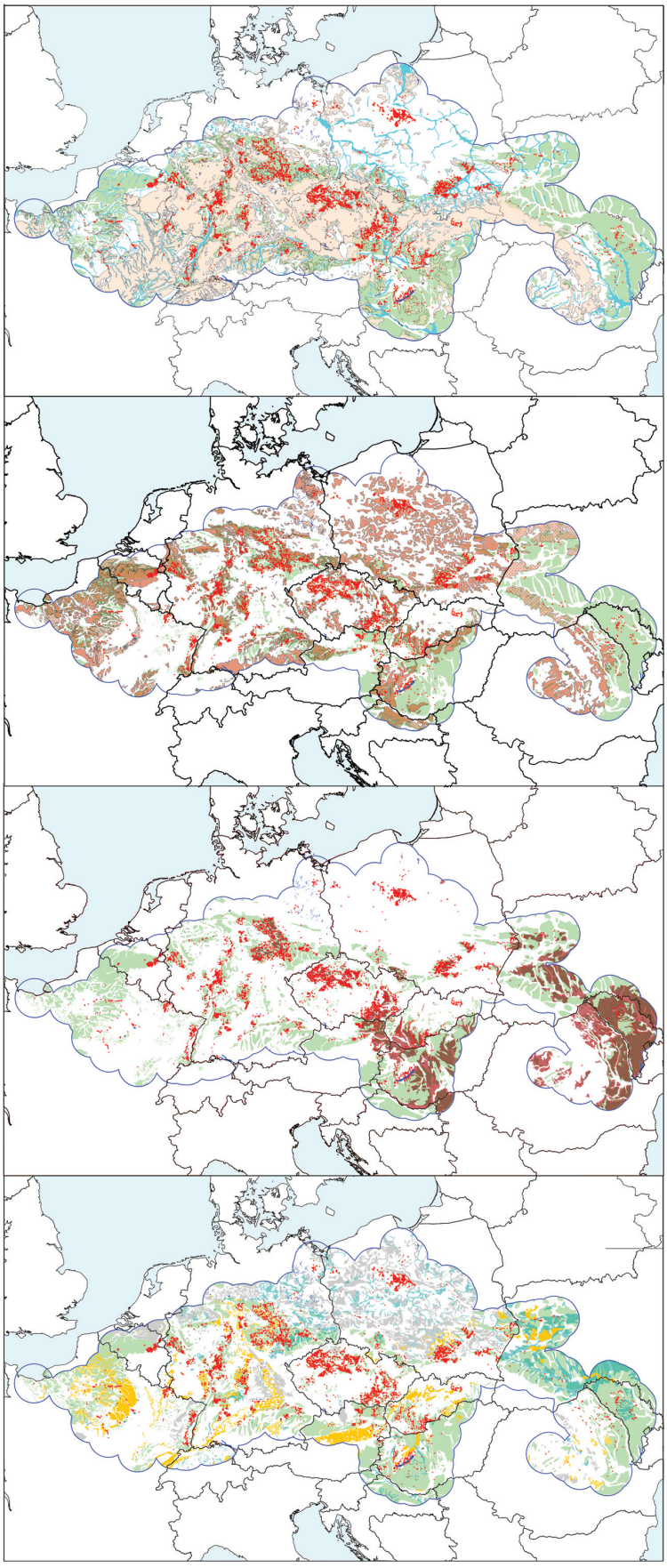
Appendix 11. Contributions to F3 of the MCA.

The third factor is mainly built (~78% of its variance) upon the opposition of the negative modalities SO2/clinohumic soil (16.6%), FR1/very good fertility (10.5%), PR3/deep depth (9%), and HY1/low hydric saturation (3.8%), for a total of ~40%; against positive modalities PR1/shallow depth (10.9%), PR2/moderate depth (5.8%), SO8/thin soil (5.2%), SO5/gleysol-vertisol (5.2%), HY3/high hydric saturation (4.1%), OP1/closed landscape (3.7%), FR3/moderate fertility (3.2%) and FR4/low fertility (2.7%), for a total of ~41%.

This is an expected contrast between settlements on deep and very fertile soils of Chernozems-Greyzems-Phaenozems types and those on very thin or waterlogged soils.



Appendix 12. Geographical distribution of the main soil groups in the LBK' occupation area.



Cambisols (SO1 : beige),
fluvisols (SO3 : light blue),
lœss (light green),
and LBK sites (red)

Luvi–podzoluvisols
(SO7 : light brown),
lœss (light green),
and LBK sites (red)

Clinohumic soils
(SO2 : brown),
lœss (light green),
and LBK sites (red)

Gleysols (SO5: green),
Podzols (SO6: light grey),
Renzinas–Régosols (SO8: yellow)
lœss (light green),
and LBK sites (red)

Appendix 13. Chronological stage-system in this paper.

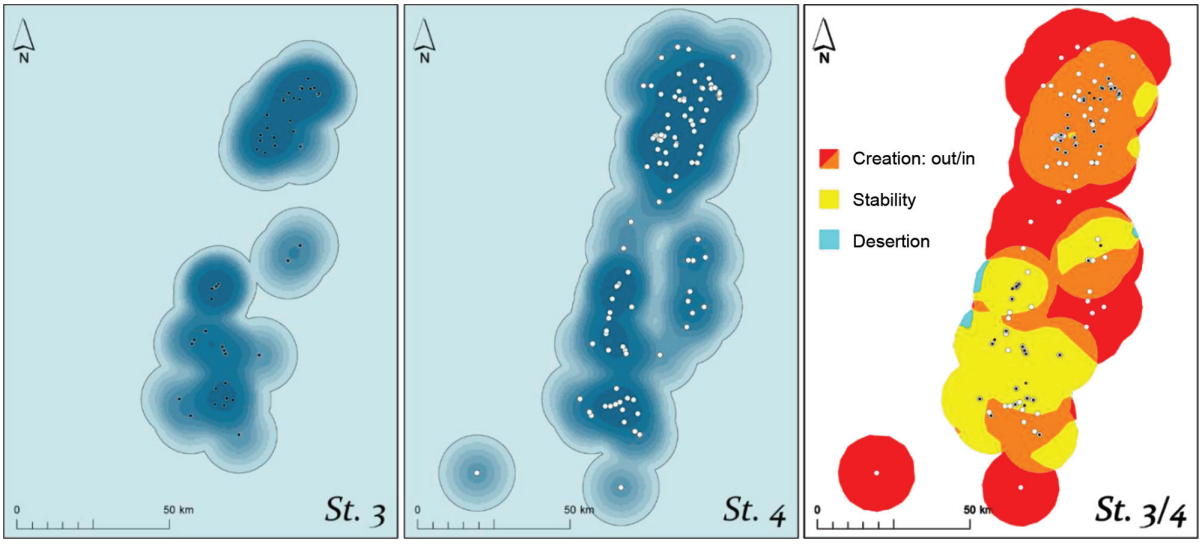
Unified phasing of the whole LBK's extension, at least in large stages, is required for this research project: continuities and discontinuities across time and space have to be considered at once. However, this ambition is particularly sensitive between the Western and Central Eastern chronological systems. Although many specialists may not be satisfied, we have nevertheless made such an attempt at chronological standardisation, according to the following approximative six stages sequence.

Approx. cal BC	**5600–5500**	**5500–5325**	**5350–5325**	**5325–5150**	**5175–5125**	**5125–5025**	**5025–4925**
This paper	**St 0**	**St 1**	St 1/2	**St 2**	**St 3**	**St 4**	**St 5**
Meier-Arendt 1966; 1972		I		II	III	IV	V
Dorhn-Ihmig 1979		1a		Ib-c	Id-IIa	IIb-c	IId
Lorraine-Bassin-Parisien (*Blouet* et al. *2013*)				Rubané Ancien (Flomborn)	3–4 – Rub. Moyen	5–7 – Rub. Récent	7–9 Rub. Final/ Termin. –
Alsace (*Denaire et al. 2017*; *Lefranc 2007*)				Rubané Ancien (Flomborn)	Rub. Moyen	Rub. Récent	Rub. Final
Mit./Nied. Rhein (*Dohrn-Ihmig 1979*)			I/II? (Nieder Kass.-Uckend.)	Ib-c II- Ältere (Flomborn)	Id-IIa III-Mittlere	IIb-c IV-Jüngere	IId V-Jüngste
Würtemberg-Neckar (*Strien 2000; Lindig 2002*)		Älteste	2a ?	2b-5	6–7	8	Hi
Hessen (*Kneipp 1998*)		Älteste	2 ?	3–5	6	7–8	9
Nied. Sachsen-Elbe/ Saale-Sachsen (*Behrens 1973; Kaufmann 1987; Quitta 1970*)		Älteste	?	Ältere (Flomborn)	Mittlere	Jüngere	Jüngste/ SbK
Südbayern/Schwaben (*Pechtl, Land 2019*)		Älteste	?	Ältere	Mittlere	Jüngere	Jüngste SOB (SbK)
Český (*Pavlu 2000*)		Ib-c Ältere	I/II (Áčkový ?)	IIa-b-c/ (Áčkový)	IIIa-b	III/IV IVa-b; šarka	IV?/SbK
Morava (*Čižmář 1998*)		Ia-b Ältere LBK	1b2 (Áčkový ?)	IIa-b Jung LBK	IIc NKK/Zseliz	III šarka	?
Niederösterreich/Burgenland (*Lenneis, Pieler 2016*)	Älteste Formative	Ältere LBK	Übergangsph. I/II	II Jung LBK Notenkopf	II? Zseliz/ Keszthely	III šarka/ Zseliesovce	?
Centra a západ Slovensko (*Pavúk 2004; 2005*)	Formative?	Ältere LBK Biňa	Milanovce	Jung LBK – Notenkopf	Zseliesovce	Zseliesovce	Z.
Magyar Dunántúl (*Oross, Bánffy 2009*)	Formative	Ältere LBK Bicske-Biňa	Milanovce	Jung LBK Notenkopf/ Keszthely	Zseliz/ Keszthely	ZI-II Zseliz/ Keszthely	ZIII/L.
Malopolska (*Czekaj-Zastawny 2009; 2013*)		Ältere LBK	Zofipole?	Jung LBK Notenkopf	Zseliz	Zseliz	LPC/SbK
Kujawy/Chelm. (*Pyzel 2006; 2010*)		Ältere LBK	Zofipole?	IIa-b Jung LBK	III?	III	LPC/SbK

Appendix 14. Protocol for the elaboration of transitional maps (example of the Upper-Rhine Valley).

As shown in the figure below, the colonization sectors for a period t+1 are divided into two groups: the one (orange) that develops (at t+1) inside an area already settled during the previous period (t); and the one (red) that develops outside a previously occupied area. In this way we can better identify true expansion from densification.

Left and centre: density maps (r. 12.5km) and 12.5km buffer zone (St. 3 and St. 4); right: transition map. The area of slightly less than 500km² delimited around sites from a radius of 12.5km is only a study protocol aimed at optimizing the density maps and allowing for a synoptic representation of settlement dynamics.



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Neolithic settlement structures in Central Europe: case study of East Bohemia and the Morava River catchment

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ABSTRACT – *The study examines the degree of similarity of Neolithic settlement structures in two geographically separated regions (eastern half of Bohemia, Morava River Basin) based on the analysis of 11 variables related to the environment and the settlement structures. The period studied corresponds to c. 4900–3400 BC. Although the results of most of the variables analysed using principal component analysis (PCA) do not show significant differences in the preference of settlement locations, the analysis of the individual variables points very clearly to major differences in settlement patterns. These are manifested in different settlement dynamics, accessibility to stone raw materials, and the spatial extent of occupation. The general conclusion is that although early agricultural societies are similar in general terms regarding the location of settlements, their individual aspects are quite different, which must have been reflected in lifestyles during the Neolithic.*

KEY WORDS – *Neolithic; settlement; chronology; central Europe*

Neolitske poselitvene strukture v Srednji Evropi: primera vzhodne Češke in porečja Morave

IZVLEČEK – *V študiji, ki temelji na enajstih spremenljivkah, povezanih z okoljem in poselitvenimi strukturami, preučujemo stopnjo podobnosti naselbinskih struktur v dveh geografsko ločenih regijah (vzhodna polovica Češke in porečje Morave). Študija zajema čas med 4900–3400 pr. n.št.. Analiza glavnih komponent (PCA) pri večini spremenljivk sicer ne kaže bistvenih razlik v izbiri poselitvenih prostorov, vendar analize posameznih spremenljivk jasno kažejo na velike razlike v poselitvenih vzorcih. Te so v različnih poselitvenih dinamikah, dostopnosti do surovin za izdelavo kamenih orodij in v obsegu poselitve. Splošna ugotovitev je, da so zgodnje poljedelske družbe izbirale podobne poselitvene prostore, čeprav so posamezni vidiki izbire precej različni in so se gotovo odražali v življenjskem slogu teh družb v neolitiku.*

KLJUČNE BESEDE – *neolitik; naselja; kronologija; Srednja Evropa*

Introduction

After the end of the stage of the initial development of Neolithic society in central Europe, which is characterized by the Linear Pottery culture (LBK), the original symbolic style broke down into several regional factions in terms of the decoration of ceramic vessels. The existing research on Neolithic society in this region has been almost exclusively dependent on knowledge of pottery decoration, which serves as a basic chronological descriptor. In the traditional sense, then, symbolism on pottery is seen as a key reflection of social affiliation – archaeological culture, as a legacy of Romanticism in the form of

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the theoretical approaches of Gustaf Kossina (*1911*) and Vere Gordon Childe (*1925*). In contrast to symbolic systems, the study of settlement structures was developed under the influence of processual archaeology as a manifestation of strategic adaptation to changes in environmental conditions, which became evident in archaeological research on the Neolithic in Central Europe from the 1980s onwards (*Lenneis 1982; Rulf 1983*). Despite the influence of processual archaeology, however, questions of human adaptation to the environment were shaped by the influence of cultural historicism, particularly with regard to perceptions of the chronological development of early agricultural societies.

In previous research on settlement structures the chronology was determined solely on the basis of symbolic systems, which are reflected in the morphology and decoration of pottery and are called 'archaeological cultures'. However, these lack explanatory potential for understanding the dynamics of prehistoric societies (most recently *Furholt 2021*). However, due to their frequent occurrence, Neolithic symbolic systems captured in ceramic production are a useful means for understanding the chronology of settlements based on knowledge of their temporal occurrence using radiocarbon dates (*Trampota, Květina 2020*).

In this study, we focus on characterizing the changes in the settlement organization of human populations that inhabited two separate regions in central Europe: the Morava River Basin and the eastern half of Bohemia (Fig. 1). We hypothesise that Neolithic organization of settlements is part of the reflection of lifestyles conditioned primarily by the natural environment and by social behaviour patterns.

The basic questions we address are: (1) What variables influence the development of settlement patterns in two geographically separated regions? (2) Can some variables be regionally distinguished? (3) What weight do the selected variables have for the study of settlement structures? (4) Do changes in ceramic style correspond to changes in settlement structures or some of the variables under study?

The beginning of the period (*c.* 4900 BC) included in the study corresponds to the end of the Early Neolithic, when there is a decline in human activity in many regions of central Europe, as reflected in the frequency of radiocarbon dates (*Shennan 2018*), and at the same time the symbolic Linear Pottery style (LBK) comes to an end. In terms of the traditional nomenclature of symbolic styles, the period we study corresponds to the Stroked Pottery (SBK), Lengyel Pottery (LgK), Jordanów/Epi-Lengyel Pottery, Michelsberg Pottery (mainly Bohemia) and the Funnelbeakers (TRB), which occur together with Retz-type pottery (mainly Morava River catchment).

The first region of interest is the eastern half of Bohemia. Here, the settlement area is bounded to the north, east and south by mountains and highlands,

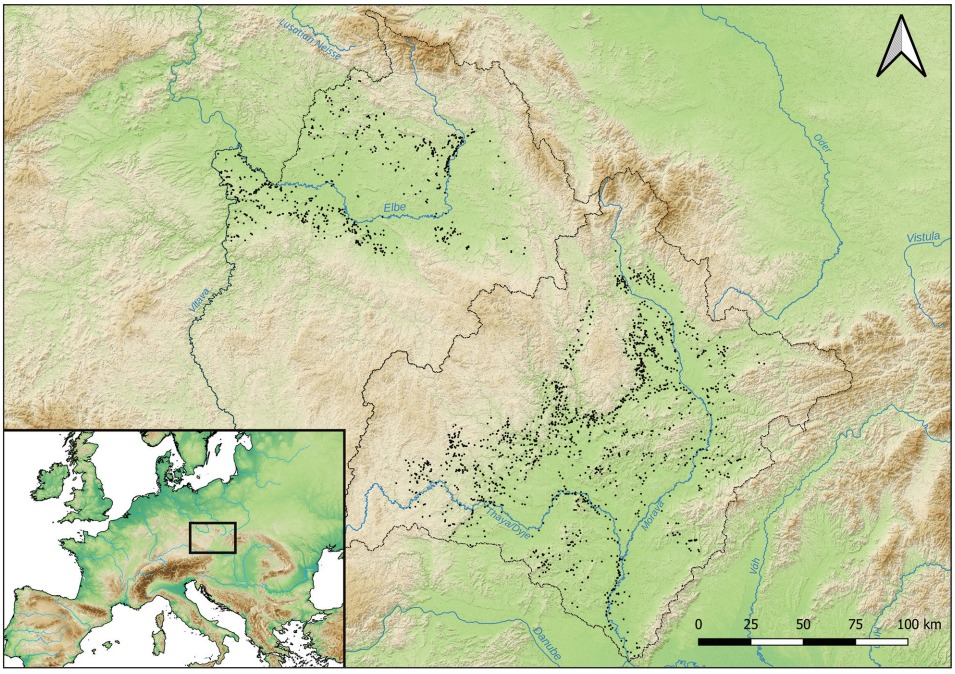

Fig. 1. Area of interest and all studied sites from the period of c. 4900–3400 BC.

while the eastern part is artificially demarcated by the watercourses of the Vltava and Jizera rivers, which have an approximately north-south course. The number of analysed settlements in the area of *c.* 9000km^2 is 597, which corresponds to an average density of 0.06settlements/km^2.

The second settlement area is the Morava River Basin, which is mainly located in Moravia, in the northern part of Lower Austria and in the westernmost part of Slovakia (Záhorie). This area is bounded by mountains and highlands to the west, north and east, while at the southern border the settlement area continues further. The number of analysed settlements in the settlement area of *c.* 19 000km^2 is 1556, which corresponds to an average density of 0.08sites/km^2.

The two settlement regions are located in similar geographical and climatic areas of the temperate zone of central Europe; the terrain relief is not categorically different, and we consider them comparable in terms of the natural environment.

Data and methods

Chronology

In the absence of a dominant successor interpretive model, the model of archaeological culture has been used until now, at least in the sense of the basic classification of material culture, while the change of ceramic style is taken into account as a unique chronological factor through whose transformation other changes in the structure of society can be captured. This *a priori* model is problematic because it does not assume the possibility of significant social changes during the existence of a given symbolic style. On the other hand, we do not currently have a more appropriate chronological identifier that could better characterize the chronological position of most settlements.

In order to understand the chronological evolution of settlement transformations, we turn to three forms of describing individual settlements based on (a) symbolic systems on pottery (archaeological cultures – ceramic traditions); (b) basic subdivisions of ceramic typology (phases of archaeological cultures – ceramic groups) based on knowledge of their temporal occurrence (following *Trampota, Květina 2020*); and (c) knowledge of radiocarbon density data that reflect concentrations of human activities. While the chronological distribution is expressed in the aforementioned publication, the determination of the chronology based on the frequency of occurrence of radiocarbon dates is a sub-subject of this study. A similar analysis has already been performed for both Bohemia and the Moravian-Lower Austrian area (*Timpson* et al. *2014.553*) using the summed probability distribution (SPD). Given the currently significantly higher amount of available radiocarbon dates for both areas, we performed a new SPD in OxCal (*Bronk Ramsey 2009*) using the IntCal 2020 atmospheric calibration curve (*Reimer* et al. *2020*), which we interpreted using kernel density estimation (KDE; *Bronk Ramsey 2017*).

All ^{14}C dates from anthropogenic contexts were included in the input radiocarbon database (see Supplementary material). All ^{14}C dates related to the period between the beginning of the agricultural prehistory to the end of the TRB, *c.* 3350 BC, were considered. Only dates with a 1σ greater than 100 and dates measured from humic acids were excluded from the dataset. The resulting SPD and KDE plots are validated by the number of known settlements (Fig. 2).

In the Morava Basin, the structure of the radiocarbon dates is divided into three peaks representing three distinct units of population activity. The first peak corresponds to the occurrence of Linear Pottery (LBK), and the marked decrease in the frequency of radiocarbon dates at the end of the LBK around 4900 BC is a known phenomenon in other regions in western central Europe (*Shennan 2018.104*). The second peak is represented by the pottery styles with Stroked Pottery (SBK) and Lengyel pottery (LgK). At the end of this peak, some archaeologists use the term Jordanów culture or Epi-Lengyel. Between *c.* 4000 and 3800 BC, there is an apparent hiatus in human activity that has not been considered in archaeological research to date, as it cannot be detected outside the context of absolute dates. The last peak of human activity is associated with the Funnelbeakers (TRB) and Retz-type pottery. However, its termination is artificially based on the initial definition of the period under study, which is only associated with TRB, but actually continues in the context of at least Baden pottery.

The three identified peaks are a new chronological indicator which we henceforth refer to as Neolithic A, Neolithic B and Neolithic C (Neolithic A is not the focus of this study).

In Bohemia, the resulting model is far more problematic, as there are significant data biases. At pre-

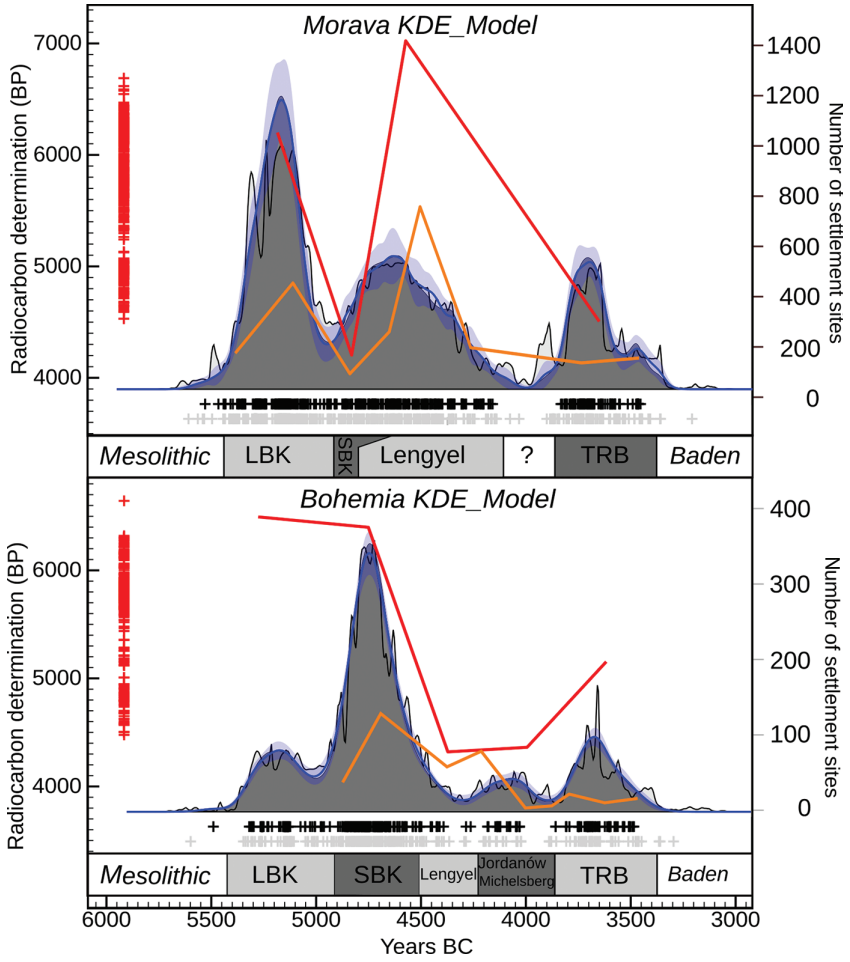

Fig. 2. SPD and KDE of ^{14}C data from anthropogenic contexts in the Morava River catchment (above, n=516) and in Bohemia (below, n=299). The red curve shows number of settlement sites defined based on pottery traditions, the orange curve shows number of sites based on more detailed typochronology.

sent, it is not possible to say whether there is a significant decline in the frequency of ^{14}C dates during the transition from the LBK to the SBK, as the underdating of contexts associated with Linear Pottery is evident when comparing the number of settlements and the amount of radiocarbon dates. A subsequent significant peak is associated with Stroked Pottery or the study of rondel ditch fills. In this respect, we can speak of a heavy overestimation of the accumulation of ^{14}C dates in favour of the one problem addressed. After the SBK period, there is a decline in both the frequency of ^{14}C dates and the number of settlements, which indicates a different development compared to the situation in the Morava Basin. The possibility of a settlement hiatus after 4000 BC is reflected in the modelled dates, but the number of ^{14}C dates from the Early Eneolithic is too low to obtain a relevant result. However, similar to the Morava Basin, there is a clear increase in the density of ^{14}C dates and the number of settlements around 3800 BC. The resulting density curve of ^{14}C dates is not representative in part, so we provisionally use the same model for Bohemia, which divides the Neolithic into periods A, B, and C.

For the analysis of settlement characteristics, we use this broad chronological concept in terms of long-term processes. We are interested in whether the settlement during each population phase was chronologically or regionally specific.

Settlement data

The choice of variables related to Neolithic settlements reflects the real possibilities of studying the data structures of the region. Some complex datasets are defined by institutions in three countries and may not be compatible or available. For this reason, pedological and geological data, in particular, which may be important for the formation of Neolithic settlements, are not taken into account. The studied variables form two groups – the first is labelled environmental variables, and in general it is comprised of variables determined by the environment and terrain surrounding the settlements; the second group is labelled social variables, and in general these are influenced by processes taking place in the Neolithic society.

The database of settlement sites (n=2154) is based on our desire to maximize the information potential with regard to Neolithic settlement sites. In addition to published sites, we acquired data from archaeological archives and some unpublished sources in museum collections. Data were obtained in the form of standard excavations, as well as collections from surface surveys. In its minimalistic form, the Neolithic settlement is defined by the repeated presence of ceramics that can be assigned with certainty to at least one of the ceramic traditions (archaeological cultures). Neither isolated lithic finds nor hoards or any cave finds are taken into consideration. The mi-

nimum distance separating two settlements is *c.* 200m.

The data is described in detail in a dedicated data article (*Pajdla, Trampota 2021*) and is also published in a separate repository under https://zenodo.org/record/5768049#.YydAhLRBxPY.

Data is analysed in the R programming language (*R Core Team 2022*). To enhance transparency, the compendium containing code is published at the Zenodo data repository under https://zenodo.org/record/6703463#.YydBi7RBxPY according to principles outlined in Ben Marwick (*2017*); the original repository is at https://github.com/petrpajdla/settlements.

The most important software packages used in the analysis are the tidyverse family of packages (*Wickham* et al. *2019*), sf (*Pebesma 2018*), and spatstat (*Baddeley* et al. *2015*).

We approach the analysis as a multidimensional problem, dimensionality reduction (PCA) is used on the continuous input variables and, consequently, model-based clustering (mclust package, *Scrucca* et al. *2016*) is used to define groups of similar settlements.

Analysed environmental variables
Altitude is derived manually from online map servers (https://geoportal.cuzk.cz, https://www.geoportal.sk, and https://www.niederoesterreich.at/karte), and also from a digital elevation model (DEM) to verify this approach. The values derived from DEM and by hand correlate well (R = 0.97). For the analysis, the values derived by hand are used.

The value of slope at the settlement location is derived from ASTER GDEM (*NASA* et al. *2019*). ASTER GDEM is used because the territorial scope of the area of interest intersects several state boundaries, namely the Czech Republic, Slovakia and Austria, and obtaining and/or harmonizing individual digital elevation models with identical resolutions, *etc.*, for each of the countries was not possible. The slope value is derived as a mean value in a buffer zone around each of the settlement sites with a radius of 300m.

The density of the watercourse is the preferred method of assessing the relationship between human occupation and water courses over the distance to a water course. The approach used is based on methods used to study road networks in modern urban areas (*Lin* et al. *2020*). The watercourse density is derived from three individual layers for each of the countries, DIBAVOD (*Fojtík* et al. *2022*) for the Czech Republic and Geofabrik for Slovakia and Lower Austria. The density of watercourses is estimated using kernel smoothed intensity from a line segment pattern with a kernel size of 2km. The mean value in a buffer zone with a radius of 300m around the settlements is recorded.

The topographic position index (TPI) is used (together with the slope) as a proxy for terrain fragmentation. It is derived from the digital elevation model using Wilson's approach (*Wilson* et al. *2007*), *i.e.* TPI is the difference between the value of a given cell and a mean of eight surrounding cells. TPI effectively shows whether the surroundings of a site are flat, or the site is located on a hill (positive values) or in a valley (negative values). As in the case of slope, the TPI for a given settlement site is defined as a mean TPI value in its buffer zone with a radius of 300m.

Analysed social variables
Settlement density was calculated using kernel density estimation with a kernel size of 4km. Not that in the figures we used a kernel size of 10km.

The linear arrangement deals with settlements organized in linear formations along watercourses and on terrain contours, typically in the foothills of uplands. Settlements have not yet been analysed in this way on a larger scale. Settlement lines were manually defined in the GIS environment based on base layers from ZABAGED and Geofabrik (for Slovakia and Austria) for watercourses and a digital elevation model (OpenStreetMap) for terrain lines. The minimum number of settlements per line is three.

The location of sources of lithic raw materials in the studied areas (Fig. 3) is defined by Antonín Přichystal (*2013*). Subsequently, the distance of each settlement to each source during the periods when each raw material was exploited was calculated. Resource exploitation was categorized for each period as: none, sporadic, significant.

The hierarchical element of settlement structures is considered to be a palisaded or ditched enclosure, which is assumed to have had primarily an economic or fortification purpose. We do not include rondels typical for the first half of the 5th millennium BC in this category because of the distinctiveness of rondels from other enclosures – both with regard to the shape of the ditch and the single-phase occurrence within prehistory. The rondels have a V-shaped

ditch, whereas the settlement enclosure ditches are flat-bottomed. In the case of hilltop enclosures, then, we observe the remains of a stone wall. Rondels are specific in the context of agricultural prehistory because of their short-term, single-phase occurrence, while settlement enclosures are observed continuously.

The distance from each settlement to all enclosures has been calculated.

The presence of individual ceramic groups at individual sites was observed, for which we assume chronological succession. On the basis of the frequency of successive settlements we observe changes in settlement continuity.

Results

Altitude

The character of settlements in relation to altitude differs significantly in Bohemia and in the Morava Basin, both in terms of the evolution of preferences and in terms of data homogeneity. While in Bohemia the values of altitude are very similar for the mean and median, in the Morava Basin the mean and median are significantly different, reflecting the wide range of settlement values; in Bohemia they have a homogeneous character and thus less dispersion of values (Fig. 4). For developmental trends, there is a clear tendency in the Morava Basin to settle sites at higher elevations from the interval 4800–4600 BC (Early Lengyel), which gradually decreases to very low values in the interval 4200–4000 BC (Epi-Lengyel). A renewed increase in preference for higher altitudes is observed from 3800 BC (TRB) onwards.

On the other hand, in Bohemia there is a slight, steady decline in the preference for higher elevations from the beginning of the period under study to 3800 BC. As in the Morava Basin, we observe a preference for higher elevation settlements from 3800 BC onwards in relation to the TRB.

The described trends are consistent with the data defined by both ceramic traditions and ceramic groups.

Slope

The data categorized by ceramic tradition show a similar tendency for slope preference as for elevation, which is indirectly related. If we classify the data in more detail according to ceramic groups, there is a greater dynamic (Fig. 5). For both study areas, low

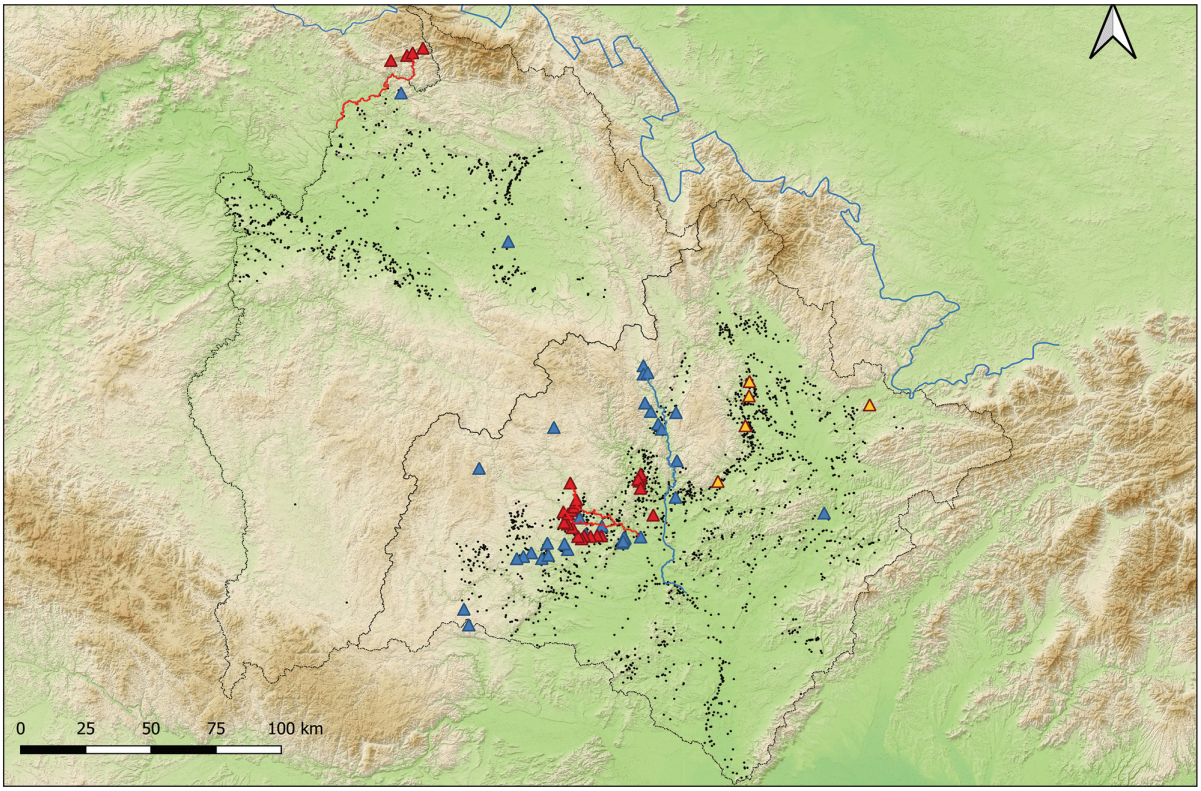

Fig. 3. Map of studied area with lithic raw material sources. Red – sources for polished stone tools; yellow – speculative sources for polished stone tools (culm rock); blue – sources for chipped stone tools. Triangles – primary sources, lines – secondary sources in river gravels or moraines.

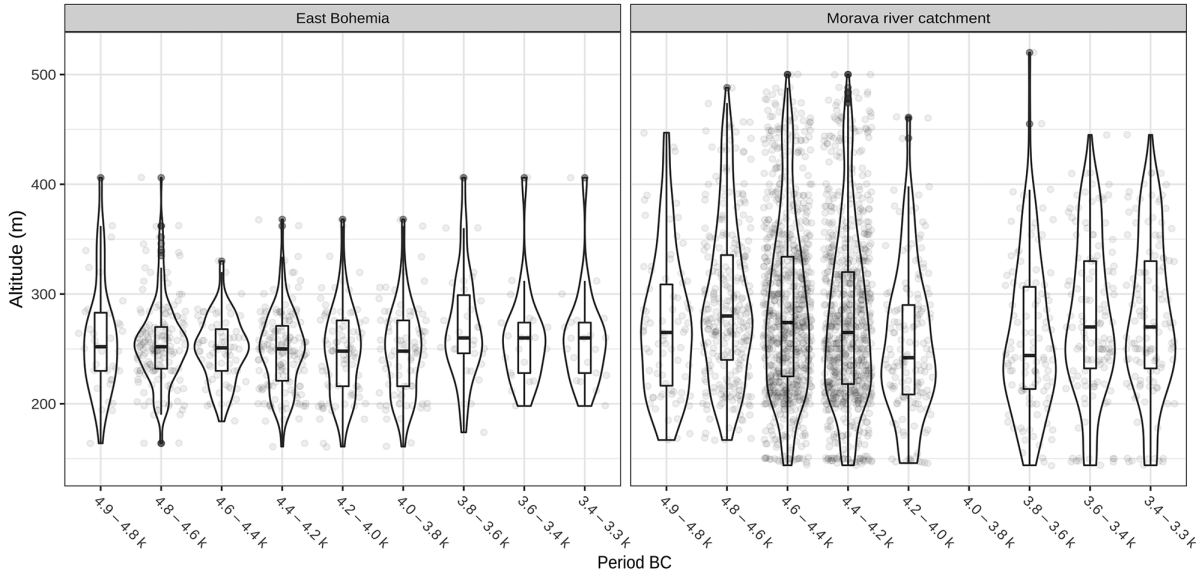

Fig. 4. Violin plot with elevations of settlement sites in individual periods. Data are classified according to pottery groups.

settlement slope values (Early SBK) are present at the beginning, followed by an increase from 4800 BC (Early Lengyel, Late SBK) and followed by a gradual decrease until 3800 BC. A reversal towards higher values occurs in Bohemia from 3800 BC and in the Morava Basin from 3600 BC. Towards the end of the period under study in Bohemia (Saalzmünde, Boleráz) the settlements are located on flatter sites, while in the Morava Basin (Boleráz) there is a clear preference for more sloping sites.

Watercourse density

The basic characteristics of the development of the relationship between settlement and watercourse density is the same for data categorized by both ceramic tradition and ceramic group. During the period 4900–4600 BC (SBK), settlements in Bohemia are located in areas of high watercourse density, followed by a sharp decline and a slightly downward trend in the rest of the period. In contrast, the situation in the Morava Basin is negatively correlated with this and the trend is exactly the opposite (Fig. 6).

Kernel density (KDE) of settlements

The density of settlements in terms of general trends is similar for the data categorized by ceramic tradition and ceramic group, but some changes in the short-

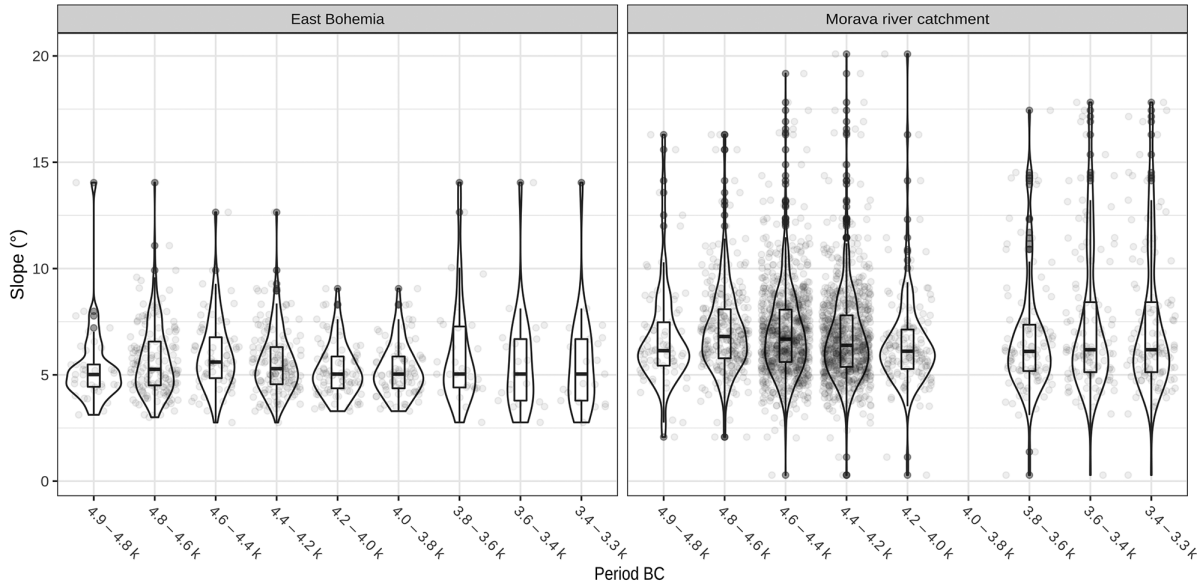

Fig. 5. Violin plot with slope values of settlement sites in individual periods. Data are classified according to pottery groups.

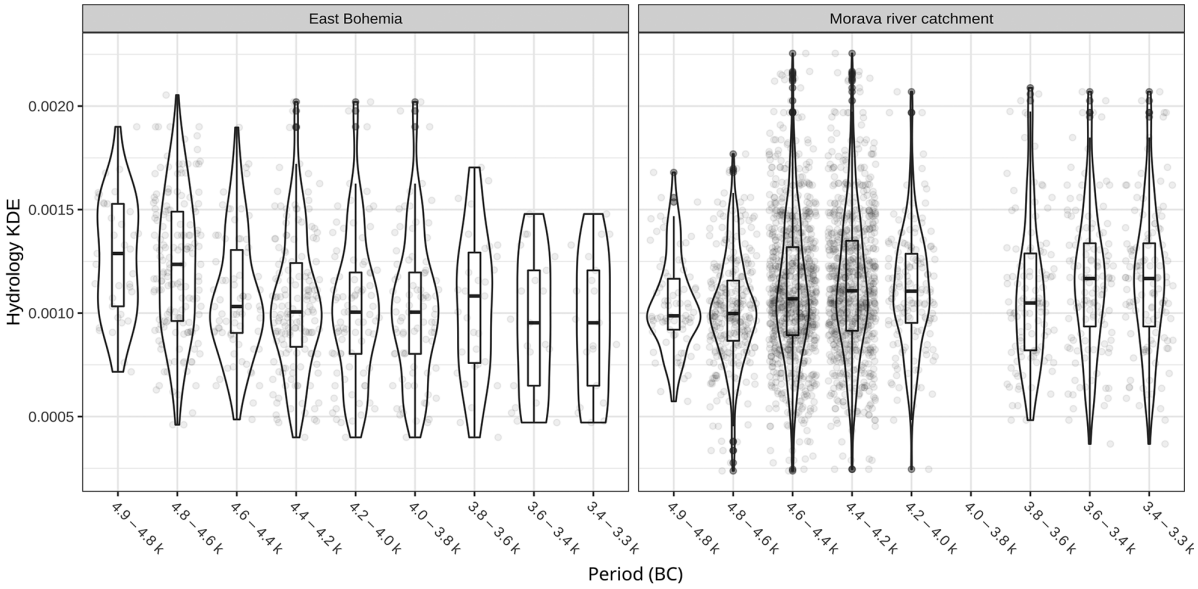

Fig. 6. Violin plots with KDE of watercourses in individual periods. Data are classified according to pottery groups.

term trends are significant in the case of the ceramic groups (Fig. 7). In both regions, the beginning (Early SBK) is characterized by low settlement density. This is followed by an increase in settlement density, but in the Morava Basin the settlement density reaches almost twice the values in Bohemia. While in the period 4600–4200 BC (Late Lengyel) the values in Bohemia no longer reach the previous maximum, in the Morava Basin the density continues to increase, followed by a sharp decline in values in the period 4200–4000 BC (Epi-Lengyel). In the Morava Basin a settlement interlude follows in the period 4000–3800 BC, whereas in Bohemia the settlement hiatus is not yet evident in the radiocarbon dates. The lowest settlement densities, however, are shown by settlements in 3800–3600 BC in association with the beginning of the TRB, but this is probably related to the relatively small proportion of TRB settlements whose ceramic typology is more closely subdivided. During the TRB, settlement density increases slightly in both regions.

Beyond the statistical results, it is important to consider the spatial location of the main settlement clusters and their size. We categorize these data only in the context of ceramic typological groups. In Bohemia, the settlement core in the Early SBK period is located in the north of the settlement area in the

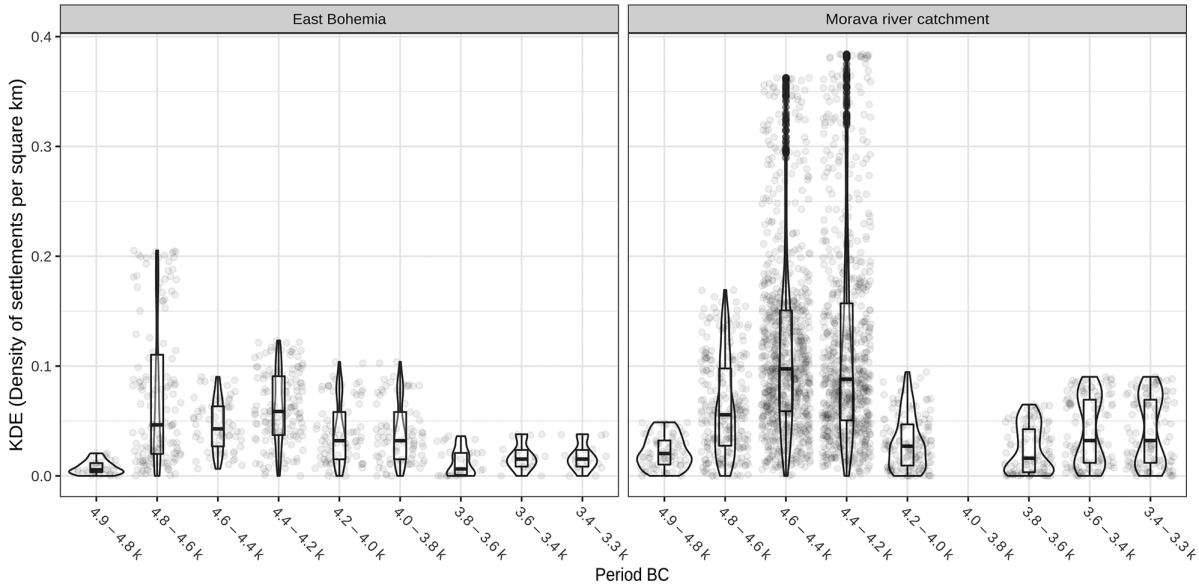

Fig. 7. Violin plot with KDE of settlement sites in individual periods. Data are classified according to pottery groups.

broader vicinity of the Jičín Upland, an area that is somewhat less populated in other periods, especially in comparison with the Polabí (Elbe) region (Fig. 8). Subsequently, in the context of the Late SBK, settlement appears in several distinct settlement clusters on the right bank of the Elbe in eastern Bohemia and in the vicinity of Chrudim and Kolín. Settlement during the Late Lengyel (Fig. 9), albeit in smaller numbers, is organized very similarly, but the settlements are more concentrated in the broader vicinity of the Elbe. Settlement structure changes markedly during the Proto-Eneolithic (Fig. 9), when settlements are concentrated in the Polabí region between Prague and Kolín, while settlements in eastern Bohemia are sporadic. In Bohemia, TRB settlements occupy the area in central Bohemia south of the Elbe River and in eastern Bohemia west of the Elbe River. The sub-typochronological classification of TRB settlements is at a low level, but it can be assumed that the characteristics of settlements in 3800–3400 BC are similar to those of the TRB in general. The conclusion of the TRB (Fig. 10) is interesting in terms of settlement organization because of the occurrence of one distinct cluster in and around Prague characterized by Saalzmünde pottery, while a separate second smaller cluster of settlements is located in the Čáslav Basin and is characterized by Boleráz pottery.

In the Morava River Basin, the smaller number of settlements in the period characterized by the Early SBK are concentrated in the western half of the settlement area, while the area east of the Morava River shows almost no settlement activity (Fig. 8). Subsequently, in the context of the Early Lengyel there is an increase in the number of settlements concentrated mainly around Brno and in southwest Moravia. The area east of the Morava River is only sporadically settled, and in central Moravia there is also very sparse settlement, moreover the ceramic production is characterized by Late SBK. In the Late Lengyel period (Fig. 9), the settlement situation reverses: while in the southern half of the basin the density of settlements

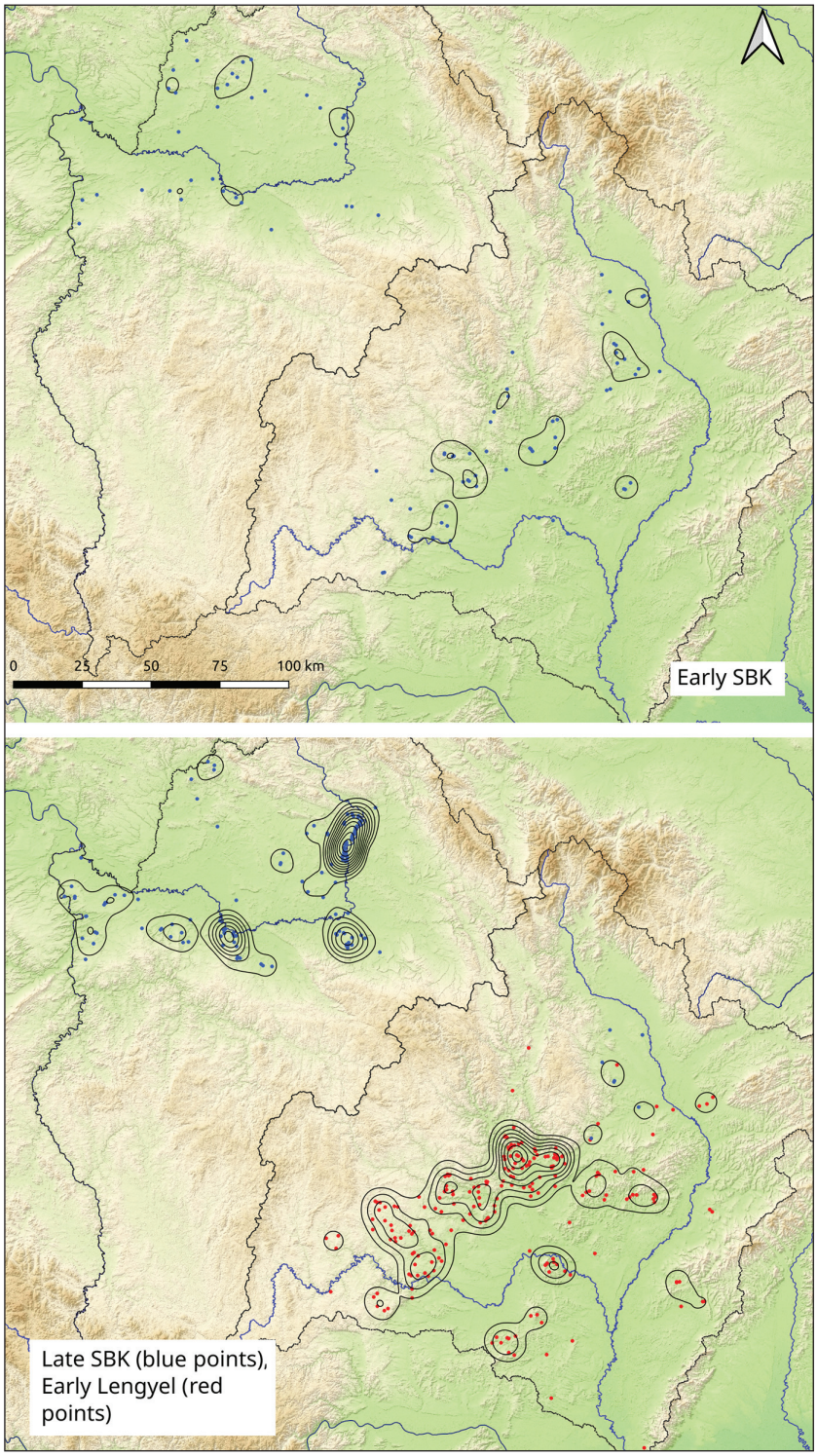

Fig. 8. Settlement KDE of sites with SBK and Early Lengyel.

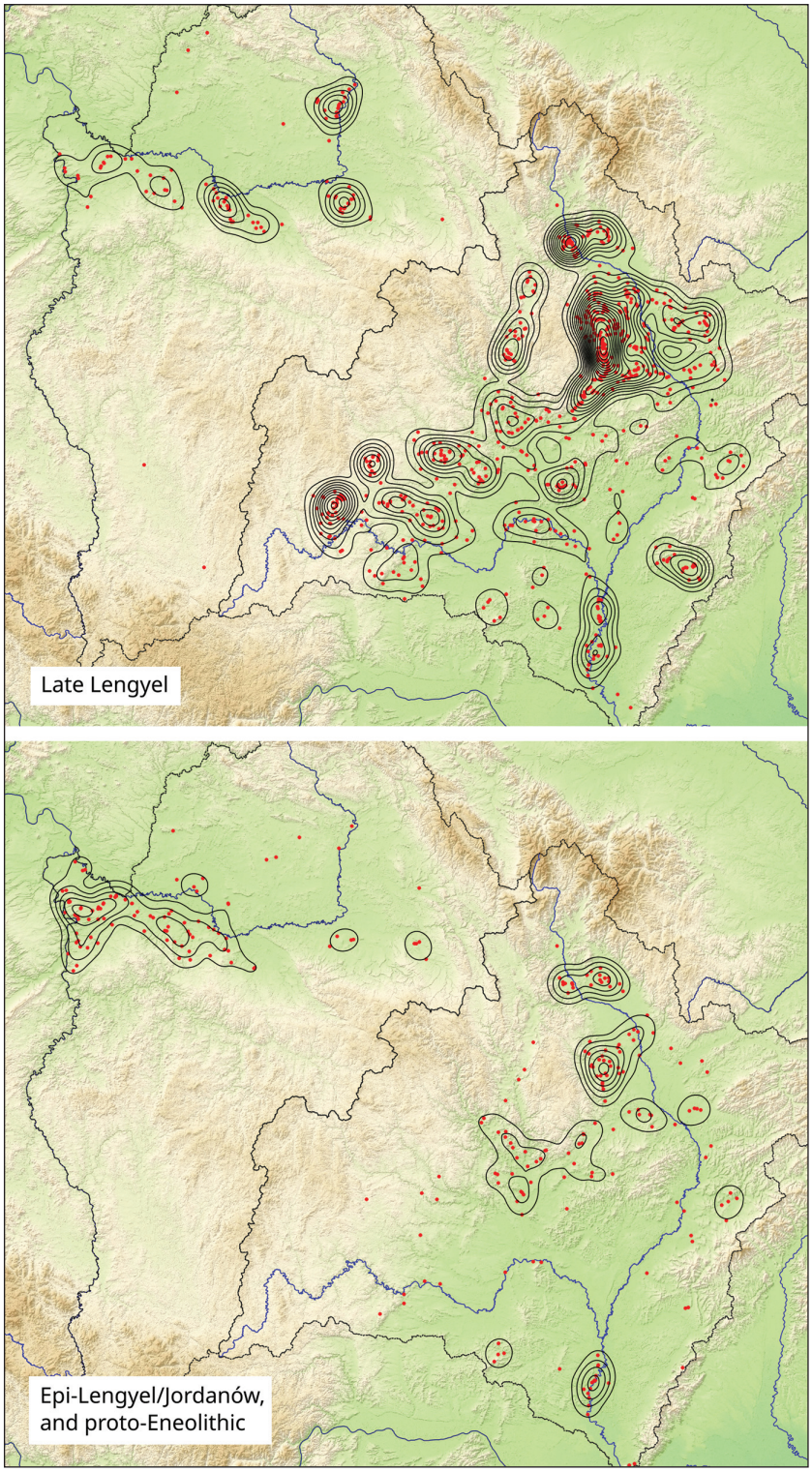

Fig. 9. Settlement KDE of sites with Late Lengyel and Epi-Lengyel/Jordanów/Proto-Eneolithic.

decreases considerably and they are concentrated into more small settlement clusters, in the northern half of the basin (central Moravia) a large settlement cluster is formed. The area to the east of the Morava River is for the first time since the LBK more heavily populated. During the Epi-Lengyel (4200–4000 BC), the southern half of the Morava Basin is sparsely populated, except for the area along the right bank of the lower course of the Morava River. As in the previous period, settlement is concentrated in central Moravia. Between *c.* 4000 and 3800 BC, we assume a settlement hiatus, or a form of human presence that left no significant archaeological traces. In *c.* 3800–3500 BC (Early TRB, Baalberge, Retz-type), three unequal settlement clusters (Fig. 10) emerge in the vicinity of present-day Prostějov, Brno and Znojmo. The southeast of the studied area is sparsely settled, if at all. Towards the end of the period under study (TRB – Boleráz) we observe an increase in the concentration of settlements in central Moravia, with a small cluster in southwest Moravia and the lower course of the Morava River. The rest of the Morava Basin is not significantly populated.

Linear arrangement – along terrain lines

In terms of proportions, settlements are located along the terrain lines mostly in the period 4900–4800 BC (Early SBK), after follows a decline, especially in Bohemia. Here, settlements form slightly more distinctly along terrain lines from 4200 BC onwards (Proto-Eneolithic and TRB). In the Morava River catchment, on the other hand, the formation of settlements along terrain lines is a very fundamental phenomenon for the period 3800–3300 BC (TRB), with the main area where settlements are organized in this way being the southern and eastern margins of the Drahany Uplands (Fig. 12). Parallel to these, the linear organization of the hillforts forms a specific structure during the Boleráz phase.

Linear arrangement – along water lines

In terms of frequency, the organization of settlements along water lines appears less pronounced than for terrain lines. The only period and region where settlements are significantly located along water lines (Fig. 11) is 4900–4800 BC (Early SBK) in the Morava Basin. There is also significant settlement organization along watercourses in the Morava Basin during the Late Lengyel, *c.* 4600–4300 BC, but statistically this disappears in the face of the very high number of settlements during this time. The organization of settlements along watercourses and on terrain lines during the Late Lengyel is also significant (Fig. 12), but this is not statistically significant in the context of the large number of settlements.

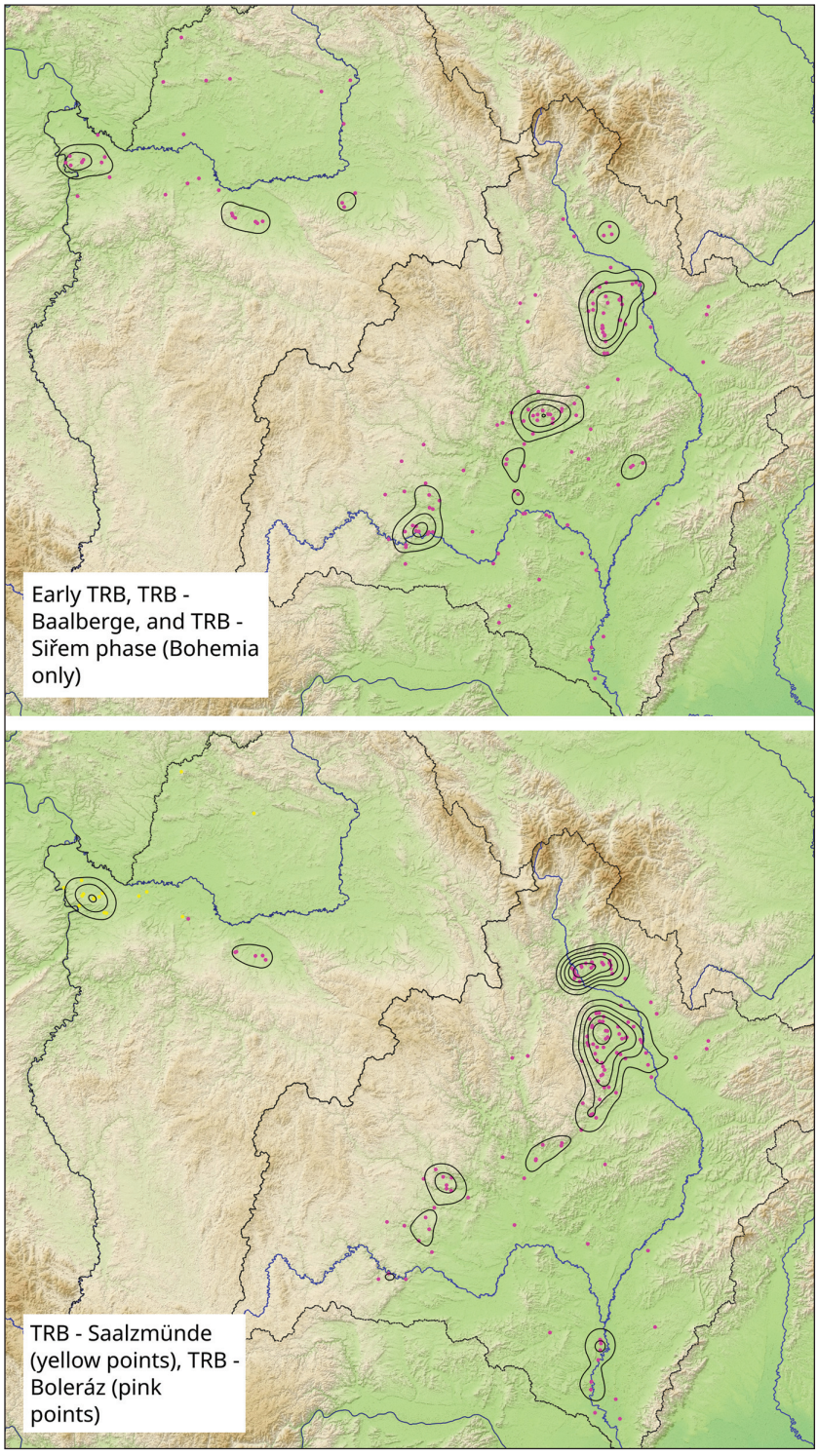

Fig. 10. Settlement KDE of sites with TRB.

Hierarchical arrangement

The analysis of the relationship between settlements and enclosed sites (Fig. 13) was carried out only in the context of data described by ceramic traditions, as the detailed chronology of many enclosed areas is unknown. The analysis shows that for most of the periods the distance between settlements and enclosures recorded in the Morava Basin is smaller, which is mainly due to the larger number of known enclosures. The opposite situation is in Bohemia during 4200–3800 BC (Proto-Eneolithic), when a large number of lowland enclosures are recorded in central Bohemia (*Krištuf, Turek 2019*). In the Morava River catchment, on the other hand, the distance to enclosed areas decreases significantly in 3800–3300 BC in the context of the TRB, when a number of new hillforts are established, often with evidence of a stone rampart. The spatial distribution of enclosures in the Morava Basin is interesting from the long-term perspective, with almost all of these enclosures located in the western half of the occupied area.

Distance to raw material sources for chipped stone industry

A comparison of the data distribution by ceramic tradition and ceramic group shows no

structural differences. For the settlements in Bohemia, the mean and median values are above 100km; their slight diachronic increase is probably not a reflection of a change in the relationship between sources and settlements in the context of such large distances.

In the Morava Basin, the situation is significantly different, mainly due to the proximity of the sources of raw materials for chipped industry. In the period 4900–4800 BC (Early SBK), a significant concentration of settlements is evident in the vicinity of chipped industry resources (Fig. 14), which is related to the depopulation of the eastern part of the Morava Basin, where resources are less abundant, and the localization of settlements in the western part, where more raw material resources are concentrated. Krumlovský les chert played a key role in this period. It is completely predominant in the chipped stone industry assemblages within a radius of at least 60km (*Trampota 2015.180–183*) and is also significantly present at distances above 80km (*Olomouc-Slavonín; Kazdová* et al. *1999*), thus quantitatively the most abundant raw material and the one distributed over the greatest distances in the entire studied period. In subsequent periods, the distance to the resources increases in connection with establishing new sites in the whole settlement zone. The highest distance to the sources of raw materials for chipped stone tools is recorded in the period 4200–4000 BC (Epi-Lengyel), when the number of settlements decreases to the level of the period 4900–4800 BC (Early SBK), but their main concentration is in central Moravia, in a region relatively distant from the sources. As such, two types of relationships of settlements to the sources of the chipped stone industry can be observed in similarly few populations.

A distinct phenomenon since 3800 BC (Early TRB, Baalberge, Retz-type) is the mining and local distribution of chert from Stránská skála near Brno (*Bartík* et al. *2019*), but the overall settlement pattern does not statistically correspond to this activity, although a small cluster of settlements forms around the source.

Distance to raw material sources for polished stone industry

As with the raw materials of chipped industry, the division of data by pottery traditions and pottery groups shows no structural differences.

In Bohemia, Jizera Mountain-type metabasite was an important resource during the Early Neolithic (*Přichystal 2013.192*), whose distribution radius extended beyond central Europe. The use of this raw material continues in the following period, but only on a regional scale in Bohemia (*Šída 2007*). In 4900–4800 BC (Early SBK), the settlement structure in relation to the sources of raw materials of polished stone industry is oriented more towards the vicinity of the source. In the subsequent period, however, no changes in settlement structures are evident in relation to the distance from the sources of raw materials.

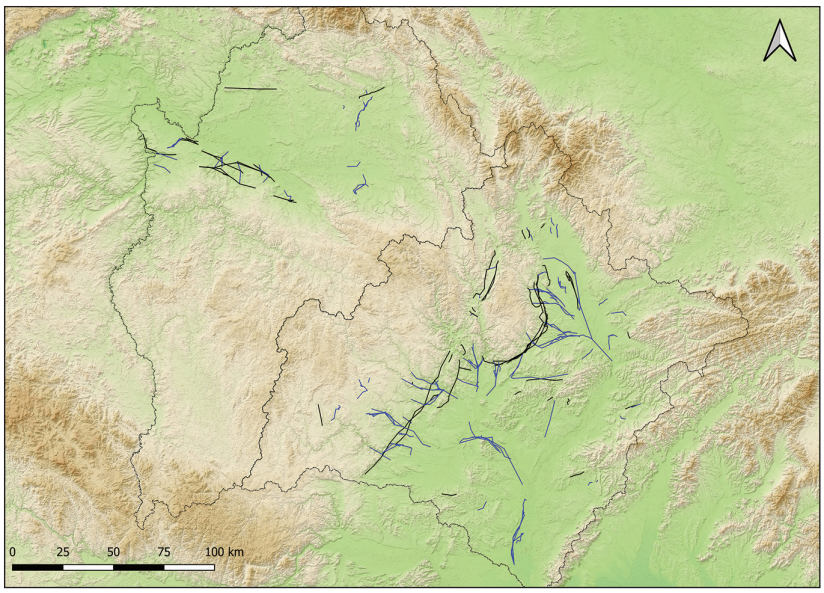

Fig. 11. Linear arrangement of settlement sites along terrain lines (black) and along water lines (blue). The map shows merged lines for all periods.

In the Morava River Basin, settlements are not related to sources of stone raw material at all in 4900–4800 BC (Early SBK) and raw materials are generally located at a great distance, which reflects the low frequency of tools found. From *c.* 4800 BC onwards (Lengyel), a marked change follows, with settlements very much located in the vicinity of raw material sources for polished stone tools, which is strongly reflected in the archaeological record. Subsequently, the distance from the sources increases slightly, which is statistically due to the occupation of a wider area. Settlements are more strongly oriented in relation to the period

3600–3300 BC (Boleráz phase), but this is not as pronounced in the occurrence of polished stone tools as during the Lengyel period.

Settlement continuity

The use of data from settlements defined by pottery traditions is not very suitable for the analysis of settlement continuity, as this division includes broad time categories and results in the appearance of often significant settlement continuity.

The first time period studied is artificially discontinuous, as we do not compare the data with the previous period (LBK). In the Thaya River basin (*c.* half of the entire Morava Basin), continuity between the Late LBK and the Early SBK is found for 37% of settlements (*Trampota 2015.138*).

Data classified by pottery groups (Fig. 15) show a higher proportion of continuously occupied sites in Bohemia than in the Morava Basin. In general, a higher proportion of continuously occupied positions can be observed when the number of known settlements is low; when population growth and/or settlement of new positions occurs, the proportion of continuously occupied positions is low.

TPI index

The structure of data is the same for pottery traditions and pottery groups. Values for most settlements in both regions are around zero, reflecting a preference for flat locations (Fig. 16). In the case of concave landforms (hills), a gradual transition to higher values is evident, especially in the Morava Basin, during the period of 4800–4400 BC (Lengyel), while in 3800–3400 BC (TRB) hilltop sites form a specific cluster of values (also less pronounced in Bohemia). Here the hillfort sites are separated, whereas in the earlier period hilltop settlement is not a defined category.

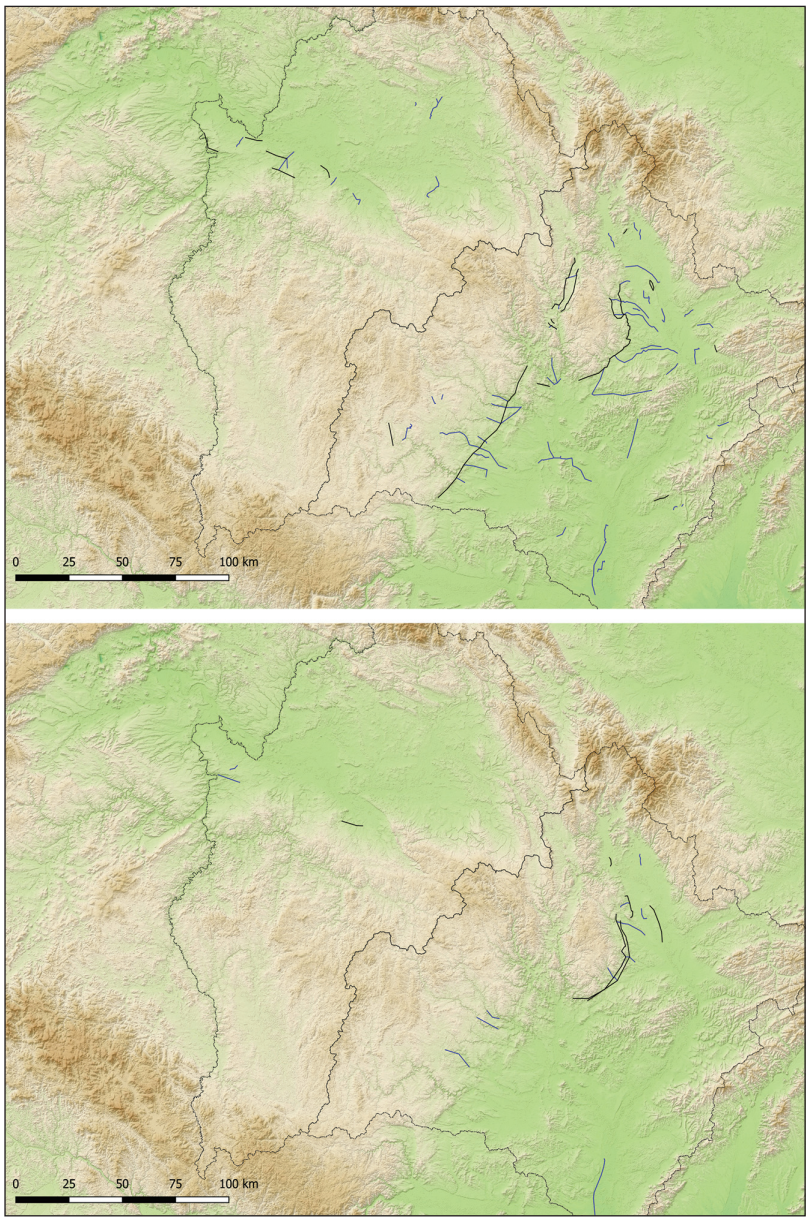

Fig. 12. An example of the linear arrangement of settlement sites during Late Lengyel (above) and during Boleráz (below).

Results of multivariate statistics

The similarity of settlement structures based on long chronology (Neolithic B and Neolithic C) were analysed using principal component analysis. All variables except settlement continuity and the hierarchical arrangement of sites were included in the analysis. However, the results did not yield significant differences that could be interpreted according to the significant factors, nor according to clusters of points (Fig. 17), which are more a manifestation of random arrangement. As a result, the settlement patterns defined by long chronology did not differ in principle, and reflected similar preferences for locations suitable for agriculture.

Discussion

Importance of individual variables

We evaluated the weight of each variable using the summed factor scores on the axes, which reflect 75% of the total variability. The number of axes varies, so the average value for each variable was calculated. From the results for the individual chronological classifications (Tab. 1), it is clear that the variables with the largest sum of factor scores are those that show great stability over time and do not change much. These are always the topographic position index and the settlements organized along terrain lines in Bohemia. In the Morava River catchment, these are also the topographic position index and the estimation of the kernel density of watercourses. These variables are therefore not very suitable for explaining the dynamics of settlement structures.

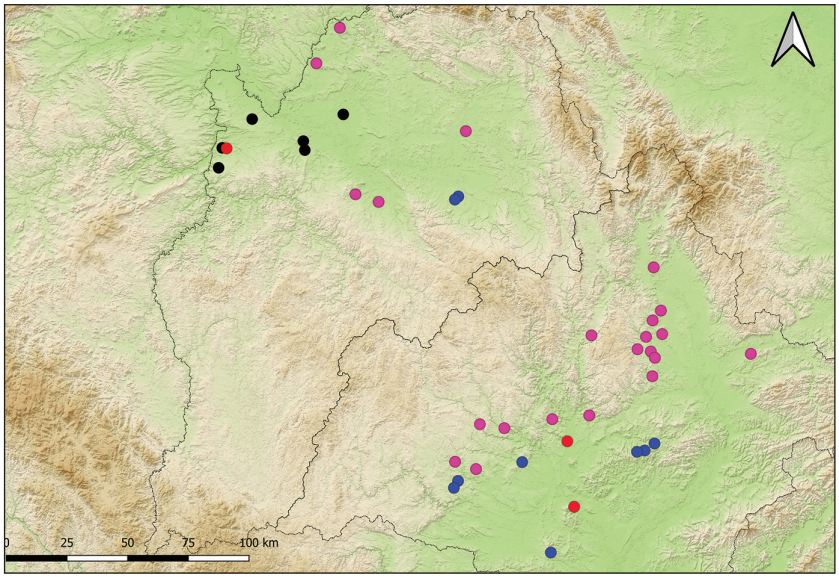

Fig. 13. Distribution of enclosed sites in the studied area. Red – Early SBK, blue – Lengyel, black – Proto-Eneolithic, pink – TRB. TRB enclosed sites are exclusively elevated, others lowland.

In contrast, variables that have the lowest sum of factor scores can be expected to have more variability and thus these variables may be important for understanding the organization of settlement structures at certain time intervals. A second possible explanation is then that they are generally insignificant. In Bohemia, these variables are mainly distance to sources of raw materials, especially chipped industry, and an estimate of the kernel density of settlements. In the Morava River Basin, distance to sources of raw materials of polished industry and altitude mainly have the lowest sum of factor scores. These two variables are chronologically highly variable in the Morava River Basin, while in Bohemia the variables with the lowest sum of factor scores have low explanatory potential.

Difference between settlement structures in two regions

Some of the observed variables are different in the two separate settlement regions and are important for understanding the unequal dynamics of the evolution of social organization, subsistence or lifestyle.

Analysis of the altitude of individual settlements reveals that areas up to 500m above sea level were commonly settled in in Moravia, whereas in Bohemia settlement was common only up to 350m above sea level, and only rarely at higher altitudes. This is not due to different geomorphological conditions, but another factor. A possible demarcation of settlement areas between Neolithic and Mesolithic populations comes into consideration, which leave archaeological traces on a limited scale. Parallel coexistence between Late Mesolithic and Neolithic populations in Bohemia can be considered in the context of Bohemia rather than in the Morava River Basin.

region	variable	r
B	tpi	0.2895
B	line_terrain	0.2648
B	hydro	0.2548
B	altitude	0.2276
B	slope	0.2109
B	settlements_kde	0.2078
B	line_water	0.2053
B	rm_dist_polished	0.1888
B	rm_dist_chipped	0.1865
M	hydro	0.2661
M	tpi	0.2368
M	settlements_kde	0.2348
M	slope	0.2177
M	rm_dist_chipped	0.2128
M	altitude	0.2029
M	line_terrain	0.2010
M	rm_dist_polished	0.1934
M	line_water	0.1931

Tab. 1. Table with the sum of factor scores of individual variables. The resulting value is the average value against the number of axes expressing 75% variability.

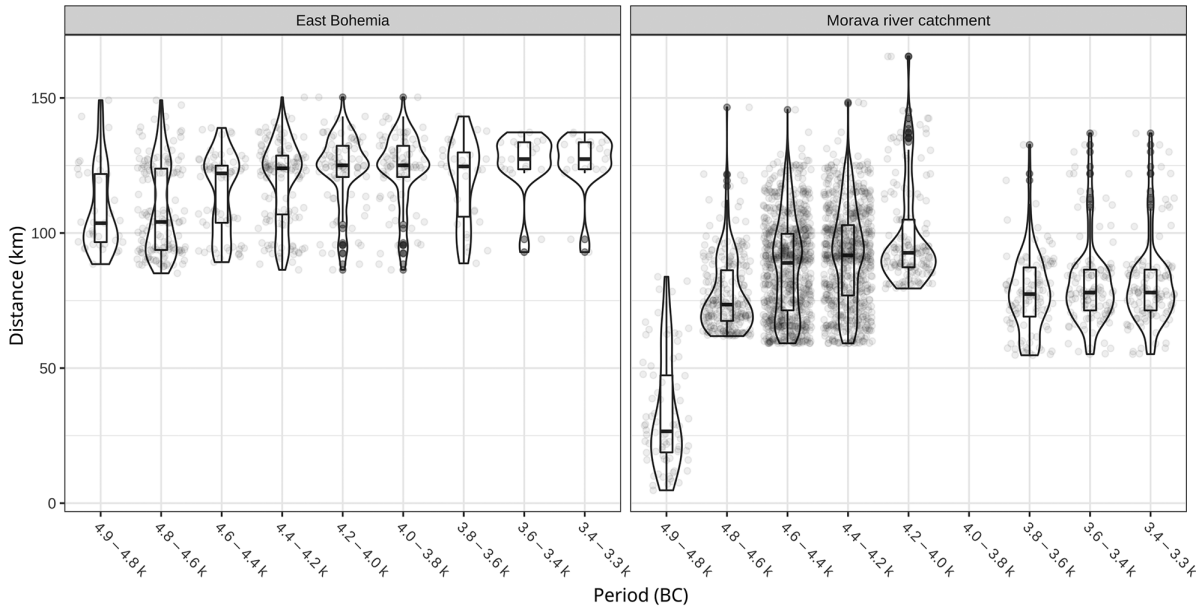

Fig. 14. Violin plot with distance between settlement sites and used lithic raw materials in individual periods. Data are classified according to pottery groups.

This is consistent with the relatively large number of known Mesolithic sites in Bohemia (*Čuláková 2015.Fig. 10.10.3*). In contrast, the number of Mesolithic sites in the Morava River Basin is very small (*Svoboda 2008; Oliva 2018*) and the chronological coexistence of the two distinct populations is unlikely. As such, in terms of the spatial extent of Neolithic settlement, the fact that the Morava River Basin experiences the most extensive settlement during the Neolithic in agricultural prehistory, which was only surpassed in extent after 1000 AD, is crucial. The situation is just the opposite in Bohemia. The Neolithic settlement area here occupies a relatively small area, which only increases significantly with the onset of the Bronze Age (*Demján* et al. *2022.Fig. 10*). David Graeber and David Wengrow (*2021.262–263*) explain the rapidity of the Neolithic colonization of central Europe by the absence of human settlement. This colonization stopped mainly before the coastal areas, which were strongly occupied by Mesolithic populations. Whether we can draw a similar conclusion for the absence of Neolithic settlements in parts of Bohemia, especially in the south, is uncertain.

In our case we observe the secondary consequences of this colonization, which do not differ substantially in their extent from the original situation during the LBK.

Another important variable is the sources of stone raw materials. Jizera Mountain-type metabasite played an important role at the beginning of the studied period in Bohemia, but after 4800 BC there was a reversal, with the production of polished stone tools dominating quantitatively from sources in south Moravia, around which settlements were heavily concentrated.

In the eastern part of Bohemia, local sources were never used to a great extent for the production of chipped tools, and the vast majority (silicite of glacigene sediments) came from Silesia or Saxony, an area separated by mountains. On the other hand, especial-

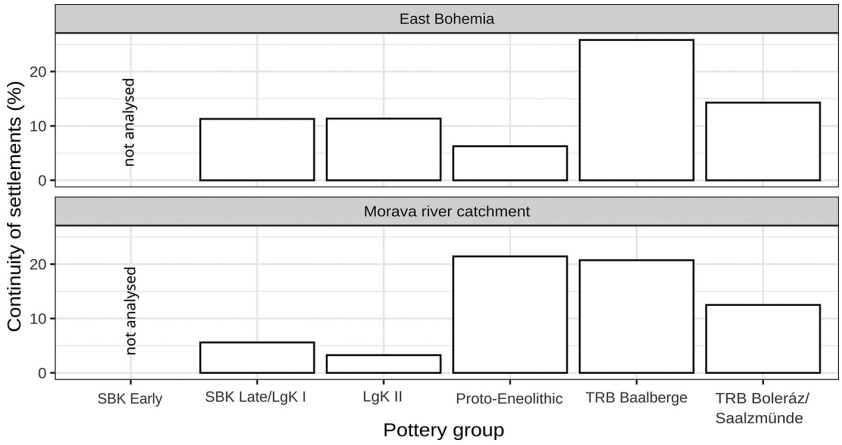

Fig. 15. Bar plot expressing share of continuity of settlement activities in relation to previous chronological phase.

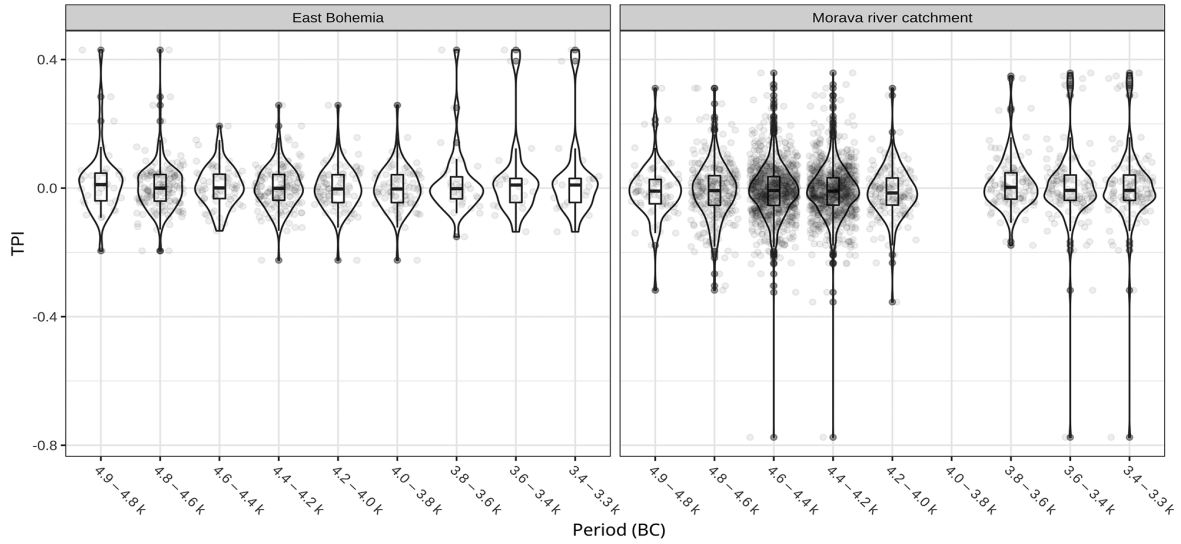

Fig. 16. Violin plot expressing values of TPI index. Positive values express the position of sites on concave shapes of the landscape (hills), negative values on convex shapes of the landscape (valley).

ly in south Moravia, the sources of chipped stone industry were mostly part of a densely populated area, which was reflected in the quantity of their exploitation. The Epi-Lengyel period, when settlements were generally concentrated at a great distance from the exploited sources, is a significant deviation from this. This may indicate that stone artefacts were of low socio-economic importance at this time.

Another significant difference is the dynamics of settlement, which took place in different ways in the two regions. In Bohemia, settlement reaches its peak in the context of the Late Stroked Pottery (*c.* 4800–4500 BC), whereas in the Morava Basin it is not until the Late Lengyel (*c.* 4500–4300 BC). It follows that to understand the lifestyle of each society, it is necessary to study each region separately, and the lifestyle of Neolithic people cannot be generalized by similarities in symbolic expression using 'archaeological cultures'.

The relationship between settlement site and slope gradient in the two regions follows a broadly similar pattern according to the expected population dynamics, which we estimate based on the frequency of the occurrence of radiocarbon dates combined with the number of settlement sites. In periods when we record low population density, mainly flat sites are occupied, while in periods of the estimated highest population density, sloping sites are also occupied.

Pottery style as a social identity indicator?

During the period under study, both areas are characterized by one decorative style, but there are exceptions. In central Moravia, there was in 4800–4600 BC a small cluster of settlements characterized by the Late SBK, while in the area further south there was dense settlement characterized by Early Lengyel pottery (Fig. 8).

Towards the end of the studied period, the settlement of the Čáslav Basin in central Bohemia is characterized by Boleráz pottery, with settlements with Saalzmünde pottery concentrated especially around Prague (Fig. 10). In both cases, the two groups with different symbolic styles are separated by an uninhabited or very sparsely inhabited area. In the results of the statistical analysis of settlement structures, apart from spatial location, these groups do not differ. This reflects the similar nature of lifestyle or subsistence, but in the social dimension there is an obvious geographical distance.

A distinct form of the relationship between two different decorative styles existed especially in the Morava Basin (and other parts of Lower Austria) in 3800–3400 BC, when Funnelbeaker pottery is often found in contexts together with Retz-type pottery (also known as *Furchenstichkeramik*). These two styles, completely different in vessel morphology and decoration, are not territorially exclusive but directly intertwined. While the Morava Basin is the south-eastern periphery of the distribution of Funnelbeakers, pottery of the Retz type is most often found in the western part of the Carpathian Basin.

Two different examples of the spatial occurrence of the different pottery styles thus illustrate the ambiguity of its interpretation.

Evolution of Neolithic settlements

The evolution of Neolithic settlements was clearly dynamic. The rate of change of settlement structures was greater than the change of symbolic systems – 'archaeological cultures'. A weakness of the presented study of settlement structures is the fact that we frame the development of settlement structures on the basis of the development of particular pottery styles. While the pottery style is the most appropriate descriptor of settlements from a quantitative point of view, its disadvantage is its interval nature, which may not capture the other possible and even more rapid dynamics of the development of settlement structures. Nor can it be used as a prism to consider whether the transformation of settlement structures occurred gradually or in leaps. With the number of settlements analysed, it is not realistic at present to have a series of radiocarbon dates that would define the probabilities of the beginning and end of most settlements.

Conclusion

In this article, we have analysed the relationships between Neolithic settlement sites and the environment. The research covered a total of 2153 sites from two separate areas, the eastern half of Bohemia and the Morava River Basin for the period of *c.* 4900–3400 BC.

The two separate settlement regions studied differ fundamentally in their characteristics. What is striking is the different chronological development of the number of settlements, which in the Morava River Basin correlates relatively well with the long-term development of the frequency of radiocarbon dates, whereas in Bohemia only the development of the number of settlements can be relied upon at present. The two regions differ in the extent of settlement, with the Morava Basin being extensively settled, while the eastern half of Bohemia is only sparsely settled compared to later phases of prehistory. The two regions differ markedly in their access to raw material sources for the production of chipped and polished stone tools. In the Morava River Basin, the importance of amphibole diorite and porphyritic microdiorite for the first mass production of axe-hammers is particularly evident in the significant concentration of settlements around the source area.

The chronological evolution of most of the variables studied can be seen as proxy information of population dynamics. The evolution of settlement structures does not correlate with archaeological cultures, but

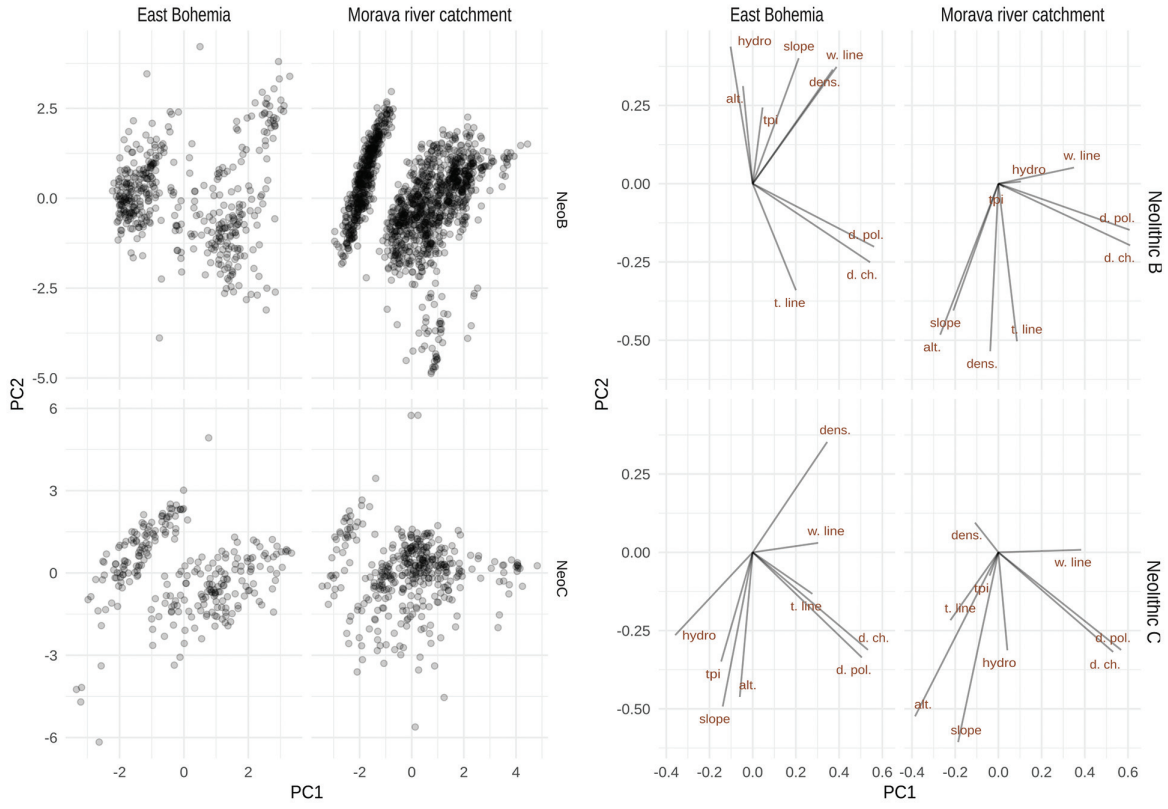

Fig. 17. Result of principal component analysis on two main axes, data are classified based on long chronological segments.

greater dynamics can be observed. The information found can be generalized to the European level by stating that the Neolithic had an insular character, the dynamics of the settlement development of each region is specific, and to understand the lifestyle of the people it is necessary to study these regions separately.

While it is not relevant for the Neolithic to work with the question of centrality in terms of individual sites, broader regions can be understood in this way. In this respect, these are defined by dense and long-term settlement, whereas the periphery is only heavily populated at the population maximum. In the Morava Basin, the central area can be defined as primarily the eastern edge of the Bohemian Massif, while Outer Subcarpathia and the Vienna Basin can be understood as Neolithic peripheries. In Bohemia, then, the central areas are the right bank of the Elbe in the upper reaches and the wider area of the left bank in central Bohemia.

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Disuse of spaces and discard of artefacts during the abandonment of Erimi-*Laonin tou Porakou*

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ABSTRACT – *The aim of this paper, starting from the analysis of the assemblage and stratigraphy of the unburned rooms, is to analyse the possible discard and disuse processes during the planned and gradual abandonment at Erimi-*Laonin tou Porakou *(Cyprus). Scholars note how the decision to leave objects when a place is abandoned depends on multiple factors, from functional reasons to ritual practices. At Erimi some markers suggest a possible intentional closure treatment of parts of the site in which it is possible to recognise a mix of functional and symbolic abandonment behaviours.*

KEY WORDS – *abandonment; discard processes; artefacts; Bronze Age; Cyprus*

*Opuščeni prostori in odvrženi artefakti med opustitvijo Erimi-*Laonin tou Porakou

IZVLEČEK – *Namen tega prispevka, ki sicer temelji na analizi artefaktnih zbirov in stratigrafiji nepožganih prostorov, je študij procesov morebitne neuporabe in zavrženja med načrtovano in postopno opustitvijo naselja Erimi-*Laonin tou Porakou *(Ciper). Raziskovalci ugotavljajo, da je odločitev o tem, katere predmete pustiti, ko kraj zapuščamo, odvisna od različnih dejavnikov, tako utilitarnih razlogov kot obrednih. Na Erimiju nekateri označevalci kažejo na mogoče namerno zapiranje delov mesta, v katerih je mogoče prepoznati mešanje funkcionalnega in simbolnega vedenja med zapustitvijo.*

KLJUČNE BESEDE – *opustitev; procesi zavrženja; artefakti; bronasta doba; Ciper*

Introduction

All architectural remains and associated objects are conditioned by abandonment processes (*Tomka, Stevenson 1993.191*), which affect the related structures, activity areas, whole settlements or regions, and are caused by various factors (*Cameron 1991; Cameron, Tomka 1993; Lightfoot 1993*). Excluding rapid and unanticipated abandonments, due to natural disasters or enemy attacks, these processes are often planned. Settlements are therefore transformed by a sequence of practices and behaviours that entail the decision to leave behind or transport to the new site artefacts and, in some cases, building materials (*Schiffer 1972; Schlanger, Wilshusen 1993. 91*). Factors that influence this decision are the degree of preabandonment planning, the distance from the new settlement, the capability and means of transport, the activities foreseen in the next location, the season of movement and ritual practices (*Cameron 1991.172; Cameron, Tomka 1993; Deal 1985; Lange, Rydberg 1972; Lightfoot 1993.166; Schiffer 1972.160; 1985; Stevenson 1982*). In many cases, places return to be lived in cyclically, involving the recovery and reuse of objects and building materials (*Schiffer 1985.27*). This phenomenon causes a significant loss of information related to the previous stages of life and the disuse episodes of an area.

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Planned abandonments are often gradual (*Cameron 1993.4*), and it is fundamental to recognise the pre-abandonment behaviours to investigate the reasons, possible length and socio-political and economic processes behind the decision to leave a place (*Nelson 2000; Schiffer 1976.33; Stevenson 1982*) in order to define the moment of change that is always linked to an abandonment (*Nelson, Hegmon 2001*). What is commonly found – when abandonment dynamics are not distorted by scavenging or resettlement – is the result of a choice, influenced by functional and ritual practices. In order to define various type of deposits and their transition from the systemic to the archaeological context, scholars have identified eight different formation processes of the floor assemblage (*Schiffer 1985.24–30*; see also *Hayden 2000*). The conditions of objects, their location in the rooms, the possible practice behind the discard of them and finally the moment in which they were discarded (prior, during or after the abandonment of the settlement) characterise these different processes (*Schiffer 1985; Iannone 1990; Hayden 2000.300*).

The aim of this paper is to present an analysis on the discard practices and gradual disuse of some units of the workshop complex (area A) during the abandonment phase of Erimi-*Laonin tou Porakou* at the end of the Middle Bronze Age on Cyprus (*c.* 1650 BC). The transition from the Middle to the Late Bronze Age (MC III-LC I) has been defined as a moment of change and a first step to the urban society of Cyprus (*Crewe 2017.140*). This transformative period entails the abandonment of a series of villages left in various conditions and following different practices. Abandonment studies on prehistoric Cyprus could provide information that would help us to better define the social changes which characterise the period, and also fill the related gaps on the study of this phenomenon in prehistoric settlements.

The site of Erimi-*Laonin Tou Porakou*

Erimi-*Laonin tou Porakou* (Limassol district) extends over an area of *c.* 1.20ha on the upper slopes of a natural hill located 250m above sea level. The general topography of the site is characterised by a hilltop surrounded by a series of lower terraces sloping southward and eastward (*Bombardieri 2017; Amadio* et al. *2021.302*). The settlement presents two main areas organised in roofed units carved approx. 0.60–0.70m into the bedrock and open spaces (Fig. 1). The workshop complex (named area A) develops on the top of the hill and a residential area (areas B, T2-T5) is located on the first lower terrace, while a massive wall divided the settlement from the cemetery (area E) (*Christofi* et al. *2015*).

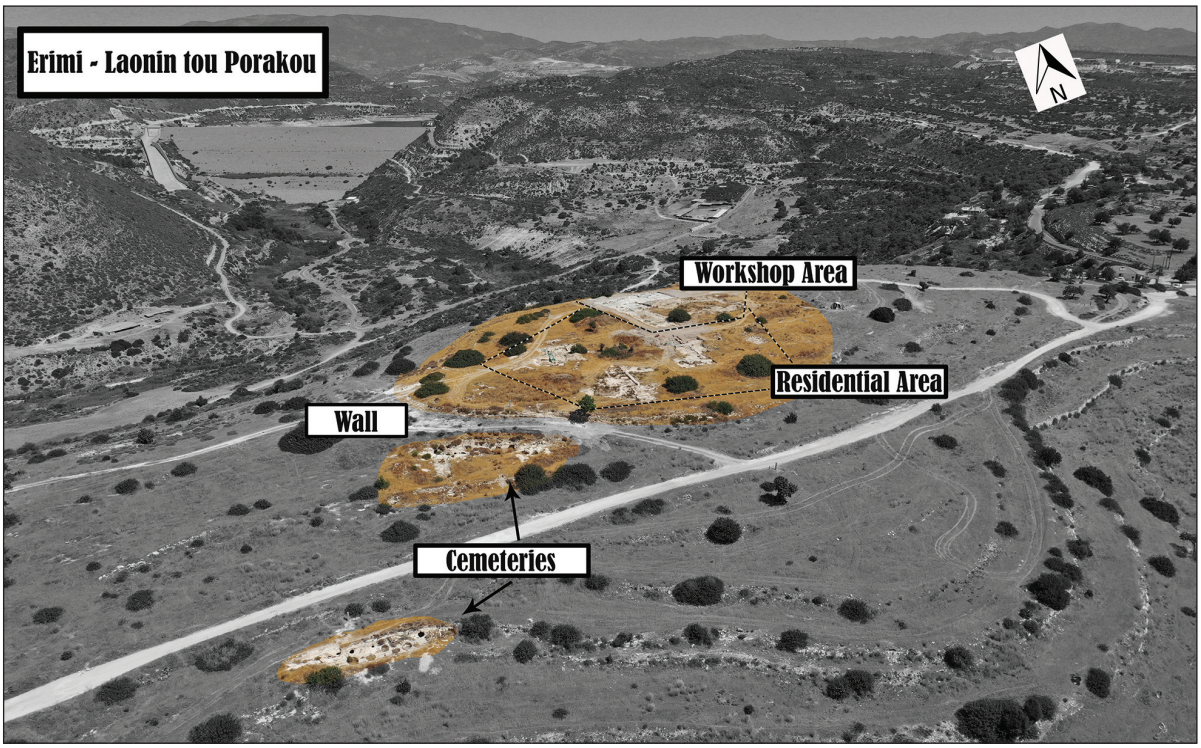

Fig. 1. The site of Erimi*-Laonin tou Porakou *(elaborated by the author; archive Erimi archaeological project/Italian archaeological mission in Erimi, Cyprus).

The position of the productive area (workshop, named area A) in the upper flat plateau and the peculiar layout of its rooms permitted the conservation of the majority of objects in their context of primary deposition, saving them from washout and other post-abandonment formation processes. At the same time, the use of the area for cultivation partially destroyed the upper layers of stratigraphy. In contrast, the residential area was subjected to considerable erosion and soil movement by natural agents and slope wash. Due to its position, the accumulation of soil partially saved walls and structures from destruction or massive reuse of building materials in post-abandonment periods (*e.g.*, areas B2 and T2). In addition, frequentation of the area during the Hellenistic and Roman periods could be noted (*Bombardieri* et al. *2009.134–138*).

***Refuse types at Erimi*-Laonin Tou Porakou**

Archaeological investigations suggest a planned and gradual abandonment of the settlement. While some units were discovered empty of objects, most of the still usable artefacts were concentrated in a group of rooms. Finds were recovered sealed on the floors by the collapse of roofs and walls, in some cases accelerated by a fire. The rapid destruction meant that these rooms were not used for resettlement or massive reuse in post-abandonment periods and, thanks to this possible closure practice, this can provide a precious opportunity to analyse the site's last phase of life.

Abandonment studies stress the recurrence, in various areas of the world, of a deliberate use of fire to voluntarily destroy structures or part of a settlement. This action would be performed by those who lived at a place at the end of a sequence of practices linked, in most cases, to funerary rituals (*Cameron 1990; Lindskoug 2016; Schiffer 1985.29; Schlanger, Wilshusen 1993; Verhoeven 2000; Wilshusen 1986.246*). In addition, other cases of destruction by fire are represented by unexpected natural catastrophes or enemy attacks, and by sites which were affected by closure practices performed by the inhabitants (*Cameron 1991; Chapman 1999; Lightfoot 1993; Stevanović 1997*).

Some evidence seems to suggest that the case of Erimi-*Laonin tou Porakou* belongs to the last group. No human skeletal remains sealed by the collapse of structures as a result of catastrophic disaster have been found, and no signs of scavenging or any attempts at rebuilding activities can be detected at the site (*Amadio* et al. *2021.312–313*). Moreover, the concentration of some artefacts in specific units, and the presence of a sequence of functional practices, such as the possible recovery of building materials from disused spaces, as well as possible ritual practices made before the fire, can support this interpretation. Analysis in this paper are focused on the assemblage and stratigraphy of the unburned units with the aim to describe a sequence of functional practices during the abandonment phase at Erimi.

In order to define the abandonment behaviours, and the transition of artefacts found in the rooms from the systemic to the archaeological context (following *Schiffer 1985.24–30; La Motta, Schiffer 1999; Hayden 2000.300*), objects have been divided into three different categories:

- *De facto* refuse refers to objects still usable which were left behind at the time of the abandonment. Michael B. Schiffer (*1972.160*) defines these as "*elements which reach archaeological context without the performance of discard activities*".
- Primary refuse refers to artefacts left in their location of use or in proximity to their original position (*Schiffer 1972.161–162*).
- Secondary refuse refers to objects discarded anywhere other than in their location of use (*Schiffer 1972.161*), about which Hayden (*2000.300*) noted: "*this is refuse that has been cleaned up and removed from its primary use or manufacturing context and dumped elsewhere, usually in designated refuse areas*".

It is worth specifying that even if they will be used as guidelines in the present work, these categories are not universal but conventional. For example, in the case of the stone tools in the depositional history of stone artefacts at Maki-*Alonia*, David Frankel and Jennifer M. Webb (*2012.480*) distinguished expedient tools (*de facto* refuse), described as still intact objects, discarded at or near their location of original use after a short use-life, from curated tools (normal refuse) that they define as objects that spent a long period in the systemic context and were discarded "*in or near their context of final use when damaged, broken, near exhausted, or exhausted*". Moreover, Arthur A. Joyce and Sissel Johannessen (*1993.138*) stated that primary and secondary refuse disposal, prior or during a gradual process, must be seen as abandonment refuse. As noted by Schiffer (*1985*), the identification and categorization of these different kinds of refuse, particularly concerning pottery, is difficult, but in the case of Erimi-*Laonin tou Porakou* it is possible to suggest a dis-

tinction based on the particular conservation and distribution of some assemblages of artefacts. In the workshop complex some *de facto* refuse, mainly represented by ground stone and vessels, was discovered. Despite being still usable and in good condition, these items were still left in the buildings, suggesting functional motivations, such as difficulties in transport due to the large size and heavy weight of the artefacts, behind their abandonment (*Villani, Tripodi, under submission*). At the same time, some rooms returned artefacts which it is possible to define as primary or secondary refuse (Figs. 2 and 7). They represent objects at or near the end of their use-life (*Joyce, Johannessen 1993.138*). The presence of artefacts broken before the collapse of the structures (*Webb 2017.187–191; Dionisio 2017.341–343*), modified or reused for a secondary function, such as some ground stone (see *Webb 2017.214–215; McCartney 2017.253–256*), repaired (*Dionisio 2017.336*; see *Dooijes, Nieuwenhuyse 2009*) or with traces of macro use-wear (*Bombardieri* et al. *2017.250*) suggests that they were left in the proximity of their original positions or displaced and discarded because they were both easily replaceable and almost at the end of their usefulness (*Tomka 1993.22*; see also *Frankel, Webb 2006.226–232; Webb 2006*). As noted by scholars, when secondary refuse had some potential value, it was usually concentrated in provisional discard, until the reuse of the items or their displacement to a permanent dumping location (*Joyce, Johannessen 1993.139; Deal 1985.253*; see also *Wilson 1994* and *Tani 1995.234–235*). Frequently the inhabitants of the settlement use abandoned structures for this type of refuse (*Seymour, Schiffer 1987.554*). To conclude, the presence of primary and secondary refuse – *e.g.*, a broken *pithos* recovered in unit SA IIa with the upper part in the centre of the room and pieces of the lower part near the north-western corner (*Bombardieri 2017.45, Fig. 3.41*), or a group of objects (in the small room SA X) which it is difficult to correlate with the place where it was found – suggests a particular function of some rooms during the gradual abandonment of the site. An in-depth description of the assemblages, and the possible identification of some artefacts as *de facto*, primary or secondary refuse, will be provided in the following paragraphs.

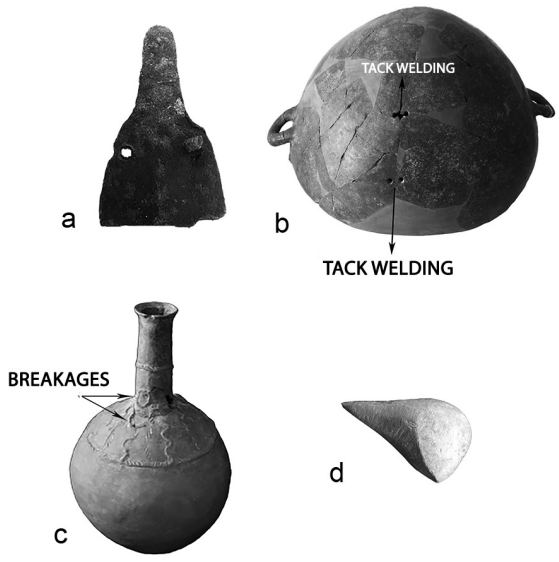

Fig. 2. Examples of refuse recovered in room SA IIa.* a *broken bronze knife (A.423.1);* b *large bowl with repair in antiquity (A.516.18);* c *jug with ancient breakages (A.434.8);* d *picrolite with traces of macro use-wear (A.342.95) (readapted from* Bombardieri 2017*).

Artefacts from the workshop complex (area A)

The objects found in the workshop units are terracotta vessels (in part destroyed by the collapse of the structures, as accelerated by the fire), ground stone tools and small objects like spindle whorls, worked and unworked ornamental artefacts made of picrolite, loom weights, bronze knives and chipped stones (*Bombardieri 2017.219–250*).

Several studies have shown that the distance from the new settlement, the capability and means of transport, the artefacts' size and weight and the presence of repairs or damage, tend to influence the choice to leave an object (*Schiffer 1976; Schlanger, Wilshusen 1993.91–92*). In the case of Erimi-*Laonin tou Porakou*, some of the above motivations can justify the abandonment of the larger vessels and of the *pithoi* found *in situ*, often supported by stone emplacements (like in units I, IIa, III, IV and XII). A similar explanation can be applied for the querns (discovered in burned and unburned units) and for the heavy or easily replaceable stone tools in general. At the same time, the presence of a number of transportable objects such as ceramic vessels (which in some cases have few signs of use-wear and do not show repairs or breakages), spindle whorls, bronze blades (two of which have been recovered, of which one is broken and the other almost complete), loom weights and worked picrolite artefacts (in particular, two pendants), suggest the possible decision to abandon some still usable artefacts before setting fire to the area. The units containing concentrations of artefacts were totally or partially destroyed by the fire, while the others returned few objects and appear to have been partially dismantled and cleaned out (Fig. 3). The ten exca-

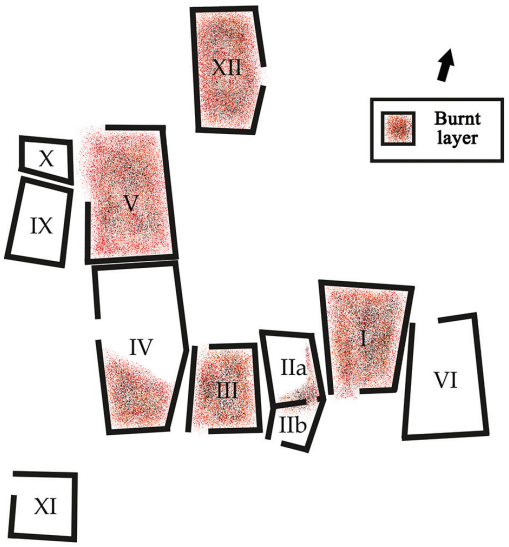

Fig. 3. Rooms investigated in the workshop complex of Erimi-*Laonin tou Porakou *and the distribution of the burnt layer (elaborated by the author).

vated units of the workshop complex are characterised by a similar layout, since they were carved in the bedrock and share walls with the adjacent buildings.

The result is an area with contiguous roofs, connected as if they were only one. In this respect, it would be very hard to stop the burning of the roofs to limit the fire only to those units where the artefacts were concentrated in a phase of use of the entire area. In addition, stratigraphic analyses show evidence for the presence of possible intentional ignition points employed to feed the flames in units SA I and SA III (*Bombardieri 2017.276*), while a specific treatment seems to have been reserved for unit SA V, where the fire started from the roof (*Amadio* et al. *2021.311–313*).

The unburned units

The outermost units investigated in area A, namely units SA VI, SA IX, SA X and SA XI, are those that partially surrounded the rooms affected by the fire. When compared with the burned spaces, these rooms have yielded few artefacts and no *pithoi* were found on the floor, while in SA X only a spindle whorl was discovered. Scholars have hypothesised that in case of planned and gradual abandonment the areas near living spaces could become discards, and that when people know that a place will be left they tend to reduce the standard of cleaning (*Schiffer 1985.25; Stevenson 1982.247–248, 252*). Unit SA VI (6.5m x 3m) is the easternmost roofed space in the southern wing of the workshop complex and has the same NE–SW orientation as the adjacent units, but it was carved at a lesser depth of 0.50m into the limestone bedrock (*Bombardieri 2017.52*). This room yielded a small number of fragmentary artefacts, two medium-sized Red Polished (RP) jugs, two Drab Polished (DP) juglets, a small Red Polished (RP) bowl, a Coarse Ware (CW) mealing bin, a rubber and four chipped stone tools (*Bombardieri 2017.55*). Two fragmentary gaming stones, as noted by Luca Bombardieri (*2017.56*), were discarded in a previous occupation phase and reused as building material. The access from the north, the presence of few objects, the absence of *pithoi* or big storage vessels and its multiple phases of construction and occupation, suggest that the use of this space has probably been changed several times (*L.c.*). In the contiguous unit SA I, which shares the perimeter walls with SA VI and SA II, three possible ignition points were found. It is therefore arguable that, if a fire occurred during the last phase of use of SA VI, its roof would be affected by the fire. However, the absence of a burnt layer – as recovered in the adjacent unit – and the few artefacts found on the floor, make it possible to hypothesise that this space was dismantled and consequently disused before the deliberate burning of SA I. SA IX is a small annex of SA V. In this unit only fragments of vessels and ground stone tools were found, and no evidence of *de facto* refuse can be observed. The room appears to have been filled with clay, while in the last phase of use a small structure has been built near the eastern limit, on the top of a pre-existent basin. This feature has probably been disused and filled before the burning. Indeed, no ashy deposits have been noticed in the filling of the basin, which additionally appears to have not been covered by the layer of plaster which constitutes the floor of SA IX. Worth noting is the case of unit SA X, where the presence of different layers of limestone blocks associated with ceramic sherds could confirm its intentional filling and disuse in an early stage of the abandonment phase.

In summary, these units returned few artefacts, mostly interpretable as primary or secondary refuse, and the proximity to the burned rooms suggests the loss of their function at the beginning of the workshop's dismantling. Having presented the overall picture, the next section analyses in detail the disuse of the unburned unit SA X.

Unit SA X

Unit SA X is a small space (3.35m x 3.10m) located in the north-western part of the workshop complex,

lacking a well-defined entrance and interpreted as an annex of SA V. The stratigraphic sequence was characterised by the presence of three different layers of limestone blocks (more than 130 of various sizes) associated with ceramic sherds (most of them are bowls with less than 1/3 preserved, and found in all the filling layers) suggesting a deliberate deposition, especially if compared with the lower number of limestone blocks discovered in the largest units of the same area (Fig. 4). At the same time, the unit does not show traces of ashy layers, which would have surely been identified if the burning of SA V occurred during the use of SA X. The assemblage found on the floor was composed of two partially worked picrolites, a spindle whorl, two fragmentary vessels, three chipped stones, a quern (at an early stage of use or not used), a hammer and more than 300 ceramic sherds. It is difficult to establish *a priori* that all these objects belong to a specific category of refuse, but the small dimensions of the space, the absence of a defined entranceway, the heterogeneity of the assemblage and its casual disposition on the floor, suggest an unspecialized function. It is therefore possible that objects found on the floor are secondary refuse discarded in the unit when it was disused.

It is interesting to note that SA X returned one of the highest dimension/sherds ratios of the whole workshop (*c.* 35 sherds for m^2), but only few attributable to the same vessels. These data and the presence of sherds in all the filling layers suggest that the concentration could be related to the practice of cleaning the units still in use, and when people knew that the site would be left and there was no need to redeposit the refuse elsewhere it accumulated here. This hypothesis could support its final treatment as a discard, particularly for building materials.

The burned units

At Erimi-*Laonin tou Porakou*, major concentrations of artefacts were found in the larger units SA I, SA II (in both sub-units, A and B), SA III, SA IV, SA V and SA XII. Only five of the ten rooms investigated in the workshop complex – units SA I, SA III, SA IV, SA V and SA XII – were directly affected by a fire, which partially reached the contiguous unit SA II (*Bombardieri 2017.46*).

This first macro evidence suggests a gradual spatial reduction in the use of the workshop, with a progressive transformation of some units into discard rooms destined to be filled with no longer usable artefacts. Therefore, if some objects appear to have been discarded because they had been consumed, exhausted, damaged or were easily replaceable, still usable objects seem to have been intentionally concentrated in the room whole or partially affected by the fire. These units yielded the highest number of portable artefacts, some of them in good condition, such as the pendants from SA I, SA IIb and SA XII, the spindle whorls recovered from all the units excluding SA IIa, the bronze blade from SA XII, and numerous loom weights and some vessels found in this area. Interestingly, not all these objects can be attributed to the common typologies, as in the case of the decorated RP biconical spindle whorl (*Bombardieri* et al. *2017.219–236*) and the RP goat-shaped *askos* from unit SA III (*Bombardieri 2017.49*). Among the burned units, only one returned a rich assemblage without showing the massive ash layer or the presence of possible intentional ignition points observed in some of the other rooms. This peculiar situation is represented by unit SA II, the assemblage and stratigraphic data of which will be analysed in the following section of this paper, with the aim to define its possible (dis-)use and final treatment during the abandonment phase of the workshop area.



Fig. 4. Unit SA X before and after the archaeological investigation. On the bottom (left side) are shown the blocks removed from the room (archive Erimi archaeological project/Italian archaeological mission in Erimi, Cyprus).

Unit SA II

Unit SA II, located in the southern part of the workshop, was underwent a change in layout during phase A, when the position of the opening which connects the two sub-units (named SA IIa and SA IIb) was modified (*Bombardieri 2017.38–39*) (Fig. 5). Some easily transportable and still usable artefacts were found in the smallest SA IIb (*Bombardieri 2017.43–46*). Particularly intriguing for the analysis of the abandonment discard processes is the larger sub-unit SA IIa.

The stratigraphic analysis revealed the absence of possible ignition points, in contrast to the contiguous SA I and SA III, while an ash layer was recorded only near the perimeter of the room with a particular concentration along the east and south walls (*Bombardieri 2017.46*). The assemblage discovered on the floor of SA IIa was composed of a high number of artefacts (35 from phase A; Fig. 6). The state of preservation of most of these objects is fundamental to define the role that this space played during the abandonment phase of the settlement. Regardless of the preservation of vessels – which in this work includes all the diagnostics fragments without distinction, from almost complete to not restorable – the majority of them can be ascribed to the more common ceramic classes found at the site (see *Webb 2017*). As noted by scholars, local items are more likely to be left at the time of the abandonment (*Tomka 1993.22; Joyce, Johannessen 1993. 150*).

Contemporaneously, they present a bad state of preservation: the RP large bowl, for example, is the only almost complete vessel found at the settlement with a repair (*Dionisio 2017.336*), while the large *pithos* located near the northern limit of the unit was found crushed on the floor, with the upper part unbroken in the centre of the room (Fig. 7). Moreover, the DP spouted jug was broken in antiquity, and presents a small hole of 5mm on the body (*Bombardieri 2017.41; Webb 2017.187– 191*), the only almost complete vessel – despite a high level of fragmentation (*Dionisio 2017.341, Fig. 15.15*) – found in the room without repair or breakage is the amphora (*Webb 2017.197*). Other vessels are composed of a few fragments, such as a mealing bin in Coarse Ware or a cooking pot. Residual artefacts are represented by three picrolites (one broken, one unfinished and one with signs of macro use-wear from a post-phase A layer), a broken axe (a third preserved), a broken, very heavy pounder (1.9kg), a broken chipped stone and two reused objects (a broken pestle transformed into a pounder with extensive use damage, and a broken perforator made from a reused gloss crescent) (*Bombardieri 2017.43*). Furthermore, the unit yielded one of the only two bronze knives discovered in the settlement, broken near the junction between the blade and the handle (*Bombardieri* et al. *2017.247*). Interestingly, one of the more representative artefacts of Erimi, that is to say spindle whorls, was not found in unit SA IIa.

The room returned few partially complete artefacts. Among them, only a complete quern was described as a *de facto* refuse "*in storage or active use into the unit*" (*Webb 2017.208*). Contemporaneously the ground stone shows various traces of use-wear (see Fig. 7; see also *Frankel, Webb 2006.227*) and, if we

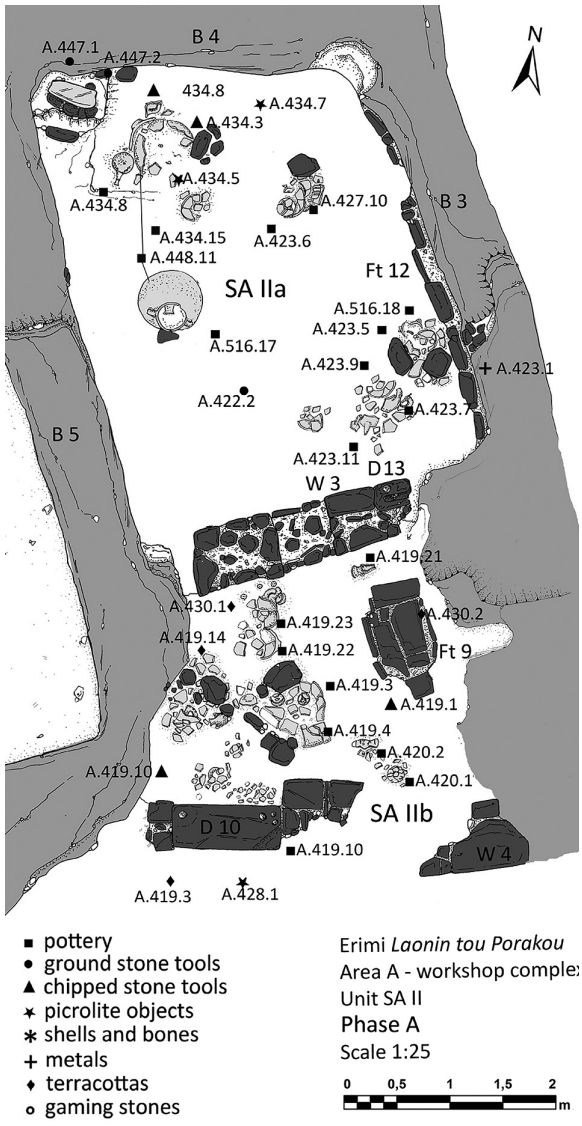

Fig. 5. The plan of Unit SA IIa with the location of the majority of the artefacts (readapted from* Bombardieri 2017.44, Fig. 3.37*).

Artefact	Broken	Secondary use/ unfinished/repaired	Macro use-wear	Fragmentary	Partially complete/ complete	Inventory
Amphora				x		A.423.19b
Axe	x			x		A.447.2
Bronze blade	x			x		A.423.1
Cooking pot				x		A.423.16
Cooking pot				x		A.423.14
Cooking pot				x		A.423.11
Core trimming element				x		A.434.3
DP amphora	x				x	A.423.7
DP amphora					x	A.423.6
DP hemispherical bowl				x		A.434.6
DP jug	x			x		A.423.9
DP spouted jug	x				x	A.434.8
Flake/blade bladelet		x			x	A.423.3
Jug or juglet				x		A.427.16
Jug or juglet				x		A.423.19
Jug or tankard				x		A.508.1
Mealing bin				x		-
Medium bowl				x		A.427.7
Perforator	x	x			x	A.427.14
Pestle	x	x	x		x	A.422.2
Picrolite		x			x	A.434.7
Picrolite	x	x		x		A.434.5
Picrolite			x		x	A.342.95
Pounder	x				x	A.423.2
Pyxides				x		A.427.11
Quern					x	A.447.1
RP decorated jug					x	A.516.17
RP hemispherical bowl				x		A.423.5
RP large bowl	x	x			x	A.516.18
RP large pithos	x				x	A.448.11
RP storage jar				x		A.434.15
Small bowl				x		A.427.13
Spouted jug or tankard				x		A.427.12
Spouted jug or tankard				x		A.427.10
Tool (Piéce esquillèe)		x			x	434.8

Fig. 6. Artefacts discovered inside unit SA IIa.

hypothesise that the room lost its function during the gradual abandonment, it could represent primary refuse left in the place where it was used. Almost all the other objects are fragmentary and show damage or macro use-wear, while the well-preserved bowl repaired in antiquity found at Erimi was recovered in this room. In addition, residual artefacts were found concentrated in the northern part of the unit and in the south-eastern corner behind the doorway. In the workshop complex, the only objects discovered near a threshold belong to unit SA IV (*Amadio* et al. *2021.316*), where four piled and complete vessels were found. In contrast, the vessels, the broken bronze knife and the heavy pounder recovered behind the entrance of SA IIa do not appear to be well preserved or placed in an organised manner. Moreover, a bin (Ft. 9; see Fig. 5) was built close to the entry that connects SA IIb and SA IIa during phase A, making it more difficult to move between these spaces. The presence of residual artefacts, the absence of possible ignition points and the construction of the bin seem to suggest the gradual disuse and transformation of this unit as a provisional discard. Almost all the objects concentrated in SA IIa could be then interpreted as primary and secondary refuse. At the site the reuse of broken or exhausted artefacts is attested by the presence of ground stones and gaming stones in the walls, by the reuse of a quern as a support for a mezzanine in SA III (Ft. 59) (*Bombardieri 2017.51, Figs. 3.53, 3.54*), and by the modified neck of an RP jug inserted in another jug neck and utilised in a double-chambered hearth (*Bombardieri 2017.36–37*). As stated by Michael Deal (*1985*), when the abandonment of a building complexpeople is foreseen and planned, refuse is accumulated in areas usually kept free and not concentrated into the generally designated areas. At the same time, Marc G. Stevenson

(*1982.248*) noted that in case of gradual abandonment refuse within enclosed living area "*will be more abundant and distributed in a more clustered or orderly manner*". Some scholars have also defined provisional discard as "*the intentional storage of damaged or fragmented items for future disposal*" or reuse that had high probability of being left at sites after abandonment (*Deal 1985; Cameron, Tomka 1993; Joyce, Johannssen 1993*; see also *Frankel, Webb 2006.153–154*). The decision to concentrate these objects in a single unit is thus possibly related to their potential value for reuse. In addition, Deal (*1985.263*; see also *La Motta, Schiffer 1999.21–22*) notes that "*if a structure was slowly being dismantled within an ongoing household it might become a dumping location for large inorganic items, and especially pottery*".

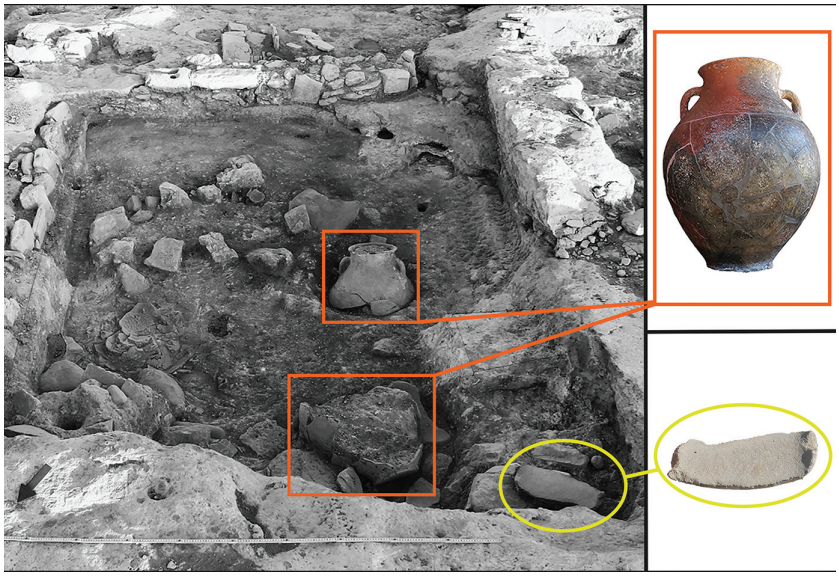

Fig. 7. The broken* pithos *(A.448.11), and the quern left on the bench (A.447.1) discovered in unit SA IIa (archive Erimi archaeological project/Italian archaeological mission in Erimi, Cyprus; readapted from* Bombardieri 2017.45, Fig. 3.41*).

In the chart, objects defined 'fragmentary' are artefacts for which only as most as a third of their entire body has been found (Fig. 8).

It is important to note that the majority of these consist of only few fragments. In the category 'partially complete (with breakage or macro use-wear)' we have included vessels and other objects interpreted as possibly broken before the collapse of the structures (*e.g.*, the *pithos*, the axe, one of the picrolite items or the bronze knife). It is interesting to note that only 14 of the 35 artefacts are complete or partially complete, of which only three are not characterised by breakage or secondary use. As mentioned above, in unit SA IIa burned deposits seem to occur mainly on the east and south walls and only along the perimeter of the room (*Bombardieri 2017.46*). The absence of a layer of ash, indicating the collapse of the roof, and the discovery of the intact upper part of the *pithos* in the centre of the room seem to indicate a partial dismantling of the roof prior to the fire. In this respect, Swiny interpreted the presence of collapsed roofs at Sotira-*Kaminoudhia* as further evidence of its rapid abandonment, caused by an earthquake, noting that serviceable beams are retrieved when structures are voluntarily abandoned (*Swiny 2003.53*; see also *Horne 1993; Schlanger, Wilshusen 1993.90–95; Stevenson 1982*) (Fig. 9).

Moreover, unit SA IIa seems to share disuse processes similar to those seen in the unburned units SA X (dismantled and filled with stones) and SA IX (filled with clay). In SA IIa the abandonment of the quern is possibly related to its weight, as confirmed by the presence of heavy querns and other ground stone tools left or discarded on the floors of other units of the workshop (*e.g.*, SA III, SA IV, SA X and SA XII). The large dimensions and difficulties in transport could also explain the decision to leave the largest RP decorated jug, while the discovery of the *pithos* deserves a more detailed examination. In contrast to

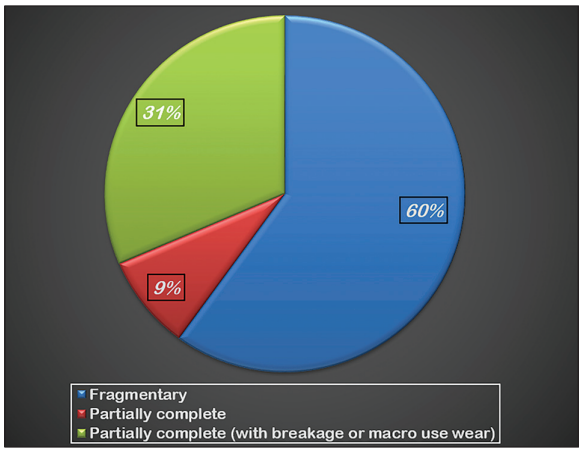

Fig. 8. Conditions of artefacts discovered in unit SA IIa.

what is observed for other units (*Bombardieri 2017.53, Fig. 3.57*), this vessel does not appear to have been crushed *in situ* by the collapse of the roof. Its upper part, in fact, was found separated from the body in the middle of the room, suggesting that it was already broken before the unit's collapse. If, in other units, most of the *pithoi* represent *de facto* refuse still usable until the destruction caused by the fire, the *pithos* from SA IIa could be primary refuse, crushed on the floor and abandoned before the collapse of the unit. As suggested by Muti (*2020. 200*), *pithoi* could be moved from their location to get rid of their contents, and the particular breakage and fragmentation of the *pithos* in SA IIa suggest that it was broken upon such displacement (*Bombardieri 2017.45, Fig. 3.41*).

Smaller and easily movable objects would probably have been curated in SA IIa on the basis of different criteria. On the one hand their bad state of preservation would make them not useful in the new settlement, on the other they would have been still usable in case of extreme necessity. At the same time, the absence of an ashy layer homogeneously distributed inside the room can suggest a partial dismantlement of the roof. The absence of beams, in fact, could force the creation of possible ignition points in SA I and SA III aimed to burn and destroy the two non-contiguous spaces. It is impossible to define if the ignition points were created to burn the rooms or if they represent a concentration of wooden materials which were destroyed by the fire. The absence of wood inside unit SA IIa could be related to the displacement of usable materials in rooms in use until the end of the site occupation. This space provided further elements in support of the planned abandonment without anticipated return. In the case of a planned return, the discard of objects would not have been occurred in the interior of one of the units and, as noted by Stevenson "*less refuse would be discarded within enclosed living areas*" (*Stevenson 1982.260*). Finally, it is important to note that SA IIb, the smallest unit (6m^2) of the workshop complex (*Bombardieri 2017.38*), returned portable artefacts that were still usable (specifically a pendant, six spindle whorls and some small vessels) and does not show traces of massive ash layer, as well as SA IIa. The concentration of burned debris near the partition wall between SA IIa and SA IIb and the massive presence of artefacts suggest that a particular final treatment was reserved for this unit. The absence of an ash layer could be due to the room's layout, since the unit has partially been carved in the bedrock (approx. 0.30m), possibly facilitating the dispersion of ash. In addition, some of the objects appear to have been destroyed by the collapse of walls and roof. The limited concentration of ash near the southern limit of the unit (*Bombardieri 2017.46*), close to the wall that divided SA IIa from SA IIb, might be related to the presence of a roof only in the smaller sub-unit IIb at the time of the fire.



Fig. 9. A typical Cypriot building after the partial dismantling (photo by A. Villani).

The residential area

Particularly interesting for the abandonment processes is area B, which brought to light a complex sequence of changes in the layout of some domestic units (Fig. 10).

The last sub-phase A1 is characterised by a reduction in terms of use of space, with the dismantling of unit 7 and the construction of a wall to close the passage to unit 6 (*Bombardieri 2017.70*). As in the case of Marki-*Alonia*, where Frankel and Webb (*2006; 2012. 488*) identified nine different phases, it is possible to define changes, renovations and modifications in the layout of the rooms. Since the reduction of dimensions occurred during the last sub-phase, the residential area seems to have experienced a gradual

and planned disuse, as noted for the Erimi workshop. At the same time, the excavation of area T2 revealed a possible 'atypical' disuse practice reserved for two contiguous doorways that give access to two distinct units. During the abandonment of these spaces, the thresholds would have been surmounted by monolithic blocks put on the short tight side, possibly testifying to the symbolic isolation of the internal from the external space of the building (see *Garwood 2011*). The peculiar disposition of the monolithic blocks suggests an action more related to an abandonment behaviour than a change in the layout of the spaces. The blocks, in fact, are isolated and not included in a possible new structure, while the passage in front of the thresholds was not closed. A similar practice appears to be represented by the threshold D3 of unit 3 in area B which, during the passage from phase A2 to A1, changed its use and was transformed into a large square basin. In this case, the decision seems to suggest a change in the layout of the unit and not its final abandonment (*Bombardieri 2017.65–70*).

Abandonment processes at Erimi-*Laonin tou Porakou*

This paper has highlighted the contribution that a cross analysis of the stratigraphy and artefacts' assemblages could provide to explain the treatment reserved for the rooms of the workshop area during the gradual abandonment of Erimi-*Laonin tou Porakou*. Ethnoarchaeological studies have shown that when the process is gradual and planned, abandonment often occurs through a differential treatment of the spaces (*Rothschild* et al. *1993*). The site was then partially disused and dismantled, and the inhabitants selected and concentrated still usable artefacts in units that were finally set on fire. Studies on discard processes in Bronze Age Cyprus note that part of the households or the alleys were used to concentrate refuse or to discard obsolete objects (*Frankel, Webb 2006; Falconer, Fall 2014.174–176*). Due to the particular layout of the workshop, with most rooms not connected by internal passages but only through open spaces, it is possible to suggest that some units lost their productive role and were gradually dismantled, while SA IIa became a sort of provisional discard, a place to concentrate objects not useful but possibly reusable in case of extreme necessity. As noted by Frankel and Webb in the case of Marki-*Alonia*, vessels with flaws have been "*maintained for use in a limited or secondary capacity or in provisional discard awaiting mending, reuse or removal*" (*Frankel, Webb 2006. 153*). Unburned units would have been disused and partially dismantled, while in some burned rooms a set of artefacts in still usable condition has been curated. This hypothesis can also be confirmed by the comparison of the ratio between entire vessels and sherds. As noted by some scholars, rooms abandoned in an earlier phase tend to show the presence of a high number of sherds but few complete artefacts. In contrast, spaces which were disused in a later phase seem to show the opposite (*Montgomery 1993.157–159*; see also *Schiffer 1985.23*). In this respect, no well-preserved vessels were found in SA X, but it returned one of the highest proportions of sherds found in the workshop. In addition, unburned spaces seem to be related to unspecialized functions due to their smaller size and the limited presence of features, an aspect that could justify their final treatment and the exclusion from the possible deliberate burning (see *Joyce, Johannessen 1993.151*).

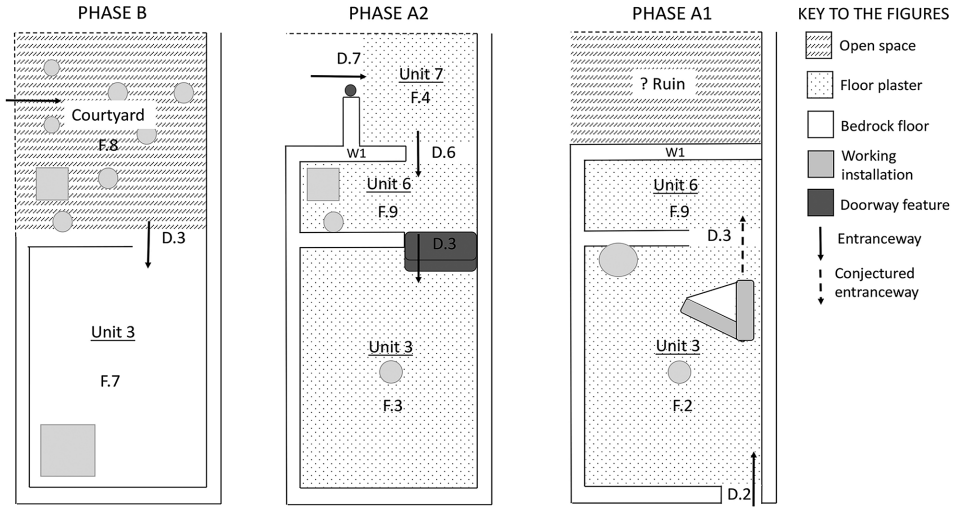

Fig. 10. Reconstruction of the renovations layout in area B (*Bombardieri 2017.70, Fig. 3.87*).

At the workshop of Erimi, the gradual and differentiated treatment of spaces could reflect the decision to intentionally seal some rooms as part of the abandonment strategy. The deposition of some objects, their location and concentration are markers of specific choices, often related to the burial of members of the community or, in other cases, to possible detachment rituals before leaving structures or settlements. As demonstrated by several ethnoarchaeological studies and experimental archaeologists, a structure could burn for days before collapsing (*Cameron 1991.162; Gheorghiu 2019.30–47*; see also *Stevanović 1997*), and the inhabitants would have had the possibility to recover at least some objects. At Erimi, however, the absence of any attempt to retrieve artefacts and the presence of possible intentional ignition points seem to confirm the decision to voluntarily seal the objects inside the units. At the same time, different studies have highlighted how the distance from the new settlement influences the decision to take or leave an object (*Schlanger, Wilshusen 1993.90–91; Schiffer 1985.26–33*). Taking into account the empty units of Erimi alone, we could hypothesise that the new site could have been in close proximity, entailing the transport of most of the artefacts to the new settlement. If we exclude possible ritual or symbolic practices, the assemblage of the burned units suggests the opposite scenario, a longer distance and the abandonment of artefacts caused by functional motivations. Deeper analysis on almost complete or fragmentary artefacts – and particularly vessels – will be fundamental to define the real quantity of still usable objects left in the site.

Nevertheless, the sequence of the gradual abandonment processes, from the reduction and disuse of some spaces to the burning of part of the workshop, seems to confirm that the selection, location and concentration of some portable and often still usable artefacts depended on specific and voluntary decisions, influenced by different motivations. Scholars have often defined abandonment as a strategy following practice determined by local populations, as well as local and regional conditions (*Schlanger, Wilshusen 1993.85*; see also *Nelson, Hegmon 2001. 213*). The conditions in which the site was abandoned and the possible foundation of a close, new settlement seems therefore to be ascribed to a wider social phenomenon that involved the island of Cyprus at the end of the Middle Bronze Age. Suggesting a gradual and pre-planned abandonment in the case of the Bronze Age site Marki-*Alonia*, Frankel and Webb (*2006.153*) stressed how some rooms returned complete or restorable vessels while in others the absence of artefacts could depend on different motivations, from the curation to episodes of renovation, which could have affected some rooms.

At Kissonerga-*Skalia* Crewe noted a decrease in the activities that would have produced a slow abandonment of the site (*Crewe 2017.146*), while the presence of intact artefacts and skeletal remains at Sotira-*Kaminoudhia* has been interpreted as a rapid abandonment caused by a seismic event (*Swiny 2003.53–54*). Even at Kalopshida, the presence of a burned layer in the house of trench 3 and in the room 7 of site C combined with the rich assemblage found on the floor suggests a rapid abandonment (*Åström 1966.139–140; Gjerstad 1926; Webb 2012. 52*), while Swiny noted that the absence of certain typologies of objects at Episkopi-*Phaneromeni* could be related to curating behaviours due to the short distance from the settlement G to A (*Swiny 1979. 330*). At the same time many artefacts were left *in situ* when settlement G was abandoned (*Swiny 1979.15*). Therefore, excluding cases of rapid and not anticipated abandonments, the choice to leave the settlement through a planned and gradual process could have been based on social and economic motivations. At Erimi, finally, the voluntary destruction of part of the workshop and the particular location of the partially complete artefacts in some units, seem to reflect the specific way in which the inhabitants decided to detach from their place (see *Lamoreux-St-Hilaire, Macrae 2020*), performing a voluntary closure (see *Adams 2016; Cameron 1990*).

Conclusions

The data presented in this paper, combining an analysis of artefact refuse with the study of the abandonment practices performed at the MBA site of Erimi-*Laonin tou Porakou*, provide interesting information. Some spaces were cleaned out and the objects were probably progressively put in the compounds still in use and then taken away at the end of a gradual abandonment. Some units were disused, partially dismantled and transformed in discard areas; contemporaneously, some artefacts were concentrated inside the rooms then possibly set on fire. The workshop has likely been impacted by a series of symbolic practices, such as the decision to leave some artefacts inside the units as well as the deposition of the piled vessels in front of the entrance of SA IV, the concentration and location of artefacts inside the burned units, and the absence of attempts to recover the smaller objects during the fire. Finally, if in the rooms it is possible to distinguish arte-

facts as *de facto*, primary and secondary refuse, the differences in preservation, concentration and selection of artefacts from some burned units suggest that in some cases objects entered in the archaeological context possibly through symbolic depositions made before the burn. Elsewhere in Cyprus, the presence of artefacts has been interpreted as the result of a rapid process caused by natural disasters. In contrast, the abandonment practices performed by the Erimi's inhabitants resulted in the possible deposition of some artefacts, clearly suggesting some decision-making in this process.

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Zoning analysis of Iron Age sites using Analytic Hierarchical Process (AHP) methods in the Middle Atrak River Basin, Northeast of Iran

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ABSTRACT – *Iron Age settlements in the Middle Atrak Basin in Iran have a particular distribution pattern due to environmental, social, and economic variables, among which geographical factors play an essential role in creating and dispersing settlements. Some of these factors play a more effective and stable role than others. The present study examines and evaluates the role of geographical factors in the distribution of Iron Age sites to determine factors that have a more significant role than others. Moreover, the zoning map of the Middle Atrak Basin should be presented using four different types of location, grouped in terms of those with a perfectly suitable, relatively suitable, suitable, and unsuitable location. To achieve this goal, seven natural factors, including the distance of sites from the river, altitude, slope, slope direction, distance from communication routes, soil type, and land use, were selected as influential factors in choosing the location of the Iron Age sites. In this study operating maps were prepared digitally using ArcGIS, and then the weight of each index was determined using the AHP model. The results of this study show that 46.7% of the Iron Age settlements (or 28 sites) were located in a perfectly suitable environment and geography, 24 sites (29.3%) in a relatively suitable location, seven sites (11.4%) in a suitable place, and one site (1.6%) in a completely unsuitable environment. This last type of location in the region's landscape indicates the choice of different livelihoods, including agriculture and animal husbandry with both seasonal and permanent methods.*

KEY WORDS – *Iron Age sites zoning; Analytic Hierarchical Process (AHP); Middle Atrak Basin; Northeast of Iran*

Analiza coniranja železnodobnih naselbin z metodami analitično hierarhičnega procesa (AHP) v porečju srednjega Atraka, severovzhodni Iran

IZVLEČEK – *Železnodobne naselbine v porečju srednjega Atraka v Iranu imajo poseben vzorec umestitve zaradi okoljskih, socialnih in ekonomskih spremenljivk, med katerimi igrajo geografski dejavniki ključno vlogo pri nastanku in širitvi naselij. Nekateri od teh dejavnikov so bolj učinkoviti in trajnejši od drugih. V študiji predstavljamo najpomembnejše geografske dejavnike pri porazdelitvi najdišč. Karto poselitvenih območij srednjega Atraka predstavljamo s pomočjo štirih tipov lokacij, razvrščenih glede na popolnoma primerne, manj primerne, primerne in neprimerne pogoje poselitve. Pri tem smo kot ključne izbrali sedem naravnih dejavnikov: oddaljenost najdišča od reke, nadmorska višina, strmina, smer pobočja, oddaljenost od komunikacijskih poti, vrsta tal in raba tal. Digitalne karte smo izdelali s pomočjo programa ArcGIS in obtežili z indeksi, ki jih določa model AHP. Rezultati kažejo, da je 46,7 % železnodobnih naselbin (28 lokacij) umeščenih v povsem primeren, 24 (29,3 %) v manj primeren, sedem (11,4 %) v primeren in ena (1,6 %) v popolnoma neprimeren prostor. Zadnji tip lokacije kaže na izbiro različnih vrst preživljanja, tako kmetijstva in živinoreje s stalno ter sezonsko poselitvijo.*

KLJUČNE BESEDE – *coniranje železnodobnih najdišč; analitični hierarhični proces (AHP); srednji Atrak; severovzhodni Iran*

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Introduction

Archaeological findings show that the development and evolution of past human settlements are closely related to the substrate of the natural and social environment. Environmental and natural substrates create the necessary conditions for establishing settlements, and some create more stable conditions than others. These natural substrates are each region's slope, altitude, geological structure, water resources, and climate. Each of these factors, both individually and in relation to each other, shows differences. The existence of such differences causes the characteristics of different regions (*Gholami Rad, Wali Shariatpanah 2013.56*). Humans have long tried to settle in the natural environment in such a way that makes the best use of it. In other words, human settlements act as the most basic link between man and the Earth, and reflect human interactions with the environment (*Zhang* et al. *2014*). Therefore, ancient societies lived in places that had favourable conditions for life and development – with environmental factors such as rivers, communication routes, and beds of deltas and river terraces along with foothills or mineral resources – which provided them with raw materials and the possibility of protection against enemies (*Magaš* et al. *2021. 21*). In addition to these cases, various other factors and forces are involved in the location and formation of rural settlements, which should be considered in any location of settlements. Although the effects of these factors and forces depends to a great extent on the underlying characteristics of the environmental substrate and ecological structures (*Zhang* et al. *2014.2818*), the primary stimulus in this process is the set of motivations that arise to meet basic needs, and the forms of various fundamental demands among different human groups. As such, different forms and varieties of locations, and the locating of human settlements in certain places because of the demands and motivations they are able to satisfy, are realized in different ways. As a result, settlements are structurally and functionally different from one area to another (*Rahimi, Hassanpour 2013.14*). For example, settlements formed in hilly areas are more affected by natural factors such as altitude, slope, and slope direction. In contrast, settlements formed in lowland areas are more affected by human factors such as communication routes and transportation, surface water networks (hydrography), and agricultural and cultivated lands (*Ma* et al. *2017.12*). Therefore, these factors affect the texture and body of the settlements and the ways of life of their people.

In this study we use several environmental variables and natural criteria, along with the Analytic Hierarchical Process (AHP) integrated with the Geographic Information System (GIS), for zoning and evaluating the Iron Age sites of the Atrak River Basin to determine: (1) What are the zones in the Middle Atrak? (2) Which of these basins were considered by Iron Age people? (3) What do the Iron Age sites in the different zones reveal?

Theoretical foundations

AHP is one of the most efficient multi-criteria decision-making techniques, and was developed by the mathematician Thomas L. Saaty (*1980*) in the late 1970s. One of the advantages of the hierarchical analysis method in the context of this study is that it can deal with the various factors that influence the location of human settlements. It prioritizes residential areas by weighting factors with pairwise comparisons (*Abdelouhed 2022.11*) and the impact rates of each of them (*Liao, Kao 2010.571*). AHP is an effective and helpful method for solving multi-criteria problems that use a hierarchical structure to show the problem, and a better way to solve such issues and prioritize different options based on user judgment. In other words, this method is used both in reality and theory in decision-making (*Toledo-Aceves* et al. *2011.975*). To be more specific, the ultimate goal of the AHP method is to determine the relative weight of each factor in a system (*Yao, Zhao 2022.17*). By solving decision problems, AHP allows researchers to focus on several criteria simultaneously and also allows decision-makers to compare quantitative and qualitative criteria (*Rodhiah* et al. *2021.197*). AHP is a multi-objective, multi-criteria decision-making approach that enables the user to reach priorities based on a set of options derived from three principles: parsing, comparative judgment, and prioritization (*Abdul Rahaman, Aruchamy 2017.3*).

The AHP method has three basic steps: (1) creating a hierarchy, which is the essential part of the hierarchical analysis process (*Cimren 2007.369*); (2) determining the importance coefficients of variables and criteria using pairwise comparison methods; (3) assessing the consistency of judgments according to the percentage of consistency (*Saaty 1980.287*).

As discussed above, AHP can be used for relative measurements by pairwise comparison of criteria and data, or measurement of data according to criteria and variables. Ranking mode and preferences

include a pairwise comparison of criteria according to purpose. Ranking levels and preferences – such as excellent, very good, good, average, poor, and very poor – are then determined for each criterion. In the next step, pairwise comparisons are made between the ranking levels of each criterion to obtain a set of priorities (weights) for these levels. For each criterion, scaled weights are considered, and each option is assigned a ranking level and will be scaled (*Bahurmoz 2004.6*).

Materials and methods

This research was carried out using a descriptive-analytical method to consider the issue of land suitability and its analysis with regard to settlement selection. Accordingly, after collecting the required information and also reviewing the status of the Iron Age settlements in the Middle Atrak Basin, using AHP and going through the steps in ArcGIS – including entering variables and criteria, preparing informa-

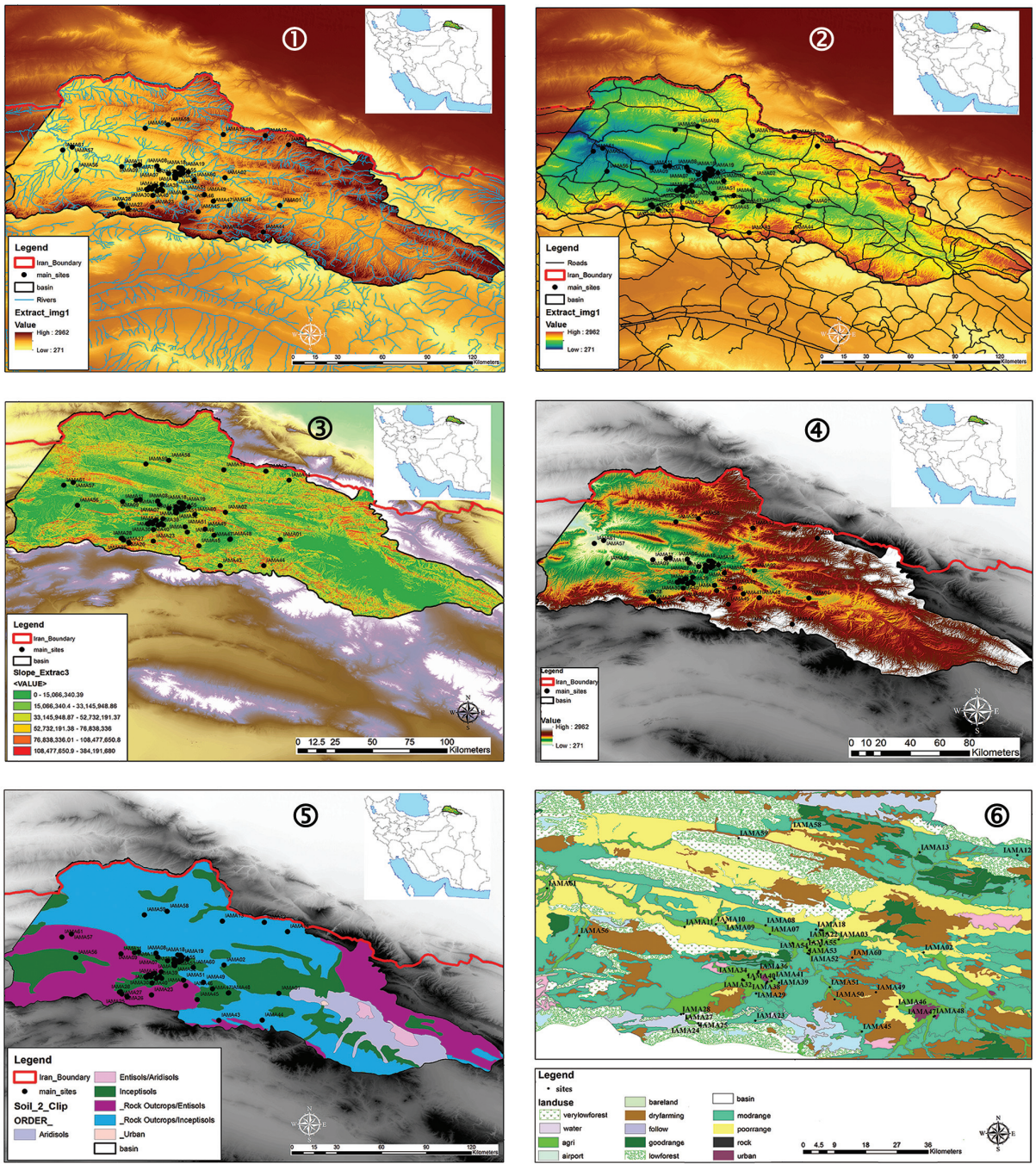


Fig. 1. Maps of the locations of Iron Age sites with regard to environmental factors.* 1 *distance of sites to water sources;* 2 *distance of sites to communication routes;* 3 *degree of slope;* 4 *height above sea level;* 5 *location of the site on soil type;* 6 *land use.

tion layers and new maps, classification and evaluation of variables, information layers and the combination of these layers – suitable locations for settlements were identified. Moreover, seven indicators – including distance from ancient sites to communication routes, distance from ancient sites to water sources, land use, altitude, soil type, slope direction, and slope degree – were used to identify suitable areas for settlement (Fig. 1). ArcGIS10 and AHP were used to prepare a database of the layers described above (Fig. 2).

Geography and ecology of the Atrak River Basin

Although there is no long-standing accurate climate record of the northeastern region of Iran for the Iron Age, studies by researchers have shown that, contrary to popular belief, there were stages of sudden climate change during the Holocene. There is a consensus that such phenomena are pervasive, and their results can be generalized to different parts of the world (*Hejebri Nobari* et al. *2021.298*). Towards the end of this period, especially from the beginning of the first millennium BC, the tendency of temperature changes tended to be colder (*Shaikh Baikloo Islam 2020.40*). The same cold and humid climate phenomenon are seen in all parts of the Tibetan Plateau (*Callegaro* et al. *2018*) and West Central Asia (*Fouache* et al. *2020.92*). The most recent long-term climate studies have been carried out near the study area of Jazmourian Playa (*Vaezi* et al. *2019*) and Hamoon Lake in Sistan (*Hamzeh* et al. *2016*), and the coast of Gorgan (*Kakroodi* et al. *2015*). The decrease in temperature caused the inhabitants of arid/semi-arid regions, such as north-central Iran (*Shaikh Baikloo Islam, Chaychi Amirkhiz 2020.40*), to adapt to the cold climate, in addition to agriculture. They also chose a nomadic-herding livelihood system, and a number of the areas covered in this article confirm this.

The Atrak basin, one of the largest water basins in northeastern Iran with an area of 33 890km^2, originates from the mountains of Hezar Masjed in the north of Quchan. About 26 500km^2 of this basin's area is located in the political area of Iran, and the rest in Turkmenistan (Fig. 3). The Atrak basin is bounded by Turkmenistan in the north, Gorgan and Kălshor basin in the south, the Qaraqum basin in the east, and the Caspian Sea in the west (*Noori* et al. *2011.160*). This basin consists of two parts, plains and mountains. Its climate is barren or continental. Rainfall is less than 200mm in the plains and up to 500mm in the highlands. The maximum altitude of this basin at the site of Tabărak River is about 2903m, and a minimum of 22m above sea level is estimated (*Sheikhvahed* et al. *2011.5*). The main waterway of the basin can be divided into three parts: upper, middle, and lower (border) Atrak. After crossing the plains of Quchan, Shirvan, and Bojnourd (Upper Atrak), the river continues its route in Măneh, Ghori Meidan, and Marăveh Tappeh, then runs to the border of Iran and Turkmenistan (Middle Atrak). After connecting to the Sumbar branch at the Chat site and forming the Border Atrak (Lower Atrak), it finally flows into the Caspian Sea. The study area includes the middle part of the Atrak River with a length of approximately 150km (the boundary between Rezaabad Gharbi and Sisab villages on the border of Shirvan and Bojnourd cities to Ghazan Ghayeh village

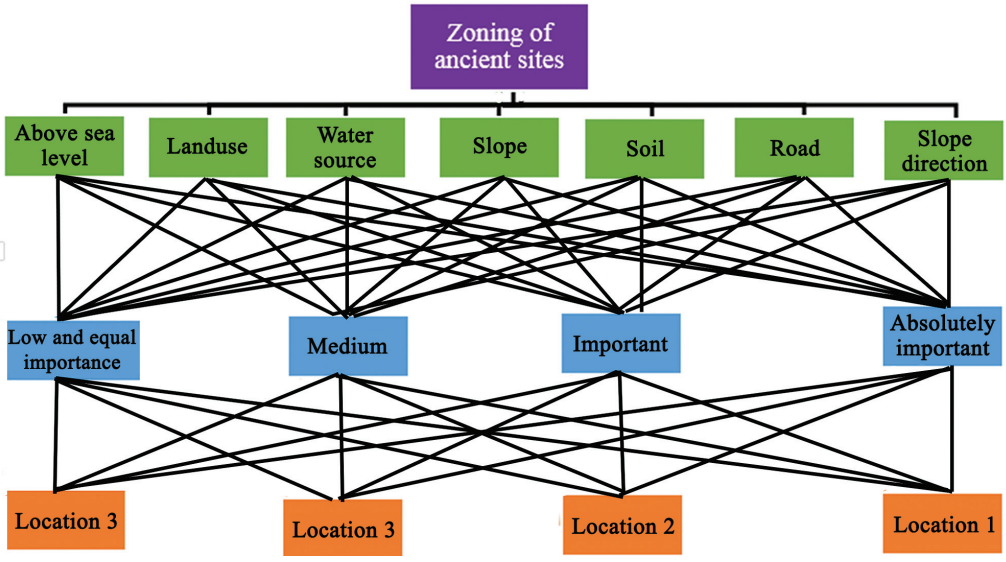


Fig. 2. The structure of the hierarchical analysis process used in the research.

on the border of Mane and Solmaghan cities with Maraveh Tappeh) (*Yamani* et al. *2010.4*).

The Middle Atrak Basin is geographically located between the Hyrkani Plain in the west and the land of Khorasan in the east. The high mountains of Alborz in the west separate it from Hyrkani, and the mountains of Kopeh Dagh in the north separate it from the Qarehqom desert. With the Aladagh-Binalood Mountains in the south, the Middle Atrak Basin is safe from the central desert of Iran. The not-so-high altitude set separates this basin from the upper Atrak valley, and such a situation has made the central Atrak basin a relatively independent and closed basin. This feature has a significant impact on the climate of this region, which is something between the humid climate of Hyrkani and the cold and dryness of Khorasan. The western parts of this basin, especially in the Solmaghan plain, sometimes find a climate similar to the Gorgan plain, such as in summer. Especially since the Aladagh Mountains, overlooking the Solmaghan plain, have a relatively dense forest cover. However, in higher latitudes (northwest of the central Atrak basin) this part is warmer and very poor in terms of vegetation and water resources, due to the impact of the Turkmen Sahra lowlands in the west on the one hand and the soil of the region on the other.

Background of archaeological research

The first archaeological activities in the area of the Middle Atrak were the studies and work of Faegh Tohidi, which led to the arena determination of some sites. However, the first scientific excavation in this basin was carried out on the Tape Qaleh Khan, which showed an extended sequence from the Neolithic to the contemporary period (*Garazhian 2011; Garazhian* et al. *2014; Garazhian, Askarpour 2018*). Exploration reports on the Tape Ashkhaneh Bimarestan (*Dana* et al. *2017; Dana, Hejebri Nobari 2018*), Tape Ashkhaneh Rivi (*Jafari, Thomalsky 2016*), and Tape Eshgh Bojnourd (*Vahdati 2014*), along with efforts to determine the area and boundaries of the tape Kalateh Mostofi Bojnourd (*Yazdani 2015*), Tape Bruski Ashkhaneh (*Adine 2012*) and Kohnekand Bojnourd (*Dana* et al. *2019*), have also been published with regard to this basin. However, studies of the cities of Shirvan (*Mirzaei 2008*), Bojnourd, Raz and Jirgalan (*Rajabi 2013*), Mane and Solmaghan (*Garazhian 2007; Ataei 2009; Zare 2011*) in this area have not been published yet.

Iron Age sites of the Middle Atrak Basin

In the study and identification work carried out in the Middle Atrak Basin, over 360 archaeological sites

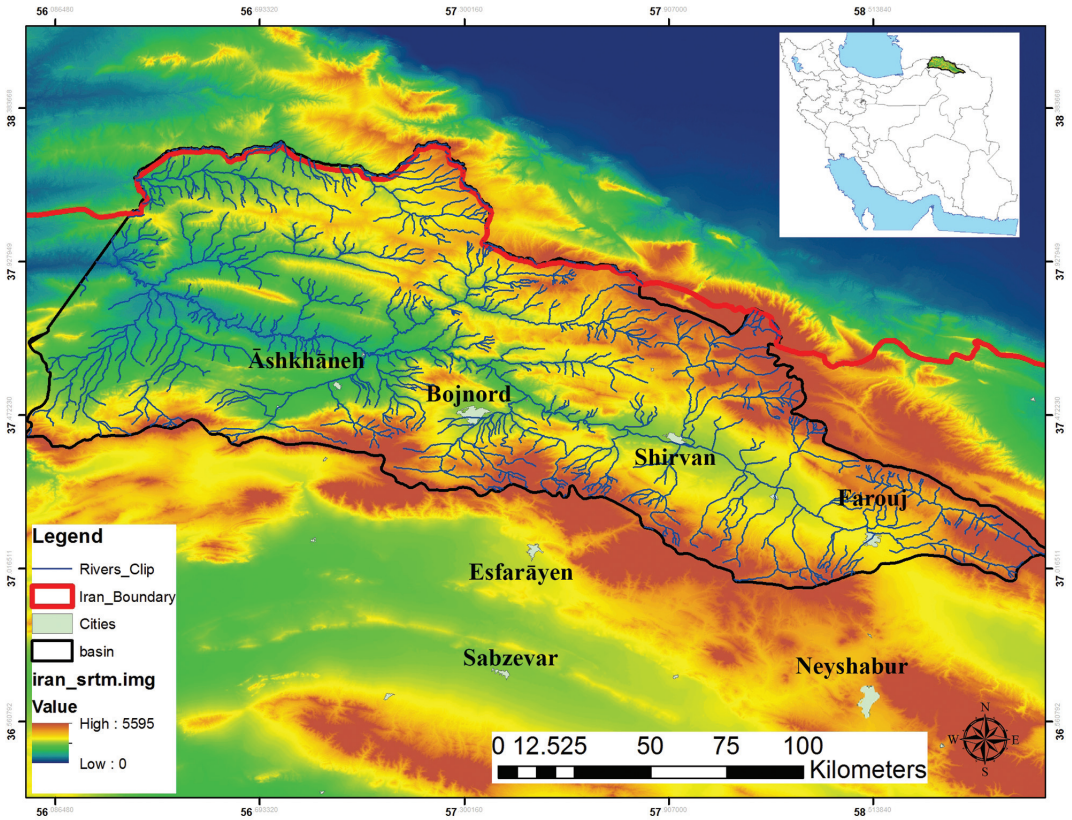


Fig. 3. Upper and middle Atrak River Basin.

from all periods have been identified. Seventeen sites have been identified in Shirin Darreh springs (a tiny part of Shirvan city), which are located in the middle Atrak area (*Mirzaei 2008*); 143 sites have been identified in Bojnourd city, which is completely located in the Middle Atrak Basin; 43 sites have been found in Raz and Jarglan city, about half of which is located in the Middle Atrak Basin (*Rajabi 2013*); and 160 sites have been identified and introduced in Mane and Solmaghan city, which are completely located in the Middle Atrak Basin (*Garazhian 2007; Ataei 2009; Zare 2011*) (see Table 1). Of these, 61 sites were inhabited during the Iron Age.

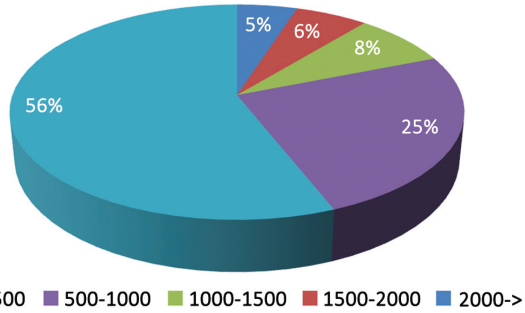
Environmental factors survey

Water resources factor

Human settlements are usually located where access to surface water is possible, and thus water is an essential factor in the emergence of human habitats and the most crucial factor in their growth and development (*Heydari Dastenaei, Niknami 2020. 316*). The land type and topographic status of each location significantly impacts water storage and flow. Accordingly, villages are established where there is enough water to meet the needs of the inhabitants (*Motarjem, Siasar 2017.58*). Atrak and its tributaries (Fig. 1.1), as a permanent and reliable water source, would be present many attractive locations in this regard. Suitable soil and altitude are also crucial for avoiding periodic or seasonal river floods when locating settlements. As shown in Figure 4, 80% of the Iron Age sites are located within 1000m from running water, indicating the connection between the ancient sites and water resources.

Communication routes factor

Communication routes are another essential variable in the formation of ancient sites, especially in the Bronze Age and beyond, when we see the formation of cities with long-distance and trans-regional trade relations in the Greater Khorasan region. In the past, ancient roads were usually built based on natural paths and systems of valleys and plains (*Hejebri Nobari* et al. *2021.301*), and this region follows this due to its mountainous nature. Communication routes in mountainous areas usually pass from the bottom of the valleys. What we have in mind today as a communication route is very different from what existed in the past. Before the creation of modern roads, people used gorges and the cuts caused by geological activity



to travel. Due to the mountainous location and the forested nature of the focal area, the only passable routes were inevitably the same cuts and the lengths of other valleys located between relatively high and steep mountains that were used as paths (*Vosogh Babae, Mehrafarin 2018.197*). This also applies in historical times, even in adjacent areas such as Dargaz, and historic sites have sometimes been formed adjacent to the main communication routes. This communication role is one of the essential factors in securing the economy of the inhabitants of these cities and rural areas (*Nami, Mousavinia 2019.239*).

There are 42 sites (69%) in the range of 0 to 1000m from the communication routes in this area, seven sites (11%) at a distance of 1000 to 2000m, eight sites (13%) at a distance of 2000m to 3000m, and four sites (7%) located 3000m or more from the communication routes (Fig. 5). Among these, only one site – Tape Dăshăd (IAMA60) – is located *c.* 9000m away from the communication routes. More than 70% of the sites are located at the bottom of the valleys, in the middle of the mid-mountain plains, and next to the communication routes (Fig. 1.2).

Slope degree factor

One of the influential environmental factors in the human settlement distribution system is the height and slope criterion. The slope is one of the essential factors in the transformation of land surface roughness (*Akbar Aghalli, Velayati 2007.48*), and thus it affects human life and activities such as agriculture, keeping livestock, and even some human settlements

Middle Atrak Basin based on city	Number of identified sites	Percentage of identified sites	Percentage of Iron Age sites
Shirvan	17	5	2
Bohnord	143	39	23
Raz and Jarglan	43	12	3
Mane and Solmaghan	160	44	72
Total	**363**	**100**	**100**

Tab. 1. Location of Iron Age Sites based on counties.

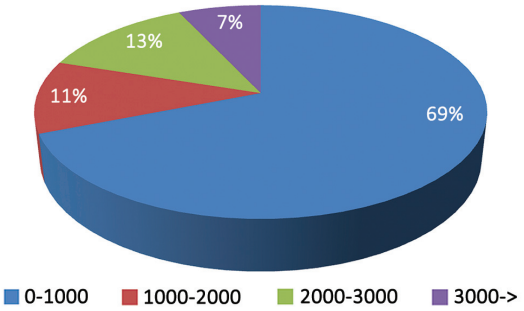


Fig. 5. Distance of sites from communication routes.

on the slopes either directly or indirectly (*Zomorrodian 1995.25*).

The degrees of the slopes in the region were classified into nine separate groups. The lowest slopes (0–5 degrees) were determined as the first group, and the highest slopes were classified as group 9. Since the best slope for establishing human habitation is a slope of 0–10 degrees (*Anabestani 2011*), we examined the location of the sites on the slopes. The slope degree of the location of ancient sites is an essential factor that affects the area due to its economic impact. Among the sites of this period (Fig. 1.3) 18 (28%) were on slopes of 0–5 degrees, 20 sites (32%) on slopes of 5–10 degrees, 12 sites (18%) on slopes of 10–15 degrees, and 14 sites (22%) on slopes of more than 15 degrees (Fig. 6).

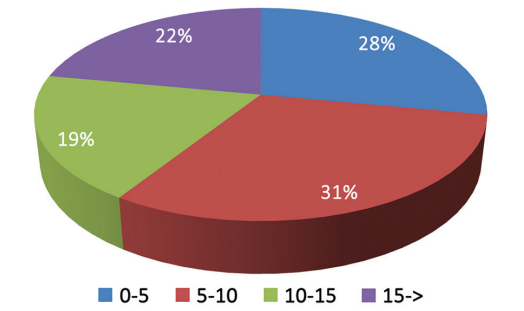


Fig. 6. Percentage of ancient sites based on their slopes.

Altitude from sea level factor

Altitude from sea level can cause climate changes and, consequently, changes in lifestyle and some climatic features (*Qazanfarpour* et al. *2013.129*). In addition, it directly affects ecosystems, vegetation, animals, and livelihood choices (*Duckstein* et al. *1973.22*). The central Atrak region's sea-level altitude varies between 226m and 2962m. The location of the sites in terms of altitude (Fig. 1.4) shows that about 60% of the sites are located at an altitude between 226m to 819m above sea level (Fig. 7). In this region, the average annual rainfall in meteorological stations is about 250mm, which is suitable for rainfed cultivation. However, it should be noted that despite the appropriate rainfall and altitude, the soil type is also crucial for cultivation. Sufficient rainfall and humidity at altitudes of about 600m above sea level and above allow optimal rainfed cultivation (*Kirkby 1979.Tabs. 83–84*). However, the annual rainfall is a more critical factor for rainfed cultivation. The minimum annual rainfall suitable for rainfed cultivation is about 200mm (*Adams 1981.12*), indicating that this area is suitable for rainfed agriculture due to having more rainfall.

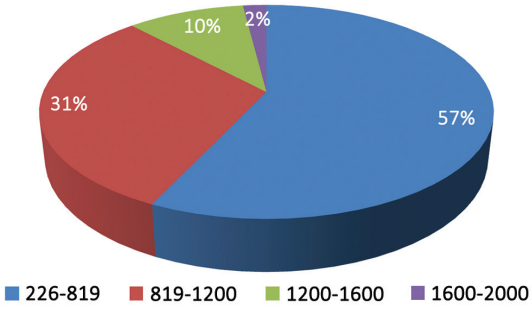


Fig. 7. Location of Iron Age sites in terms of altitude.

Soil type factor

Today, geoarchaeological studies have found a special place as a helpful tool in archaeological research and explaining ancient Quaternary environments (*Maghsoudi* et al. *2020.2*). Soil is a non-dense organic matter that has been created over many years under the influence of various factors, such as climate, vegetation, and elevation (*Salmanpour* et al. *2013*), and soil type affects the livelihood structure of an area (*Estelaji, Ghadiri Masoum 1995.126*). As can be seen on the map, large areas of the western parts of the Middle Atrak Basin are geologically calcareous and unsuitable soils that are also very poor in vegetation. The Iron Age sites of the region are in the category of Incepti soil/Entisoil rocky outcrop soils with a small amount of Incepti soil (Fig. 1.5).

In this area, 42 (68%) of the Iron Age sites are located on Incepti soil, seven sites (12%) are located on Insepti soil with rocky outcrop soil, and 12 sites (20%) are located in areas with enti soil with rocky outcrop soil (Fig. 8). The presence of fine-grained and fertile sediments usually provides suitable materials for agriculture, pottery, and other economic activities and acceptable conditions for developing settlements (*Maghsoudi* et al. *2020.7*). Incepti soils are spread all over the world, and research shows that they are suitable for agricultural and non-agricultural uses, and can be widely used for crop culti-

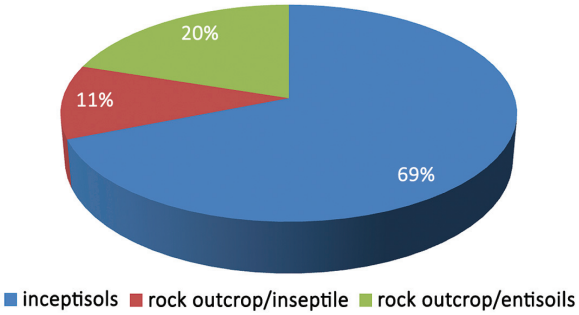


Fig. 8. Site placement on different types of soils.

vation, provided that artificial drainage is possible in them (*Sohrabi* et al. *2013*).

Land use factor

Land use results from a combination of human activity and the capabilities of a place. Although Land use is the result of population activities, it is also in some ways a reason for the existence of certain capabilities and the possibility of using the capabilities of the natural environment (*Sadr Mousavi* et al. *2018.734*). The cultivability of land is one of the factors that is influenced by many important criteria, such as altitude, presence or absence of surface water, soil type, human manipulation of the environment, and climate. However, this human manipulation can also have a decisive role on the erosion rate. Most importantly, the land cultivability and type of vegetation can also be a very determining factor in the type of livelihood of those living in the related settlements. As such the settlement or use of many shelters in an area, especially in association with raising livestock, depends on land cultivability and type of vegetation (*Afifi 2018.636*). To this end, the purpose of land surveying is to determine the land value from the location point of view (*Rahimi, Hasanpour 2011.21*).

The map of the area based on land use (Fig. 1.6) shows that about half of the sites are located in areas

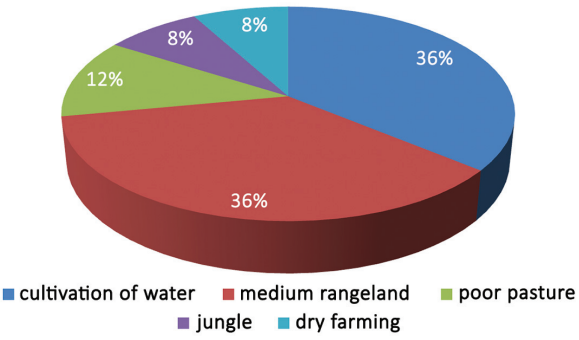


Fig. 9. Location of Iron Age sites in terms of land use.

that are currently used for agriculture, whether irrigated or rainfed, and the other half are in areas that are located in a pasture or forest areas (Fig. 9). This local difference in the sites should be considered as related to the livelihood of the residents. This means that in pasture areas the sites indicate that nomads used them for temporary settlement or cemeteries, and that the sites on suitable agricultural land belonged to sedentary farmers.

Slope direction factor

As a general concept, direction is a well-defined feature for the linear effects of a phenomenon in geometry. In the context of this study it also includes other concepts, such as slope and geological slope (*Heydari Dastenaei, Niknami 2020.320*). Slope direction determines the amount of solar energy that the soil receives. This energy determines the temperature of air and soil and the amount of available water in the soil, which are the factors that cause differences in the vegetation of different slopes. In mountainous areas slopes facing the sun seem to be more suitable for settlement, while in tropical areas this is the case for slopes that do not face the sun. In the Middle Atrak Basin the southern slopes are the most important and the northern slopes the least, because the former receive the lowest heat in summer and the most heat in winter. The eastern and western slopes are less important than the southern slopes, and are used in spring and autumn (*Heydari Dastenaei 2018.7*). Surveying the location of Iron Age sites indicates that the northern slopes contain more settlements and the southern slopes are less used (Fig. 10). Accordingly, 12 sites are located on northern slopes, 11 sites on the northeast, two sites on the east, six sites on the southeast, six sites on the south, two sites on the southwest, eight sites on the west, and 12 sites on the west areas.

Zoning of Atrak River Basin

Potential zones for the placement of Iron Age settlements have been determined by weighting and classification of the abovementioned criteria and environmental factors, including communication routes, distance from water resources, land use, slope, slope direction, altitude, and soil type. The layers' weights, which are the same factors as determined in the model, were evaluated according to the available options, and finally the total weight of the layers was obtained using the calculation formulas. The weight of each layer according to the preference options is shown in Table 2.

In AHP, in addition to considering the factors and combining their different levels, the rate of the number of achieved priorities and the accuracy of weighting results can be trusted due to the method of calculating the comparisons' compatibility with regard to the studied layers, and determining the overall compatibility rate. In this research, the value of the compatibility rate is calculated as 0.4, which indicates the appropriate compatibility of the studied layers. According to Table 3, it can be seen that altitude, distance to a water source, distance to a communication route, slope, and soil type have the highest weights, and land use and slope direction have the lowest weights.

In Table 4, according to the results obtained from the final weight of the factors affecting the creation of ancient sites, it can be seen that altitude is in the first place with a weight of 0.26, distance to rivers is in the second place with a weight of 0.19, distance to communication routes is third with a weight of 0.15, slope direction is fourth with a weight of 0.14, soil type is fifth with a weight of 0.08, land use is sixth with a weight of 0.08, and in seventh place is slope, with a weight of 0.07.

In the next step, GIS is used to prepare layers to select areas with a higher priority. The final map is obtained by stacking the existing layers in terms of weight, as extracted from Table 4. According to the results obtained in this section, those areas with a higher potential for locating settlements have lighter colours, while those with a lower potential for this settlements have darker colours.

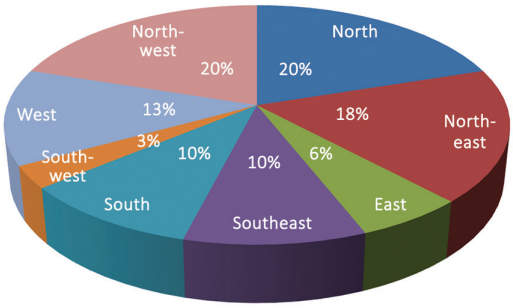


Fig. 10. Percentage of Iron Age sites in relation to slope direction.

More specifically, those valuable areas that have the most potential for establishing settlements are the relatively limited areas shown in green. These have an area of 2235km², equivalent to 10% of the total area, with a low slope of about five degrees and a suitable slope direction, land use, suitable vegetation, and rich soil, and are generally suitable for the development of settlements (Fig. 11). This area has 28 Iron Age sites, accounting for 46.7% of the sites.

Moreover, the areas marked in orange with an area of 12 550km², equivalent to 47% of the total area, also have relatively good values. These areas are geographically hilly, suitable for growing rainfed plants, and also a good place for livestock grazing. This section includes slopes up to 13 degrees, rainfed agricultural uses with an almost suitable soil type, and a short distance to water sources and communication routes. Twenty-four sites (39.3%) are located in this area.

The dark brown areas with an area of 7900km², equivalent to 22% of the total, have a relatively low value for settlement. These areas are hillsides with steep vegetation and steep slopes, and the land is used only for pasture. In addition, the type of soil and even the soil depth in these areas is low, and they are far from permanent water sources such as rivers, as well as communication routes. It is noteworthy that seasonal water springs are usually seen in these areas, and this type of area is used only for livestock

	Slope direction	Landuse	Slope degree	Distance to roads	Distance to rivers	Above sea level	Type of soil
Slope direction	1	3.03	0.45	0.45	0.29	0.25	0.83
Landuse	0.33	1	4.35	0.32	0.45	0.26	0.27
slope degree	2.21	0.23	1	3.2	0.48	0.48	4
Distance to roads	2.22	3.12	3.2	1	0.26	0.31	4.55
Distance to rivers	3.45	2.22	2.1	3.9	1	0.36	3.33
Above sea level	4	3.8	2.1	3.25	2.8	1	2
Type of soil	1.2	3.7	0.25	0.22	0.3	0.5	1
Total	**14.41**	**17.1**	**13.45**	**12.34**	**5.57**	**3.15**	**15.98**

Tab. 2. The binary preference matrix of the components.

Slope direction	0.69	0.177	0.234	0.037	0.052	0.079	0.052	0.071
Landuse	0.023	0.058	323	0.026	0.081	0.093	0.017	0.087
Degree of slope	0.153	0.013	0.074	0.259	0.085	0.151	0.25	0.141
Distance to roads	0.154	0.182	0.238	0.081	0.046	0.098	0.248	0.155
Distance to rivers	0.239	0.13	0.156	0.316	0.179	0.113	0.09	192
Above sea level	0.278	0.222	0.156	0.263	0.502	0.317	0.125	0.266
Type of soil	0.083	0.216	0.019	0.018	0.054	0.159	0.063	0.087

Tab. 3. Normalized matrix of preferences.

grazing. Seven ancient sites in this area can be seen, accounting 11.4% of the sites.

Finally, the dark red areas, with an area of 393km^2 and equivalent to 15% of the total area, do not have any settlement value. These areas have steep slopes and rocky, non-agricultural lands, with poor rangeland vegetation. Thus, due to their high altitude and steep slopes, unsuitable terrain for agriculture, and distance from communication routes, these areas are often unsuitable for settlement. However, an Iron Age site (IAMA 44) (1.6%) is located in this area, which seems to have been a short-term seasonal establishment.

Discussion and conclusion

The use of GIS and geostatistical techniques can be a useful, practical tool in archaeology. These tools make it possible to apply complex mathematical equations to maps. On the other hand, using the existing interpolation methods in the field of statistics, statistical and spatial analysis can be carried out in different places based on the locational and geographical situation of the phenomena. In the present study, we tried to evaluate the effects of environmental factors on the formation of Iron Age settlements. The results showed that environmental conditions in the form of slope characteristics, slope direction, altitude, distance from communication routes, access to water resources, soil type, and land use all positively affect the distribution and density of site in the area being studied.

Layers	Abnormal weight	Normalized weight
Slope direction	0.0500158	0.071450106
Landuse	0.0611772	0.087396017
Degree of slope	0.0987156	0.14105536
Distance to roads	0.1083421	0.154775398
Distance to rivers	0.1342631	0.191802997
Above sea level	0.1863892	0.266270269
Type of soil	0.061098	0.087282862
Total	**0.7**	**1**

Tab. 4. Calculation of final weights based on preferences with regard to the environmental factors.

In the first step, in order to determine the importance of each layer using the AHP method, indicators were compared pairwise with each other, and each indicator was weighted. According to the results of the AHP model, the highest weight is related to the altitude index with a weighted score of 0.26, and the lowest weight is related to the slope direction, with a score of 0.07. In the next step, the layers were standardized into four levels and a zoning

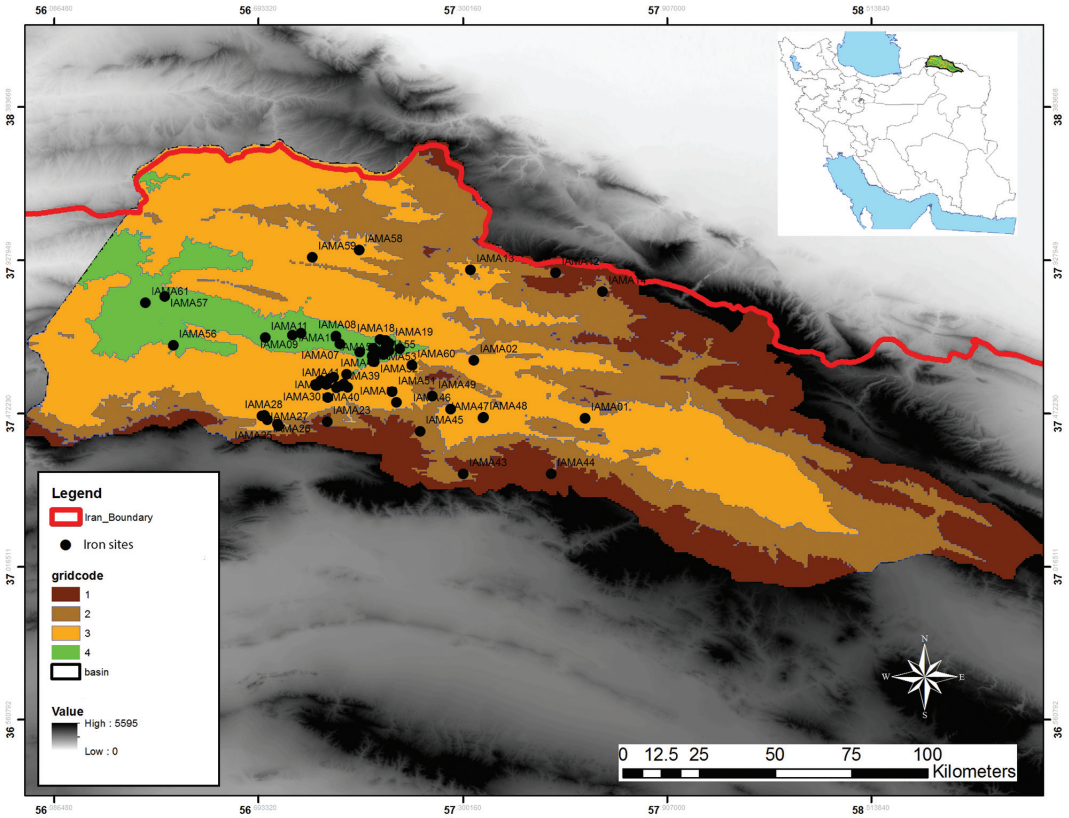


Fig. 11. Iron Age zoning map.

map of the Iron Age areas of the Middle Atrak Basin was prepared. The results show that one site is in a zone with no settlement value, size sites are in a low importance zone, 24 sites are in a relatively appropriate zone and 28 sites are in a very important zone.

The results of analyses show that the locations of the sites in different zones indicates different kinds of livelihoods were pursued there. Based on zoning analysis, it is determined that the areas that are located in Zone 4 (show in dark colours) are villages that engaged in irrigated and rainfed agriculture. The areas located in Zone 3 are areas that used both highland resources and plain agricultural resources. Such sites had a combined economy of livestock and agriculture, and also engaged in trade. Sites in Zone 3 are sites at the foot of the mountains and seasonal sites with livestock. Finally, Zone 1 is not suitable for settlement at all, and for this reason only one site is located in this area, and this site, like those in Zone 3, is a seasonal site.

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A possible case of 'accompanying dead' in the second half of the 6th millennium cal BC at Uğurlu/Gökçeada, Turkey

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ABSTRACT – *Eleven human skeletons were found in a 2m deep circular pit in an open area dating to 5389–5300 cal BC at Uğurlu/Gökçeada. The pit can be considered as a part of the pit tradition frequently seen in Thracian and Balkan prehistory. Its unique contents, however, are discussed in this paper in the scope of possible motivations. An 'accompanied dead' hypothesis is offered as the possible motivation of the case based on the contents and depositional details of bodies within the pit. This type of deposition was practiced throughout Europe starting from the early Neolithic through the Chalcolithic.*

KEY WORDS – *accompanying dead; the second half of the 6th millennium BC; Uğurlu/Gökçeada; Turkey*

Mogoč primer 'pridruženih mrtvih' v drugi polovici 6. tisočletja pr. n. št. na najdišču Uğurlu/Gökçeada, Turčija

IZVLEČEK – *Na najdišču Uğurlu/Gökçeada je bilo v dva metra globoki okrogli jami zunaj naselja, datirani med 5389–5300 pr. n. št., najdenih enajst človeških okostij. Jamo lahko razumemo kot del prazgodovinske tradicije, ki jo pogosto srečamo v Trakiji in na Balkanu. Njeno vsebino v članku predstavljamo v okviru možnih praks. Predlagana hipoteza o 'pridruženih mrtvih' kot možni praksi temelji na vsebini in podrobnostih polaganja trupel v jamo. Tak način polaganja se v Evropi začne v zgodnjem neolitiku in traja vse do konca halkolitika.*

KLJUČNE BESEDE – *pridruženi mrtvi; druga polovica 6. tisočletja pr. n. št.; Uğurlu/Gökçeada; Turčija*

Introduction

Burial customs and ritualistic behaviour patterns are a great source for understanding past belief systems, social structures, and cultural interactions between different groups and regions. Western Anatolia, Thrace, and the Balkans are of special importance in terms of understanding the spread of Neolithic lifeways and the transition to the Chalcolithic. Information on burial practices and/or any other types of rituals related to human remains is not well represented in this area. A recent discovery of a pit with human remains offers an opportunity to look into the ritual behaviours of people during the 6th millennium BC on the island Gökçeada in Turkey.

The settlement of Uğurlu is located in the western part of Gökçeada, in the northern Aegean Sea. The site is on the pathway to Europe from Anatolia, making it an important site in terms of understanding human cultural interaction (Fig. 1). Six cultural layers have been identified in the excavation at Uğurlu (see Table 1 for the phasing). The earliest phase of the site dates to the pre-pottery Neolithic 6800–6600

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cal BC, and is the earliest evidence of agriculture and animal husbandry in the area (*Erdoğu 2014; 2017; 2020*).

Uğurlu is also one of the few settlements in the region that represents the transition from the Neolithic to the Chalcolithic (5500–4900 cal BC) between western Anatolia and the eastern Aegean islands. This transitional period bears witness to changes in settlement organization, building plans, pottery production, and subsistence economy (*Erdoğu 2014; 2017*). A particularly distinct feature was the practice of pit use. This new tradition emerged in Phase IV, continued throughout Phase III, and was slowly disappearing in Phase II. To date, more than 37 pits have been found in Phase IV (3 pits) and Phase III (Fig. 2).

Phasing	Period	Date
VI	Pre-pottery Neolithic	6800–6600 cal BC
VI-V	Transition to Early Neolithic	6600–6500 cal BC
V	Early Neolithic	6500–5900 cal BC
IV	Late Neolithic	5900–5500 cal BC
IV-III	Transition to Late Neolithic to Early Chalcolithic	5500–5300 cal BC
III	Early Chalcolithic	5300–4900 cal BC
Hiatus	–	4900–4500 cal BC
II	Middle Chalcolithic	4500–4300 cal BC
I	Surface: Early Bronze/Middle Age	?

Tab. 1. Phasing of Uğurlu settlement (reproduced from* Gürçal 2021.65*).

During Uğurlu Phase III, the settlement appears to be divided into two parts. The western part has a communal building (B4) with a courtyard, while in the eastern part the buildings are multi-roomed dwellings (*Erdoğu 2020*). Most of the pits were in the northwest part of the settlement in the open area around the communal building (*Erdoğu 2020*).

The pits differ in terms of size and depth (10–90cm), and with a few exceptions they are all plastered with greenish clay and have similar inclusions. Among the contents of these pits are fragments of pottery and animal bones, clay and marble figurines, bone and flint tools, fragments of shell ornaments (bracelets and rings, *etc.*), and stone axes (*Karamurat* et al. *2021*). Three of these pits contained a small number of disarticulated human remains (seven pieces of human bone in pit 25, and a few others in pits 29 and 104). All pits were deliberately infilled and covered with large stones to end the lives of the pits. Apart from these three pits that have fragments of human remains, one other pit stands out with its remarkable deposition of several individuals (unit 188, feature 88). This paper thus aims to describe pit 188 and place it within larger contextual data, especially in relation to other pits, and to discuss the possible motivations for this deposition of human bodies.

The structural and depositional characteristics of the pit 188

The pit is located in the western part of the settlement in the courtyard of the communal building (Fig. 2). Two AMS dates were taken from the human bones. The first one from the first skeleton at the bottom of the pit which gave a date of 6380±30 BP (Beta-480187, 5389–5310 BC at 95.4%); the second date comes from a human bone from the upper layer and gave a date of 6340±30 BP (Beta-465445, 5363–5302 BC at 95.4%. This range is contemporary with the communal building's earliest use at around 5300–4300 cal BC (*Boz, Erdoğu 2019.3*).



Fig. 1. The location of Uğurlu/Gökçeada in the Aegean.

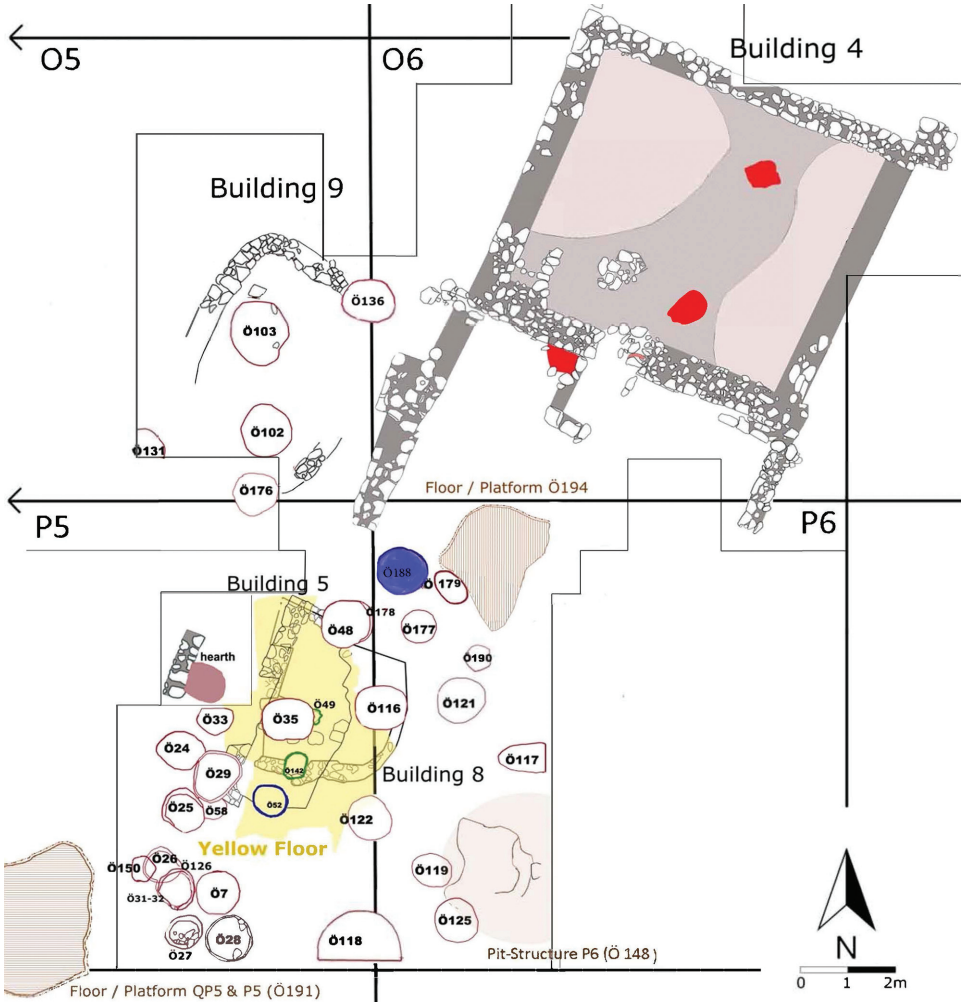

Fig. 2. The distribution of the pits around the communal building (Uğurlu Archive).

Having a 1m diameter and *c.* 2m depth, this pit is one of the largest of 34 pits found in Phase III. The pit was plastered with yellowish-green clay plaster on the side walls and the floor. Fragments of clay were found throughout the infill of the pit, indicating that the inner walls were also plastered in a similar way as the other pits. A total of 11 individuals[1] were found piled up on top of each other with numerous stones in between them. After the last body was interred, the pit was filled with stones for closure at a depth of between 60 and 80cm.

In addition to human bodies, the pit contained a large amount of archaeological material, including two large broken grinding stones, a great number of pottery sherds, three pieces of red ochre, a small number of beads, and a worked bone (for details see *Karamurat* et al. *2021*). Partially articulated leg bones and the pelvis bones of two calves were also among these finds, as well as many fragments of animal bones. A sterile grey ash deposit covering a 30cm area and with *c.* 1.5cm thickness was found on one of the largest stones in the middle of the pit.

The pit was filled up with many stones and marked by another stone, as seen in others[2].

Human remains

Standard osteological analysis was carried out for age and sex estimation. The biological sex of the adults was identified based on morphological fea-

1 Different skeletal parts of the same individual were recorded under two separate skeleton numbers in the field. The pieces were matched in the lab therefore the total number of the skeletons within this pit is 11 rather than 12, as was indicated in the previous publication (*Boz, Erdoğu 2019*).

2 Pit 187 was directly on top of pit 188 (F88) and has been interpreted as a different pit (*Karamurat* et al. *2021*). However, further excavation revealed that human bones were extended into the assumed border of pit 187, indicating that this pit appears to be the upper part of pit 188. Therefore, the marking stone on pit 187 was in fact marking pit 188, as in other pits.

tures of the pelvis and skull (*Buikstra, Ubelaker 1994*). Changes in pubic symphyses (*Brooks, Suchey 1990*) and occlusal tooth wear (*Smith 1984*) were used to group the adult skeletons into three broad age categories: young adults (20 to 30 years old), mature adults (30s and 40s), and older adults (50+). Dental development (*Schour, Massler 1941*) was used for subadult ageing. The age range of individuals varies from 3 to 4 years to mature adults, and both biological sexes are represented among the 11 individuals found in the pit (Tab. 2).

Individual number	Age group	Sex
1	MA	Female
2	MA	Female
3	Adolescent (~ 18)	Female
4	YA	Male
5	Juvenile (~ 3–4yrs)	Indeterminate
6	Juvenile (~10–11yrs)	Indeterminate
7	MA	Male
8	MA	Female
9	Juvenile (~ 12 yrs)	Indeterminate
10	MA	Female
11	Juvenile (~ 6–7 yrs)	Indeterminate

Tab. 2. Age and sex distribution of individuals from grave pit 188. Skeleton numbers represent stratigraphical order from the top to the lowest level. Age categories are: juvenile: 3–12 years; adolescent: 12–20; young adult (YA): 20–30; mature adult (MA): 30s–40s.

Taphonomic changes, trauma-related fractures, and other pathological lesions were examined macroscopically using osteological methods, as described in Silvia M. Bello and Peter Andrews (*2006*). The general condition of bones is poor and fragmentary. Some bones were crushed into a state that they were almost fused as if to form a bony layer. This condition applies especially to some bones of the last two individuals in the sequence (Indv. 1 and 2) whose bones were closer to the surface. Taphonomic analysis of the better-preserved bones revealed numerous fresh bone fractures as well as dry bone breaks (Fig. 3). Macroscopic analysis of bone surface showed no evidence of cut marks that might be related to traumatic events or sharp force wounds, chopping, or bone peeling.

Description of bodies

The first body to be interred in the pit was a 5- to 6-year old child (Indv. 11) which was found directly on randomly distributed stones on the floor of the pit (Fig. 4.a). The body was lying on its right side, with the right arm from the elbow and left leg loosely open towards to south, the rest of the body was in a flexed position. Different sizes of stones and animal bones were scattered directly on top of this child's skeleton along with articulated parts of two calves. Two large fragments of grinding stones (not parts of the same one) seemed to have been dumped into the pit. One was leaning perpendicular to the side of the pit, the other was partially covering the child's head (Fig. 4.b).

Above the child, five more bodies were piled up one after another with many different-sized stones interred with them. Even though each skeleton was articulated individually, the position of each body was randomly scattered on top of each other which indicates that they were thrown in rather than placed carefully in the pit. Stratigraphically, the second individual (Indv. 10), a middle-aged adult female, was dumped in with her head on the floor facing down and with the body leaning perpendicular against the wall of the pit. The hips and the legs were leaning on the side at a level that was about 50cm higher than the head. Her arms were twisted towards the back and the hands were found on the back of the body. The position of the arms and hands were unlikely to happen naturally unless they were tied at the back. The two biggest stones in the pit were thrown/ placed in the pit after this female. One of the stones was on top of her head, crushing her skull completely (Fig. 5). Before the other bodies were placed, sterile grey ash was thrown on top of the biggest stone in the middle, which weighed 80kg.



Fig. 3. Fresh bone breaks (indicated by arrows) related with the stones between the skeletons (Uğurlu Archive-Photo Nejat Yücel).

After placing the ash deposit, four more bodies were dumped carelessly (Fig. 6).

In contrast to these six people, a young adult male body (Indv. 4) appears to have been intentionally placed on its left side, with the legs flexed tightly against the abdomen, the arms flexed tightly at the elbow on the chest, and the hands under the chin. This individual's arms and legs might have been tied to the body firmly or wrapped with perishable material before placement (Fig. 7). After this individual, five more bodies were dumped in the pit with a vast number of stones.

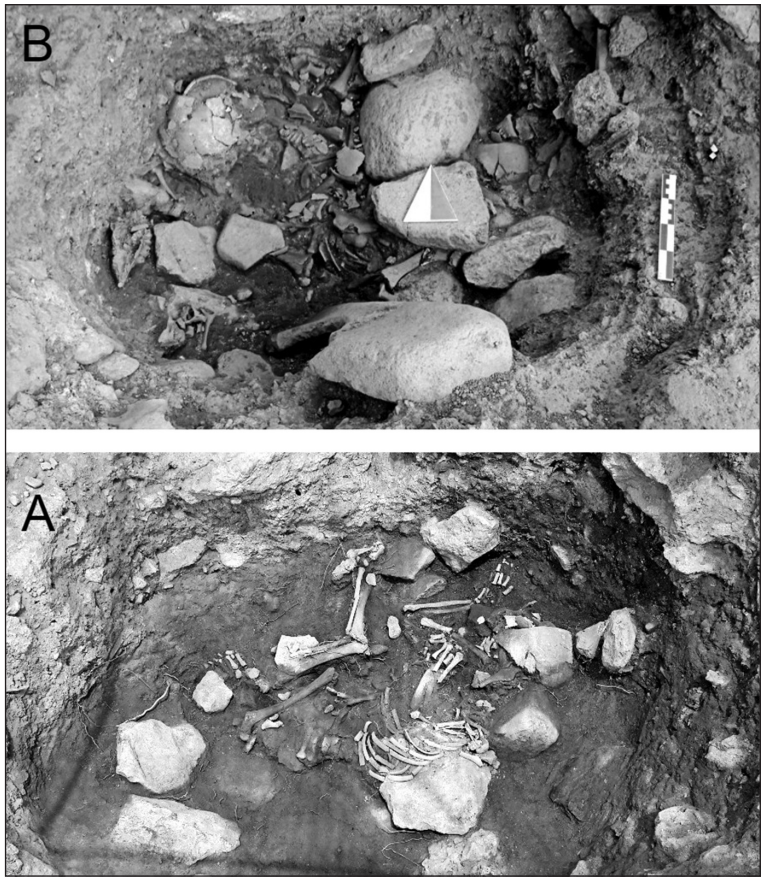

Fig. 4.* A *The first Individual 11 at the bottom of the pit,* B *stones and animal bones over the skeleton (Photo Başak Boz).

Along with the mature adult female (Indv. 10) and young male (Indv. 4) mentioned above, another individual, a mature adult male (Indv. 7) also has a body position that suggests binding. This mature male's body was in full articulation, with the head and the chest facing upwards and the legs up against the side of the pit. The legs were very tightly bent at the knees so that there was almost no space between the femur and lower legs. The arms were opened to the sides and bent tightly at the elbow towards the shoulders, the hands were resting on the shoulders. This peculiar position once again is very unlikely to occur naturally and suggests that the hands were tied at the neck and perhaps the legs might have been tied together too (Fig. 8).

Except for these three individuals with the possibility of binding, other bodies' arms and legs were spread out within the pit (*i.e.* Indv. 3 and 8), and body parts of the different individuals were intertwined while the bones maintained their anatomical positions (Fig. 6).

Apart from one skeleton (Indv. 6), all other individuals' remains were intact with slight displacements of some bones, which appeared to be caused by gravity within the empty spaces of the pit. Some of the bone displacement was caused by the weight of the stones (*i.e.* the left femoral head of Individual 8 was removed from the acetabulum by the weight of the stone on top of the left knee, leaving one side of the pelvis and leg bones moved from its original position). Apart from these slight movements of bony elements of some individuals, one child's (6±2 years) body was separated into two



Fig. 5. Skeleton of a female (Indv. 10) with her hands at her back (Photo Başak Boz).



Fig. 6. Illustration of the position of individuals in relation to each other.* A *is the top view of the pit with skeletons and* D *is the lowest level. Only the bodies are shown here to avoid further crowding with the stones in between the bodies (illustration by Begona Rodriquez).

parts at the lumbar vertebrae. The child (Indv. 6) was located directly on the abdomen of Individual 7 with no soil in between, lying on its right side. The upper body was in full articulation down to the lumbar vertebrae, including the hyoid bone and small manual phalanges. The bones of the lower body, on the other hand, were disarticulated and commingled.

A few individuals from the upper layers have missing skeletal elements. For example, chronologically the last individual placed in the pit (Indv. 1) was lacking one lower arm bone (right ulna), a young female (Indv. 3) was missing the right fibula, and lastly a 3 to 4 year-old child (Indv. 5) was missing the right lower leg bones.

Discussion

Deposition of the bodies

Eleven individuals were squeezed into a pit measuring one meter wide and two meters deep, along with dozens of large and small stones (Fig. 9). Such an occurrence is rather bizarre and enigmatic. How could eleven bodies possibly fit in this relatively small pit? One possible scenario is that long intervals elapsed between the interments of each body, which would allow the previous ones to decay and occupy less space. Throwing/placing stones would also weigh down the bodies. In this scenario, the pit must have been covered with a lid to prevent soil accumulation in between interment events. The slight displacement of some bones of articulated bodies (*i.e.* the sacrum of the vertically placed pelvis of Individual 7 slipped down with gravity) suggests some void spaces within the pit during the decay process indicating that the pit was not filled with soil after the disposal of the bodies. The extremities of some individuals were found intertwined with other bodies and there was almost no fill between the bones (Fig.10). The only exception to this is the first child's body at the bottom of the pit, where the body was covered with random stones and animal bones. The bones of none of the above individuals were mingled with or directly touching the bones of this child (Fig. 4).

The other possible scenario would be that the bodies were kept unburied for some time before being moved to this death pit, perhaps for a special occasion. A ritual ceremony may have been performed, and these 11 bodies may have been moved to this pit to be interred together as a secondary burial. The



Fig. 7. Tightly flexed position of individual 4.

only case that is plausible for this is the body of a child (Indv. 6) whose body was separated into two and whose lower body was partially disarticulated. These data could have indicated different stages of decomposition if only the bones of the upper body (even the small finger bones, and the hyoid bone) were not in full articulation. Therefore, it seems unlikely that this body was half defleshed when it was thrown into the pit. Cultural intervention (*i.e.* dismemberment) is a likely option for this kind of separation of body parts that may have occurred before placing the body into the pit. However, no cut marks were visible on the surviving bones to support the argument of dismemberment. Another plausible case for dismemberment is the missing the right lower leg of a 3 to 4 year old child (Indv. 5); however, the presence of animal holes throughout the pit could be another possibility for the loss of the small bones of this child. Along with this child, missing single elements from two other individuals (the right ulna for Indv. 1 and the right fibula for Indv. 3) makes the dismemberment option unlikely for these two cases. Both Individual 1 and the legs of Individual 3 were close to the surface, and thus these single bone losses might have been the result of a later intervention (*i.e.* animals) or poor preservation.

Neither scenario is firmly supported by the condition of bones in terms of articulation, skeletal completeness (with a few exceptions), the taphonomic evidence, or the depositional structure of the pit. It is therefore plausible that the bodies were deposited in two different processes. The first one includes two actions; placing/throwing the first child (Indv. 11) as the first event, then the other ten bodies being deposited of as the second event after a certain time. The second option is that all bodies were deposited simultaneously in a single event or within short intervals (Fig. 9). However, these tentative attempts at explaining the deposition of 11 bodies in this relatively small pit remain highly speculative.

Burial customs in western Anatolia in the second half of the 6th millennium cal BC[3]

Mortuary practices in the region of Thrace, Balkans, Greece, and Anatolia show great diversity during the Neolithic and Chalcolithic periods. However, despite the well-documented mortuary practices of central and south-east Anatolia throughout the Neolithic period (see for example, *Andrews* et al. *1995; Bıçakçı* et al. *2012; Boz, Hager 2013; 2014; Büyükkarakaya 2019; Erdal 2015; Özbaşaran 2012; Öztan 2012; Lichter 2016; Borić 2015*), western Anatolia is less known.



Fig. 8. Illustration of an adult male (Indv. 7), the arms and hands positions suggesting binding (illustration by Begona Rodriguez).

For north-west Anatolia, our information comes mainly from the Marmara region. During the middle of the 7th millennium BC, at Barcın Höyük VI (6600–5900 cal BC), adults were buried in courtyards while infants were buried in abandoned houses (*Roodenberg* et al. *2013; Özbal, Gerritsen 2019*). At Aktopraklık, bodies are flexed and buried under the house floors in the Late Neolithic (6400– 6235 cal BC) layers. The emergence of cemeteries starts in the first half of the 6th millennium at the Early Chalcolithic level (5736–5635 cal BC) at Aktopraklık C in the abandoned settlement (*Karul, Avcı 2013; Lichter 2016.72*). Also, at Ilıpınar X/IX, most of the Late Neolithic and Early Chalcolithic burials were located in a non-residential area at around the first half of the 6th millennium (*Lichter 2016.72; Roodenberg 2008*).

In contrast, western Anatolia has revealed very little information to set a pattern of burial customs and related ritual activities during that period. For example, at Ulucak only a small number of infants have been found buried in the settlement during the

3 The process of Neolithization developed in different regions with different dynamics and different processes. Neolithization and subsequent changes in material culture in the excavated settlements in coastal west and northwest Anatolia have led some researchers to propose a different chronology and terminology for this region (for detail see *Erdoğu, Çevik 2020*). Comparative chronology between sites and regions is provided in Table 3.

first half of the 7th millennium (*Çevik, Abay 2016. 12; Çevik 2019.223*), while sites like Yeşilova and Ege Gübre have no information on the ways of disposing of human remains in the studied period.

During the Early (the first half of the 6th millennium) and Middle Neolithic (the second half of the 6th millennium) in the Balkans, burials are rare and found within settlements (*Stratton* et al. *2018.1*). They are generally grouped into two body positions – flexed burials and extended supine burials (*i.e.* Cernia, Muntenia). According to Dušan Borić (*2015*) the latter is a continuation of the local Mesolithic burial customs in the region. The flexed body position was a new way of burying the dead in the region and is considered to originate from the Near East (*Borić 2015*). There are also different ways of dealing with dead bodies and burials in Balkan prehistory. These forms of burials mostly consist of fragmented bodies, recombination/hybrid burials, or the replacement of body parts with an object and removing body parts and other forms (*Chapman 2010; Chapman* et al. *2014*). Ditch burials are another type of burial, which are off-site burials from the eastern Balkans, such as at Nova Nadezhda (*Bacvarov* et al. *2016*). During the Neolithic in Greece, single or multiple simple pit burials were common with some variety such as cremations and pot burials (*Fowler 2004; Chapman* et al. *2014*). Diversity in mortuary behaviours was also traced in the Neolithic of central Europe (for details see *Hoffmann, Orschiedt 2014*).

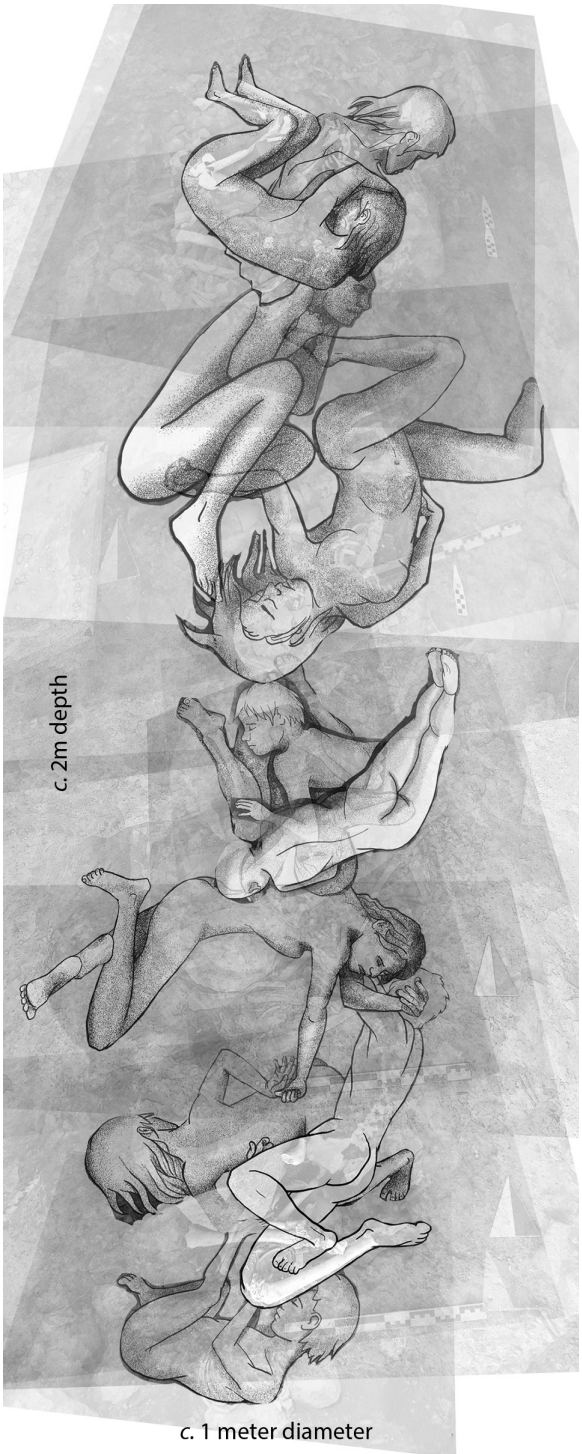

Fig. 9. Illustration of the bodies in order in the pit (by Begona Rodriguez).

Towards the late 6th millennium (5400–5000 cal BC) and early 5th millennium, extramural cemeteries emerged in the eastern Balkans in settlements such as Durankulak (*c.* 5000–4500 BC) and Cernica (5355–5215 cal BC) (*Stratton* et al. *2018.23*). This change in the way of disposition of the dead away from the settlements was interpreted as "*potentially significant new relations between the living and the dead*" (*Borić 2015; Nikolov 2011; Stratton* et al. *2018.2*). On the other hand, diversity in the treatment of the dead continued throughout the Neolithic and Chalcolithic in the Balkans (*Chapman* et al. *2014*).

This diversity in the treatment of the dead in the 6th millennium extended to another type of ritual activity. Some human remains were found within ritual places related to pits in the eastern Balkans. For instance, more than 20 off-settlement ritual areas in eastern Bulgaria have been reinterpreted as pit sanctuaries throughout the 6th millennium at sites such as Volaga-Ohaden, Dana Bunar 2, Kapitan Andreevo, and Voden (*Nikolov 2011; Bacarov, Gorczyk 2017*). These off-settlement places consist of many irregular-shaped dug-out features and pits with filled fragmented material including grinding stones, animal bones, *etc.*, and closed by a cairn of stones. Among many of these ritual pits, only a small number include human remains such as four single inhuma-

tions at early Neolithic Volaga-Ohaden (first half of the 6th millennium), five inhumations were found in Krum and two isolated skulls placed vertically in pits at Dana Bunar 2 and Usae in the second half of the 6th millennium (5400–5000 BC) (*Nikolov 2011; Bacarov, Gorczyk 2017*). Pit use is interpreted in various ways, for example, Vasil Nikolov (*2011*) interpreted 110 small cylindric pits around a big pit at Dana Bunar, as a place for ceremonial activities where sacrificial food along with fire was offered to the Mother-Goddess. John Chapman (*2010*) suggests that pit use could indicate how ritual behaviours produce social meaning or beliefs, whereas Krum Bacvarov and John Gorczyk (*2017. 439–440*), relate pit use as a way of creating a bond with a socio-culturally important landscape.



Fig. 10. Intertwined extremities of different individuals with no fill between them indicating simultaneous disposal of the bodies.

In terms of the burial practices of Uğurlu, no burials have been found up to this date within the settlement, neither in Phase IV nor Phase III. However, this could be a sign of non-residential burial areas, as in western Anatolia and the Balkans, which makes it challenging to place pit 188, whether as part of the burial customs in earlier levels or a part of the changes at the site during the transitional period along with other changes in material culture and the settlement plan. Among these changes, pit construction starts to appear at Uğurlu in the first half of the 6th millennium and continue in the second half of the millennium as in the Balkans.

Cansu Karamurat and colleagues (*2021.8*), argue that the emergence of pits at Uğurlu probably started with building closure rituals in Phase IV represented by three pits. During Phase III, pit rituals seem to be repeated more regularly and are concentrated in the communal area. Based on the findings from the 37 pits with their fragmented material contents, the locations and marking stones for each pit seem to have significance and are interpreted as places for social negotiations (*Karamurat* et al. *2021. 15*). Among these pits, three pits in Phase III include a few pieces of human remains along with other fragmented materials. This behaviour of fragmenting and circulating items is possibly part of the same rituals which served people's enchainment to the place and perhaps to a particular group. Fragmentation and circulation of pieces of items and bodies are common practices in many societies throughout Near Eastern and Balkan prehistory, and are generally associated with transforming bodies and social identities, gaining power, claiming places, negotiating relations in the societies and a bond between past and present (*Chapman* et al. *2014; Glencross, Boz 2016; Bloch, Parry 1982; Metcalf, Huntington 1991; Kuijt 2008; Karamurat 2013*).

Pit 188 was constructed during the second half of the 6th millennium (5389–5310 cal BC) which in many ways is similar to other pits at Uğurlu yet differs somewhat by its differentiating properties, especially the presence of articulated whole human bodies. Can we place this pit within the general pit rituals at the site, or could other motivations explain the contents of the pit and the reason for its construction? Even though it is difficult to give a straight answer given the nature of the archaeological record, this pit with 11 human bodies could have been more than just another variation of human disposal within a region with a wide variety in terms of mortuary practice.

In the following parts of the text, the other possibilities of the motivations for this pit will be discussed.

A consequence of an epidemic

The depositional structure of the pit contents seems to represent a single, if not two, depositional episodes. General carelessness in depositing the bodies raises the question of whether these people died of

Date (cal BC)	Northwestern-West Anatolia	Sites	Greece	Balkans	Sites
c. 7000–6800	Epi-paleolithic		Final Mesolithic		
c. 6800–6500	Initial Neolithic	Barcın, Ulucak Uğurlu	Initial Neolithic		
c. 6500–6000/5900	Early Neolithic	Barcın, Aktopraklık Ulucak, Uğurlu Ege Gübre, Yeşilova	Early Neolithic		
c. 6000–5700/5500	Late Neolithic	Ulucak, Uğurlu Ege Gübre, Yeşilova	Middle Neolithic		Volaga-Ohaden
c. 5700–5400/4900	Early Chalcolithic	Aktopraklık Ilıpınar, Uğurlu	Middle Neolithic	Early Neolithic (Starčevo)	Volaga-Ohaden
c. 5400–4600/4200	Middle Chalcolithic	Uğurlu	Late Neolithic	Middle – Late Neolithic (Vinča A, B)	Durankulak Cernica, Dana Bunar 2,Usae Krum
c. 4600-4200			Final Neolithic	Chalcolithic (Vinča C, D)	Durankulak

Tab. 3. Absolute and relative chronologies between the region and sites used for comparison. The comparative framework is mainly based on Çevik and Abay (*2016*), Erdoğu and Çevik (*2020*), Tomkins (*2007*), Demoule and Perles (*1999*), Radivojević and Roberts (*2021*), Sampson (*2018*), Tsirtsoni (*2018*), Krauss (*2011*), and Blum* et al. *(*2014*).

an acute illness. The expected mortality profile for the rapid death from disease should be similar to the living population, with a representation of all age groups with a higher proportion of infants, children, and the elderly (*Margerison, Knüsel 2002*). The presence of different age groups, including young children, adolescents, and adults, and the representation of both sexes in the Uğurlu pit make it plausible for a deadly disease to be an alternative cause of this deposition. The paleopathological analysis did not show any lesions on the bones, indicating that none of the individuals suffered from long-term disease, but this in no way diminishes the possibility of acute illness being the cause of death due to the fact that acute diseases do not show any traces on the surface of bones in a short period. Nevertheless, the indications of possible bindings of at least three individuals raises doubts about the acute disease scenario, since such binding requires close contact with sick, dead bodies. Why would they tie up the sick bodies instead of quickly getting rid of them? Moreover, the presence of some artefacts (*i.e.* animal parts, the layer of ash, and grinding stones) indicates this was not a case of the quick deposition of sick, dead bodies, as they were most likely to be related to rituals.

Victims of murder or ritual sacrifice

The composition of the pit, what seems to be the careless body positions of some individuals, and the indication of tied hands and legs of some other individuals, makes the case intriguing. Could the motivation for the construction of the pit and its deposition be a result of some sort of sacrificial killing or other types of destruction of one group within the community or outsiders? The existence of aggressive behaviours has been documented from various prehistoric sites spanning the Early Neolithic to Chalcolithic. Some of the cases were interpreted as victims of prehistoric warfare, as in Halberstadt dated to *c.* 5600–4900 cal BC (*Meyer* et al. *2018*), or the massacre of local people by invaders, as in the case of Talheim in the early Neolithic (*Wahl, Trautmann 2012*). Here we can also note Asparn-Schlets in Austria (*Teshler-Nicola* et al. *1999*), Potocani in Croatia (*Novak* et al. *2021*), and Els Traocks in the Spanish Pyrenees, where Early Neolithic farmers were massacred, possibly over resources (*Alt* et al. *2020*).

In the case of Uğurlu, the lack of weaponry within the pit and the demographic composition of the group differs from that of war victims, where young and middle-aged males are predominant, although females and children are present in cases of attacks on a settlement (*Wahl, Trautmann 2012*). Analysis of the bones in pit 188 showed no fractures related to blunt force trauma or cut marks on the skull bones or the other bones of the skeletons. On the other hand, fresh bone breaks were detected on some bones, especially on the long bones of certain individuals (Fig. 3). The presence of heavy stones directly on top of some of these fractures indicates that

these particular fractures may have been the result of the weight of the stones, and they were thrown/placed when these bodies were still fleshed. The ability of the bones to retain the flexible collagen matrix after a certain time and the general fragmented condition of bones make it difficult to assess if any of these fresh bone fractures were perimortem or early post-mortem taphonomic fractures (*i.e.* after death but still fleshed). The fractures that occur at the time in between the fresh bone and complete dry bone tend to show varying degrees of perimortem fracture characteristics (*Wieberg* et al. *2008*). For this reason, it is not possible to use these fractures to argue for either the presence or absence of violence. Besides, the difficulty of finding the intent of observed injuries is a generally accepted issue (*Schulting, Fibiger 2012.12*). On the other hand, typical battle-related injuries such as skull (including face) trauma, since this is often the main target for interpersonal/intergroup violence, traumas on ribs and scapulae, or defence injuries to the forearms and hands were not observed on the bones.

Another possible explanation for the human deposition is a ritual sacrifice, however recognizing a sacrificial event and distinguishing it from other forms of ritualized killing in the archaeological record can be very difficult (*Swartz 2017.224*). Swartz summarizes possible indications of sacrifice in an archaeological context. Analysis of architectural and stratigraphic context, repetition of the behaviour, deviations from normative human and animal depositions, and signs of violent death are some of the indications for sacrifice (*Swarzt 2017.228*). Localities can be also important signs for sacrificial purposes if the bodies were placed in a different location than usual burial places. If the case is a retainer sacrifice then it can be identified through the positions of bodies, as the person who the others were sacrificed for will have a specific body position and sophisticated grave goods, while the others will have disrespectful modes of disposition (*Chenal* et al. *2015*).

In the case of Uğurlu, pit 188 was located in the courtyard of the communal building along with other pits. This location seems to be special, although this does not entirely differentiate this pit from the others. This is also true for the pit construction and some of the inclusions. The specific structure of the pit in terms of lining with plaster, closing and sealing by stones, placing 'marking stones', the inclusion of fragmented artefacts, and the ubiquitous presence of animal bones are the shared features of almost all pits. Therefore, based on construction specifications and contents other than the human remains, pit 188 seems to represent some of the common ritual behaviours related to pits.

The presence of a distinct artefact could be a sign of a sacrificial act such as an altar, a specific ornament, or animal parts that might have been used during ritual behaviour (*Swartz 2017*). For example, an imported pink stone slab was found in the Skull Building at Çayönü Tepesi (southeast Turkey) which contained human and animal blood (*Özdoğan 2007; Croucher 2010*). Pit 188 contains some fleshed parts of animals, specifically the upper legs and arms of two young calves, which is the only case within 37 pits at Uğurlu. Three small lumps of red ochre, a thin layer of sterile grey ash deposit, and broken grinding stones are also distinct depositions that could be remnants of offerings in pit 188. In terms of specific ornaments, none of the individuals had grave goods directly associated with the bodies, including the adult male (Indv. 4) in the centre, whose body was in a tightly flexed position as opposed to the other individuals with aberrant positions. It is unclear if the objects found in the fill were part of ritual activities and placed intentionally, or if they arrived there through accidental intrusion, as none of the artefacts were directly associated with the bodies.

Philippe Lefranc and colleagues (*2010*; see also *Schmitt, Déderix 2018*), in a literature review, agreed that 'accompanying dead' seem to be widespread in the Late Neolithic Upper Rhine region (see also *Testart 2010*). However, it is difficult to conclude that this is a common or ordinary way of disposing of the dead, since this type of burial has only been found in small numbers. Because of the variety of different modes of disposal of the dead, including 'non-normative' body positions accompanied by grave goods, Lefranc and colleagues (*2010*) indicate that some of these disposals might have had other social implications than sacrifices for a high-status individual. An example from the late Neolithic site Bergheim in Colmar/France reveals a case where at least 14 individuals' body parts were scattered within the pit and showed various modifications, *i.e.* amputation, cuttings some limbs, and some traces of violence (*Chenal* et al. *2015*). Fanny Chenal and colleagues (*O.c.1322*), suggest that these individuals were sacrificed to accompany a privileged individual. Another example is from the Didenheim region in Alsace, where a man was accompanied by one adult and two children (*Testart* et al. *2010*).

Traces of violence on human and/or animal bones are other indications of a sacrificial event if confirmed that they were not caused by warfare or murder (*Swartz 2017.229*). As explained earlier, there are no observable fractures that could be directly related to violence on the Uğurlu human remains (*i.e.* cranial blunt force trauma, cut marks on bones). Nonetheless, killing a person or an animal does not have to leave marks on bones. For example, heart extraction, throat-slitting, and decapitation were modes of sacrifice for the victims in Mesoamerica and Andes (*Swartz 2017.232*).

Despite the lack of observable evidence of violence on bones, the presence of an adult male tightly bound in the middle (Indv. 4) whose body was apparently carefully placed as opposed to the other ten bodies, along with some special deposition (*i.e.* a layer of ash, ochre lumps) raises the possibility that the others might have been sacrificed for the individual in the centre.

Conclusion

The first proper human body deposition (except for a few fragments of human bone) has been found at Uğurlu, and has the potential to give insight into the ritual behaviours of the inhabitants of the island. Taking all the evidence together, pit 188 stands out as part of the pit ritual practice. However, the pit deviates from others by its inclusion of people with a variety of positions (side, at the back, and face down), including bodies with haphazard body positions, one individual separated into half and three bound bodies, which makes interpretation a challenge. The nature of this deposition within the wider pit tradition context at Uğurlu indicates a symbolic act, but the impetus and motives behind this specific pit are difficult to interpret with certainty. Considering the possibilities based on contextual evidence and information from other sites, ritual killing is certainly one possibility and may have been a regular practice at Uğurlu among the inhabitants during the 6th millennium, as also seen in the Balkans (see *Chanel* et al. *2015; Testart* et al. *2010*). If these ten people were killed to accompany the individual in the middle whose body was laid out intentionally, as Alain Testart and colleagues (*O.c.*) suggest, it may indicate a hierarchy within the society and its continuity to the world of the dead. However, Testart offers another possibility of social relegation of the status of these people by burying them in unconventional positions. Nonetheless, some of the accepted indications of ritualistic purpose can change meaning in different circumstances and in different communities. For some, dedication to underground or above ground forces, for a rebirth/renewal of anything, seasonal transitions, rain, fertility, power relations or to eliminate something bad or improve what exists, may all have been factors, but overall, they seem to have been for the same greater purpose of community cohesion.

The phenomena were practiced in central and east Europe at around 4500 BC and going south at around 3500 BC (*Testart* et al. *2010*), which suggests that this cultural behaviour travelled from the northeast to west and south (*Chanel* et al. *2010; Testart* et al. *2010*). Nonetheless, Uğurlu's earlier example with the date 5300 cal BC raises another question of the origins of this type of practice of human disposal. Further findings will provide more insight into the burial practices and ritualistic behaviours of the inhabitants of Uğurlu and their relation to other settlements around the region.

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Dead and cremated: on cremation burials in the Linear Pottery culture in Central Europe

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ABSTRACT – *Cremation was one of the permissible burial practices in the Linear Pottery Culture (LPC). This treatment has largely remained unexplained by previous research in Central Europe due to its descriptive nature. As a result, we present several thoughts on some key issues here. First, we discuss the current state of research in Central Europe, as well as some specifics with regard to the LPC and cremation. Second, we focus on two graveyards with exclusively or primarily cremation graves. Based on the current state of research, our goal is to evaluate the results obtained using a quantitative data analysis method, as well as an evaluation of the interpretation of cremation within the LPC population.*

KEY WORDS – *Central Europe; Linear Pottery culture; cremation; state of research; customary mode of disposal*

Mrtvi in kremirani: o kremiranih pokopih v kulturi Linearne keramike v srednji Evropi

IZVLEČEK – *Upepelitev je bila ena od sprejemljivih pogrebnih praks v kulturi Linearne keramike (LPC). Ta praksa je v prejšnjih raziskavah v srednji Evropi ostala nepojasnjena. Zato v članku predstavljamo nekaj razmislekov o nekaterih ključnih vprašanjih. Predstavljamo trenutno stanje raziskav v srednji Evropi in nekaj posebnosti kremiranja v LPC. Osredotočamo se na grobišči z izključno ali predvsem žarnimi grobovi. Na podlagi trenutnega stanja raziskav želimo ovrednotiti rezultate, ki smo jih pridobili z metodo kvantitativne analize podatkov in oceniti pojasnitve upepeljevanja v LPC populaciji.*

KLJUČNE BESEDE – *srednja Evropa; kultura Linearne keramike; kremacija; stanje raziskav; običajen način pokopa*

Introduction

Linear Pottery culture (hereinafter LPC) played a key role in the Neolithization of Central Europe. It is a period of the early Neolithic farming communities, and is dated between the middle 6th and the second half of the 5th millennium BC (*Manning* et al. *2014*).

Not much attention has been paid to the topic of cremation burials of the LPC in Central Europe so far, perhaps except for the study by Edith Hoffmann (*1973*). The main reason was the previously small number of LPC graves found in the burial context. The situation was changed by the discovery of the biritual burial grounds in Kleinhadersdorf, Austria (*Neugebauer-Maresch, Lenneis 2015*) and Kralice na Hané, Moravia (*Šmíd 2006; 2012*), and of the cremation cemetery in Modłniczka, Little Poland (*Czekaj-Zastawny, Przybyła 2012*).

The last person to deal with the analysis of the beginnings of cremation from the Mesolithic to the Early Neolithic with a focus on the LPC culture with-

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in the wide territory of Europe was Agnieszka Gil-Drozd (*2011*), a decade ago. Therefore, the present study attempts to fill in this gap and utilize new data and information which have been added to the study of the topic. The concept of cremation within the presented archaeological material is used to indicate the burial rite, *i.e.* method of burial of a dead individual. According to Howard Williams (*2004.Tab. 1*) and Lise Harvig (*2015*) cremation can be defined as the use of fire to dispose of a body (burying a dead individual's body), *i.e.* it is a process in which the dead body was partly or completely burned.

For the analysis, we selected two examples (burial grounds), which in the current state of research seem to be the most suitable for using the method of correspondence analysis[1] (CA). CA (*Greenacre 2007*) works on a presence/absence basis. It does not consider the number of items in any individual grave. To qualify for the analysis, each object and variable must be represented twice (each burial must contain two or more grave good types; each grave good type must occur in two or more burials). For both selected sites a catalogue of burials and grave goods was available. Besides aspects about the body (sex and age), we recorded the grave goods associated with the burial (number and type of grave goods in each burial). We were looking for potential patterns between the grave goods themselves, and by adding in further information such as age and sex, we were able to see if these variables explain the variation seen in the dataset.

We intend to find out whether the obtained terrain information or the state of cemeteries itself, is suitable for this type of analysis and what results can be expected. We will study the place in which the cremation burials are situated, who was buried in them and what grave goods were added to the individuals' graves. We want to know what it says about the buried individual, and if the burial method reflects the deceased person's social identity.

Historical context of cremation in hunter-gatherer society

Fire has been part of prehistoric burial rituals since the Mesolithic, with its cleansing but also destructive power (*Gray Jones 2017; Larsson, Nilsson Stutz 2014*). The number of known Mesolithic cremation burials has increased significantly in the last two decades. In Europe approximately 22 sites are recorded, which seems to be a small number in comparison to more than 200 sites of Mesolithic inhumation graves with more than 2100 individuals (*Grünberg 2000.I, 51–54, 170, 171; 2008.40, 54; Gray Jones 2017.Fig. 2.1; Little* et al. *2017.Tab. 2*). Specific features of burial rituals associated with Mesolithic cremations include, for instance, collecting or cleaning of bones before the burial (*e.g.,* Hammelev, Gøngehusvej 7 – grave Æ) or, on the other hand, the custom when bones were not completely collected from the funeral pyre (*e.g.,* Hermitage – pits A and B, Gøngehusvej 7 – grave N, Oirshchit V, Coswig, Rotterdam, Heffingen?, la Chaussée-Tirancourt; see *Gray Jones 2017.Tab. 2.1*). The research is focusing on various methods of depositing the bodily remains in the ground (*Fahlander 2012; Gray Jones 2017.41–45*) as well as on interpretation of the variability in the number and typological composition of grave goods to confirm their active role in the burial ritual (*Little* et al. *2017.235–236*). Within Central Europe, cremation in the Mesolithic was discovered in Poland and in the territory of the great Danube Bend on the border between Serbia and Romania (the region of the Iron Gate). In Poland, this includes the cremation of an adult male(?) in a shallow pit on the Wieliszew VII site and the cremation of several individuals (at least one child and other individuals) in a dwelling at the Pomorsko 1 settlement (*Sulgostowska 2006.196*). Intentionally burned human skeletons were recorded in four Mesolithic graves at Mszano 14, which the author considers to be evidence of a combination of cremation and inhumation (*Marciniak 1993.7*).

In the Iron Gate region at the site of Vlasac, 18 contexts with burned human remains were examined between 1970 and 1971, and the number of documented cremations increased further between 2006 and 2007, when seven more cremation graves and at least six secondary cremations were found in skeletal graves (*Borić* et al. *2009.247–282; 2014.14, 20, Tab. 3*). The phenomenon of secondary cremation consisted of disarticulation of some parts of the skeleton and their tanning/burning, while other parts of the skeleton remained without cremation (*Borić* et al. *2009.257*). The secondary cremation on the site was characteristic of the Late Mesolithic and had the purification aim to prepare the spot for a new grave (*Borić* et al. *2009.272, 273*). This habit

1 Correspondence Analyses was carried out using the PAST software (version 4.05 online on: https://www.nhm.uio.no/english/research/infrastructure/past/) (*Hammer* et al. *2001*).

persisted until the transitional period of Mesolithic-Neolithic dating in the region between 6200–5900 BC (*Borić* et al. *2014.20, 25*).

All in all, the Mesolithic cremations in Europe provide clear evidence that hunter-gatherers knew and used cremation as a method of disposal of human bodies. It is also obvious that cremation of the dead as well as depositing utility artefacts/tools on the pyre or in the grave were important aspects of the ritual behaviour of communities (*Lenneis 2007*). Some actions were undoubtedly associated with cooking or a funeral feast. We can conclude that the ritual depositing of cremated remains together with grave goods at a previously decided place was a characteristic feature of prehistoric life before the start of the Neolithic. It is also true that cremation was not the only burial practice at Mesolithic burial grounds (sites), but was closely associated with inhumation or another form of burial customs (*Borić* et al. *2014, 20; Gray Jones 2017; Little* et al. *2017*).

Evidence of biological interaction between incoming farmers and local hunter-gatherers during the earliest stages of the arrival of farming in Neolithic Central Europe (the formative LPC phase) has also recently been proved based on bioarchaeological analysis of the remains of the interred at Brunn 2 site of the Brunn am Gebirge-Wolfholz complex, one of the oldest LPC sites (*Nikitin* et al. *2019*). Furthermore, prior studies also found a limited presence of hunters-gatherers in the DNA of the LPC population (*e.g., Shennan 2018; Lipson* et al. *2017; Szécsényi-Nagy* et al. *2015; Haak* et al. *2010*).

On the other hand, cremation was not often practised in the Starevo-Körös-Criş culture, which was the likely ancestor of the LPC in Europe (*Bánffy* et al. *2007*). The oldest incineration grave is M7 from the settlement Gura Baciului (Starčevo-Criş culture) (*Vlassa 1968.371–379*). Until now, it is the only certain discovery for the Carpathian-Danubian Early and Middle Neolithic (*Gligor, Băcueţ-Crişan 2014. 50*). The find is unique not only for the peculiarity of the cremation grave in the given timeframe, but also for its position between the fragments of the house debris (complex P24), which relates to rituals committed to the priests of the time. The finding of a monumental stone head (stela) covering the burial emphasises the cult's supremacy (*Lazarovici, Lazarovici 2006.107, Fig. 6*). Another discovery that demonstrates the Körös culture's use of cremation is likewise cultic in nature. It was discovered in a secondary location on the outskirts of the tell Hódmezvásárhely-Gorzsa I (Kovács-tanya). The lower part of an anthropomorphic container called the 'Venus of Gorzsa' contained evidence of charred skull fragments and grain (*Gazdapusztai 1957.12, Tabs. I.3, II*). Calcined bone fragments belonged to the skull of a 60-year-old male (*Paluch 2012.182; Farkas 2005.13*).

Linear Pottery culture burial practices

The LPC demonstrates the diversity of funeral customs. Generally left-sided crouched inhumations dominate, right-sided crouched positions, cremations, double graves, prone and supine positions are recurrent; partial burials, disarticulated bodies, cenotaphs, and post-mortem manipulations are also documented. In addition, cemeteries and burials in settlements coexist in most areas (*Pechtl, Hofmann 2013; Bickle, Whittle 2013.46–48, 57–58, 107–114, 168–170; Hofmann, Orschiedt 2015; Zeeb-Lanz, Haack 2016*).

With regard to documented burials in Central Europe, inhumations with crouched bodies lying mainly on their left sides prevailed (*Lichter 2003.139; Kalicz, Makkay 1977; Oross, Marton 2012. 282–291*). Burial districts/areas are first recorded in the Late LPC, *e.g.,* in Austria, Kleinhadersdorf (*Neugebauer-Maresch, Lenneis 2015*) and in Slovakia, Nitra-Priemyslová ulica (*Pavúk 1972*). The proximity of burial grounds to settled areas, like in western Europe, *e.g.,* in Elsloo, the Netherlands (*Moddermann 1970*) or in Arnoldsweiler, Germany (*Cziesla, Ibeling 2014. 125–150*) is also confirmed. In Vedrovice, Moravia, dated to LPC I and LPC II, graves were located at a separate burial ground as well as in the residential area (*Podborský 2002.9–21; Pettitt, Hedges 2008*). The biritual burial ground Kralice na Hané, Moravia, was also situated near the contemporary settlement (*Šmíd 2012.14–15*).

The dead buried in the residential area near houses were either in graves or settlement pits, *e.g.,* in Slovakia – Štúrovo (*Pavúk 1994.94–99*); Hurbanovo-Bohatá (*Březinová, Pažinová 2011.168–171*), in Moravia – Žádovice (*Čižmář, Geislerová 1997*); Brno-Bohunice (*Dočkalová, Čižmář 2008.43*); in Hungary – Balatonszárszó-Kis-erdei-dőlő (*Marton 2008. 197–198; Kreiter* et al. *2017.113*); Harta-Gátőrház (*Kustár* et al. *2014.31–33*); Füzesabony-Gubakút (Alföld/eastern LPC; *Kalicz, Koós 1997; Bickle, Whittle 2013.64–66*); Mezőkövesd-Mocsolyás (Szatmár II group/Alföld LPC; *Raczky* et al. *1997.28–33; Kalicz, Koós 2014.65–69*); in Poland – Miechowice 4, Brześć Kujawski 3 (*Grygiel 2004*); Ludwinowo 7 (*Czerniak, Kabaciński 2004.154–155*); Stary Za-

mek (*Kulczycka-Leciejewiczowa, Romanow 1985. 45–47*). A burial directly connected with a house (foundations) has been confirmed in Little Poland (*Kulczycka-Leciejewiczowa 2008.176*) and in Slovakia (*Bátora 1999*).

Daniela Hoffman (*2009.230–232*) concluded that in both such cases it is a regular burial act, and thus that burials within settlements do not mean any exceptional burial tradition (*Sonderbestattung* in German), and this also undoubtedly applies to Central Europe. For instance, in Slovakia, the study of Michaela Niklová (*2014*) revealed that LPC burials at settlements became a fixed feature of funeral customs and are one of the hallmarks of this period.

In Germany, mass burials probably caused by violent conflicts (Talheim near Stuttgart, *Wahl, Trautmann 2012*; Schöcken-Killianstädten near Frankfurt, *Meyer* et al. *2015*) and cases of post-mortem manipulation (*e.g.,* Herxheim in southwestern Germany; *Zeeb-Lanz 2019*) have been discovered. In Central Europe, we can find some parallels too. Clear evidence for severe inter-personal violence was documented in Lower Austria (Asparn/Schletz; *Teschler-Nicola 2012*). Secondary manipulation with remains has been discovered at the site of Bicske-Galagonyás (*Makkay* et al. *1996.20, 21, Fig. 6*) in Hungary, where re-depositing of the upper left limb (femur, tibia, fibula) in the anatomic position beyond the head (without fingers) shortly after placing the dead in grave 1 occurred (end of LPC/Sopot-Bicske). Post-mortem manipulation was also confirmed by a newly discovered LPC site in south-west Slovakia – Vráble, where 'regular' burials with the deceased in a crouched position were placed on either side of the large outer ditch within the settlement (*Müller-Scheeßel* et al. *2021.66–69, Fig. 2*). Besides that, the second category of mortuary treatment ('irregular' burial type) was represented here by three headless individuals (*Müller-Scheeßel* et al. *2021.69, 70; Fig. 3.1, 2, 5*), who were each placed in an extended position at the bottom of the outer ditch. These buried individuals show clear signs of post-mortem manipulation, the skulls were removed during the decomposition process. Possible open-air staging of the dead for a certain period presents a burial ritual not previously taken into consideration for the LPC. Such a practice could explain seemingly disturbed burials found also elsewhere (*Müller-Scheeßel* et al. *2021. 74, 80*).

As for the grave goods of the buried LPC individuals in Central Europe, older graves usually did not contain any goods (*e.g.,* LPC graves at the burial ground in Balatonszárszó – Kis-erdei-dőlő: *Oross, Marton 2012.263*), while the Late LPC graves or the Želiezovce group graves included burials with above-average grave goods: *e.g.,* in Budapest-Nagytétény (*Gallus 1936*), Budakeszi-Szőlőskert (*Czene, Ottomanyi 2007; Czene 2008*) and Bajč-Medzi kanálmi (*Cheben 2000.72, Abb. 11.1, 12, 13*). In general, we can state that graves without goods make up more than half of the known burials (*Veit 1996.Tab. 4*). We can use the cemetery in Nitra-Priemyslová ulica (Slovakia) as an example, where burials without grave goods made up as much as 62.2% of all graves (*Peschel 1992.176*).

Cremation in the LPC

Finds from the LPC contributed profoundly to the study of cremation graves and the beginnings of the cremation burial rite (*Gil-Drozd 2011.11*). As early as the beginning of the 20th century, the first biritual burial ground of the LPC was discovered in Arnstadt, Germany (*Hoffmann 1973.71*). The twelve cremations discovered here, besides ten inhumations, represented the first case of a previously unknown method of depositing burned remains in small heaps and then covering them with vessels placed with their bottoms up. Other continuously appearing rather large biritual burial grounds of the LPC in the territory of Germany (Aiterhofen-Ödmühle: 69 cremations and 159 inhumations; Wandersleben-Gotha: 132 cremations and 179 inhumations; Stephansposching: 31 cremations and 10 inhumations) and the Netherlands (Elsloo: 47 cremations and 66 inhumations) allowed wider considerations of the burial rites of the population. Christine Peschel (*1992*), for instance, found out that cremation burials at most biritual burial grounds contain fewer grave goods. However, differences between individuals of different genders or ages were not noticeable. Based on the analysis of the burials, Peschel (*1992.199*) formed a hypothesis that individuals with lower social status were cremated, while the richer social class had full-body burials.

Norbert Nieszery (*1995.17, 18, 43, 44*) was among the first who suggested that cremation was the dominant form of burial in the Neolithic. He compared the number of uncovered graves with the coverage of LPC settlements and concluded that only around a fifth of the population is buried in the burial grounds, as most of the shallower cremation burials were eroded and destroyed by farming activities.

Iris Trautmann (*2006.183, 185*) presented some important insights with regard to the genesis and development of cremation in Europe. Based on the analysis of burnt bone remains of the LPC in Germany and their comparison with skeletal remains, Trautmann concluded that practising various funerary rites is a result of affiliation with different groups of the population, *i.e.* Mesolithic hunters and gatherers would often unite with a Neolithic population that had newly arrived in an area, still retaining their funerary traditions, in addition to the new customs practiced by Neolithic communities.

Overall, we can conclude that biritual cemeteries were once especially frequent in Central Germany, Bavaria, and the Netherlands (*Jeunesse 1997*). From a funerary perspective, while inhumations dominate, they coexist side by side with recurrent cremations in most areas. For example, the percentage of cremation burials is the following at selected sites: Elsloo 42%, Wandersleben 42.44%, Niedermerz 9.73%, Schwetzingen 4.45%, Fellbach-Oeffingen 7.27%, Aiterhofen 30.13%, Stephansposching 75.61%, Arnstadt 54.55%, Niederdorla 23.07% and so on (*Modderman 1970; Nieszery 1995; Jeunesse 1997; Czekaj-Zastawny, Przybyła 2012.49, Fig. 31; Gerling 2012*).

Moving to Central Europe (Fig. 1) the finds include mostly separate cremation burials. In Bohemia, a cremation burial of a five-to-six-year-old child, probably a male, was uncovered in a construction pit of the Late LPC near a longhouse in Litice near Plzeň (*Braun 2001; Pavlů, Zápotocká 2007. 83*). Other cremation burials are known from the Moravia region. In the south-west part of the settled area in Brno-Starý Lískovec, a cremation grave together with burned animal bones was documented (*Dočkalová, Čižmář 2007. 34*). In Prostějov-Čechůvky, three cremation burials were uncovered at the Kopaniny site, probably from a larger burial ground (*Šmíd 2011. 8*). Cremated human remains were also documented at the LPC cemetery Vedrovice-Široká u lesa (*Skutil 1941.28, 29*). Nevertheless, their condition did not allow further analyses.

In Poland, a cremation burial of probably the Eastern LPC was discovered in Gródek Nadbużny in Little Poland, where the grave itself was documented by remains of burned bones, secondarily burned pottery fragments (probably from two globular vessels) and pieces of charcoal, arranged in and east-west direction (*Kempisty 1962.284, 285*). A possible LPC cremation burial (without finds, but near to a LPC clay extraction pit) is mentioned at Zwięczyca 3 in south-eastern Poland (*Debiec* et al. *2014.107, 142*), where pit No. 409 (31x30cm) contained the burned remains of an adult individual (maturus, 35–50 years old), probably a male.

In Slovakia, at the only LPC cemetery in Nitra–Priemyslová ulica, in addition to 72 inhumation burials of the Late LPC/Želiezovce group, at least eight groups of burned human bones of adults as well as children without preserved grave pits or associated grave goods have been reported (*Pavúk 1972.39, 69*).

Reliable evidence of cremation comes from the LPC cemetery in Kleinhadersdorf in Lower Austria, where up to 100 burials are estimated. Among them, there were 57 inhumations, 26 symbolic (empty) graves and at least four cremations (*Neugebauer-Maresch 1992.5–6; Neugebauer-Maresch, Lenneis 2015*). Altogether, seven graves with traces of burned bones were found at the site. However, only four of them (graves 37, 46, 54 and 82) were identified as cremation burials (*Neugebauer-Maresch, Lenneis 2015.*

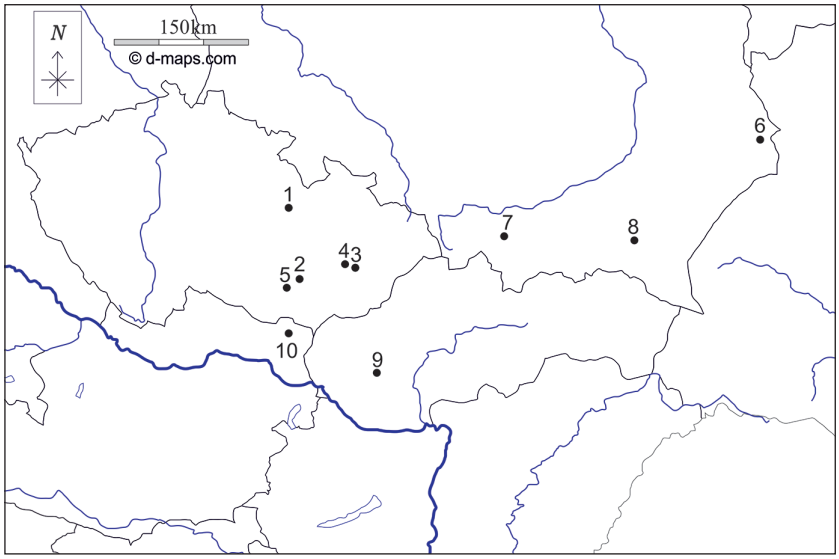

Fig. 1. Topographical map of the Central Europe region showing case study sites with LPC cremation graves. Bohemia:* 1 *Litice; Moravia:* 2 *Brno-Starý Lískovec;* 3 *Kralice na Hané;* 4 *Prostějov-Čechůvky;* 5 *Vedrovice-Široká u lesa; Poland:* 6 *Gródek Nadbużny;* 7 *Modłniczka, site 2;* 8 *Zwięczyca 3; Slovakia:* 9 *Nitra–Priemyslová ulica; Austria:* 10 *Kleinhadersdorf.

Tab. 5). Most of the cremations were in the northern (older) part of the cemetery, and one of them (grave 37) in the southern (younger) part. Their dating falls into the Late LPC phase IIa (grave 54), or Želiezovce group – LPC III (grave 37). An inhumation burial (grave 37a) was documented very close to grave 37. Similarly, inhumation burial 55 was located near to grave 54. The sizes and shapes of grave pits were difficult to identify, but it is probable that they were approximately circular, with diameters between 40 and 80cm. Grave 54 has larger dimensions – 139x116cm – and thus exceeds this range (*Neugebauer-Maresch, Lenneis 2015.Tab. 5*). Grave goods were found only in two graves (37 and 54) and did not differ from grave goods in inhumation burials (*Neugebauer-Maresch, Lenneis 2015. Tab. 13*). They consisted mainly of pottery, flakes, adzes (grave 37) or a bone tool (grave 54). No other pyre cremation remains (*e.g.,* ashes, charcoals) have been found. The remains of burned grave goods were not stated.

The discovery of the biritual burial ground at the site of Kralice na Hané (*Šmíd 2012*) in Prostějov district, Moravia, brings a significant change in our opinions on cremation in the LPC in Central Europe. Of equal importance is the cremation burial ground (39 graves) Modłniczka, site 2 in Little Poland (*Czekaj-Zastawny* et al. *2011.53; Czekaj-Zastawny, Przybyła 2012*). We deal with both cemeteries more in detail below.

Example 1. Kralice na Hané (Moravia) – birituál cemetery of the Late LPC

Kralice na Hané is located on the alluvial flat (214m a.s.l.) of the Romže flood plain in central Moravia, in the region of Olomouc (*Šmíd 2012.10*). During the construction of the industrial zone of Prostějov in Kralice na Hané, a large multi-phase settlement was excavated in 2002–2012, including a LPC settlement. On the northern edge of the LPC settlement, a contemporary biritual cemetery (Fig. 2) was discovered in 2005–2006. The results of the excavation were published with detailed descriptions of find contexts, a catalogue of graves and grave goods, anthropological analysis, *etc.* (*Šmíd 2012; Stránská 2012*).

The burial ground was situated along the northern edge of the LPC settlement. The cremation burials were only 0.3–0.4m below the current terrain. The estimated size of the cemetery is 1.8ha (dimensions: 300x60m). However, a considerable (central) part was destroyed in the second half of the 15th century because a pond was built, followed by the subsequent modern cultivation of soil (*Šmíd 2012.15*). The excavated area of the cemetery makes up only one-tenth of the burial site's area. Seventy-eight graves in total were uncovered – there were 69 cremations, eight inhumations and one empty grave pit, as well as one burial of a child without the outlines of the grave pit (*Šmíd 2012.9, 72, Obr. 5*).

Dating of the cemetery

The older phase (stage LPC I–early II) of the cemetery was characterized mainly by inhumation burials of crouched individuals in rectangular to oval grave pits. From the total of 30 cremations with datable pottery, only three burials (graves 15/05; 20/05; 28/05) belonged to the older phase (LPC Ib, I/II). A change in the funerary rite occurred in stage LPC II (cremation was used exclusively from LPC IIb on) – as many as 26 burials belonged in this period (graves 1/05; HOPI 1/06; 6/05; 7/05; 9/05; 23/05; 26/05; 30/05; 31/05; 32/05; 1/06; 4/06; 5/06; 6/06; 7/06; 8/06; 11/06; 17/06; 18/06; 21/06; 22/06; 23/06; 24/06; 25/06; 26/06; 28/06). One grave (9/06) was dated as the youngest (LPC IIc/III). Another 39 cremations were not suitable for dating (*Šmíd 2012.72–77*).

***Cremation graves*[2]**

Graves were detected on the level of topsoil and subsoil (approx. 0.3m deep). Grave pits were made up of clusters of burned small bones which were mainly situated in bowl-shaped depressions whose preserved depth varied from 2cm to max. 30cm. The grave pits were mainly circular in shape, with a diameter from 0.3m (13 examples), 0.4–0.5m (16 examples) or 0.52–0.7m (nine examples) to 0.74–0.9m (seven examples). In 19 cases, the shape of the grave pits was oval with the dimensions ranging from of 0.3x0.4m to 1.05x0.65m. Any association between age, gender and size of the grave pit has not been confirmed (*Šmíd 2012.108*), *e.g.,* in small pits with a diameter of 0.3m children (graves 16/05; 22/05; 11/06) as well as adults (graves 4/05; 11/05; 28/05; 26/06) were buried. Even a double burial (child and adult) was identified in a pit with a smaller diameter (grave 17/05). However, a young child (0.5–6 years old) in grave 18/06 was buried in a pit of 0.92x

2 In the book (*Šmíd 2012*), we noticed slight differences between the catalogue and the analytical parts. Thus, we follow exclusively the catalogue part when processing graves, their goods, dating and anthropological identification (*Šmíd 2012.19–60*). Where our results are identical and we adopt the previously discovered facts, we give the exact citation of the analytical part of this earlier study.

0.8m and an adult (grave 21/06) was deposited in a pit of 1x0.6m.

Almost half of the remains weighed less than 10g per burial (*Stránská 2012.126*). The surface colours of the burnt bones were grey to a blue-grey, the average temperature of burning reached approx. 550°C. The examined remains suggest uneven cremation depending mainly on the access of oxygen to individual body parts (*Stránská 2012.126, Tab. 2*). A funeral pyre was not discovered in the cemetery or its immediate vicinity (*Šmíd 2012. 109*).

Immature individuals were buried in 16 graves (Infans I-III, or Infans III-juvenis). A child together with an adult was buried in two graves (3/05 and 17/05). In 26 cases, adults were buried. Two in juvenis-adultus age (grave 5/05 and 41/05), another two were identified as adultus I–II (grave 25/05 and 42/05), two others were older than 30 (grave 3/06 and 8/06), and the oldest individuals included one adult in adultus II-maturus I age (grave 27/05) and male adult in maturus I–II age (grave 30/05). Gender was identified only in three cremation burials. A woman was buried in grave 19/05, probably a man was deposited in grave 32/05, and the oldest individual was a man in grave 30/05.

Two superpositions were also found in the cemetery. In one case, inhumation burial 33/05 was in superposition with cremation grave 30/05 (*Šmíd 2008. 251*). Another superposition was detected in grave

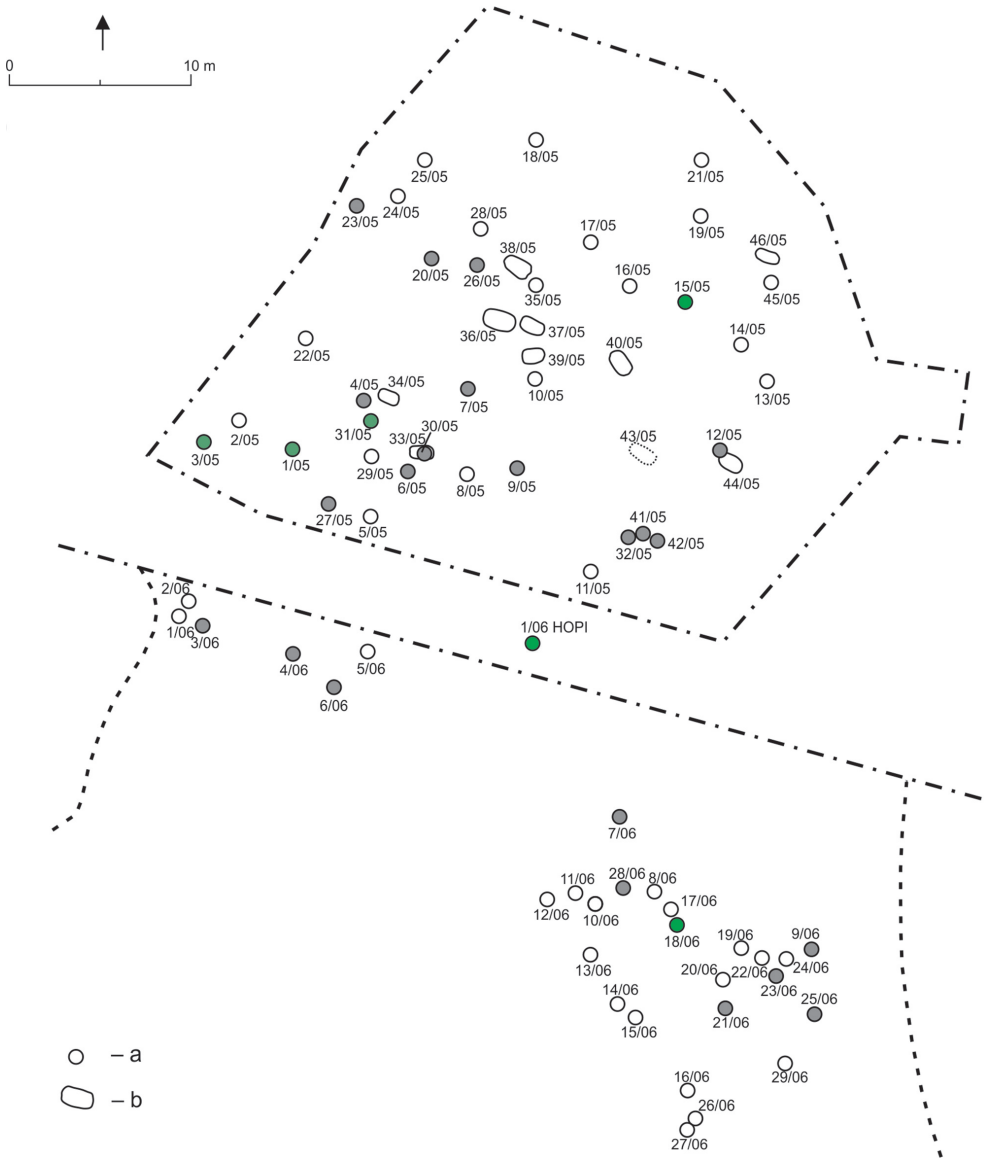

Fig. 2. Kralice na Hané, Moravia. Biritual cemetery. Location of LPC graves:* a *cremation,* b *inhumation (after* Šmíd 2012.Obr. 6*). Colour-coded graves suitable for correspondence analysis (child – green; adult – black).

8/06, where a vessel dated to stage LPC IIb was in the upper part of the 'fill' of the grave pit with a vessel with archaic decoration at the bottom (LPC IIa), *i.e.* it could be a disturbance of an older cremation grave with a younger cremation grave (*Šmíd 2012. 105*).

Grave goods

Fifteen (10%) of cremation burials did not contain any grave goods. Nevertheless, many graves were disturbed or very shallow (just below the topsoil/subsoil), and thus it is very probable that grave goods were richer and the 'empty' graves originally contained something. Twenty (14%) cremations contained exclusively pottery preserved mainly in fragments. Vessels or their fragments were present in 45 graves (31%). Complete vessels were uncovered in grave 8/06, where two vessels deposited with their bottoms up were documented (*Šmíd 2012.49, Obr. 47*), in grave 9/06, there were three vessels with their bottoms up (*Šmíd 2012.51, Obr. 48*). One complete vessel (lying) occurred also in grave 21/06 (*Šmíd 2012.55, Obr. 53*). Traces of fire were recorded also on most grave goods and vessels with traces of burning occurred also in inhumation burials (grave 33/05 and 46/05).

Nineteen graves contained polished stone industry. In 18 of them, children's or adults' adzes or their parts were found. One exemplar was also discovered in the double burial of a child and an adult 3/05. In one grave of an adult individual (grave 27/05), a complete stone hoe was found. Only seven adzes were not damaged (in graves 4/5, 9/05, 24/05, 38/05, 3/06, 21/06, 23/06), four others were perforated (in graves 1/05, 6/05, 45/05, 28/06) and otherwise damaged – it is not clear whether they bear traces of intentionally damaging or a result of internal tension caused by the high temperature of a pyre (*Šmíd 2012.83*).

Chipped stone industry (mainly silex blades and flakes) was present in 10 burials in form of miniature burned fragments of former tools. They were present in children's burials (grave 15/05, 1/06 HOPI), but dominated mostly with adults or old men (graves 27/05, 30/05, 32/05, 4/06, 6/06). It was also found in the grave 3/05 where a child was buried together with an adult individual. In the other two graves (26/05 and 9/06), it was not possible to identify the age or gender of the buried. As for the number of flakes in individual graves, most often there was one example, with a maximum of three. Burial 30/05 with an older man (maturus I-II) was an exception to this, as 12 fragments of burned silex blades were discovered among the cremation remains (*Šmíd 2012.32, Obr. 26*).

Grinding stones (without visible traces of modification) were found in two graves (15/05 and 9/06); their central (symbolic) position was obvious, as other grave goods were arranged around them (*Šmíd 2012.82*).

In three graves (12/05, 15/05, 31/05) the remains of bone (species: sheep/goat) pointed tools were preserved. It was even possible to restore the bone burin from grave 31/05 (*Šmíd 2012.Obr. 27.3*). In the other two cremation graves the remains of meaty food (medial phalanx of sheep/goat with the child in grave 1/06 HOPI; radial bone of a rabbit with the adult in grave 27/05) were discovered (*Šmíd 2012. Tab. 8*).

Red pigment (hematite) was recorded in nine (6%) cremation burials (graves 7/05, 8/05, 15/05, 23/5, 32/05, 41/05, 42/05, 1/06 HOPI, 6/06). It was found in the form of lumps of several millimetres up to 3.5mm, and its occurrence in the cemetery was not dependent on the age or gender of the buried individual (*Šmíd 2012.84*). In a single child grave 15/05, a lump of raw graphite was confirmed (35mm long).

Correspondence analysis

Twenty-eight cremation burials with grave goods (Fig. 2) met the relevant CA criteria. The plot (Fig. 3) does not show significant deviations, and no notable hidden data are visible. However, the graves with mineral pigment show an interesting position. In total, lumps of red pigment were discovered in nine cremation burials – eight of them (apart from grave 8/05) were analysed. Four burials of probably adult individuals (graves 7/05, 23/05, 41/05, 42/05) with hematite constitute a separate group, outside the main cluster of burials. Nearby, burial 6/06 of another adult individual with lumps of red pigment is located. It appears that the inclusion of ochre in a grave was based on a variable distinct to other choices of grave goods. Of course, it is worth emphasising that the CA, in this case, is based on a very small sample number, but the lack of correspondence between ochre covered burials and those without is interesting, both in terms of those with grave goods and without.

The remarkable proximity (and thus good correspondence) of children's graves 15/05, 31/05, 1/06 HOPI and 18/06 is also interesting. There is also a double

burial of a child with an adult (grave 3/05) nearby. In this case, we can assume that the grave goods of children corresponded with the standard tradition and did not exceed the conventions very much.

The last not very isolated group consisted of graves (probably adult men) containing adzes together with pottery (graves 4/05, 6/05, 9/05, 20/05, 3/06, 7/06, 21/06, 23/06, 25/06, 28/06). This combination was probably commonly used as well, although due to the small size of the sample, we cannot speak of a universal rule now. Nevertheless, certain artefacts might be associated with or point to specific identities and their combination, with other grave goods could provide information on the personality (status) of the individual.

A comparison of cremation and inhumation burials from the biritual cemetery using the CA in Kralice was not successful, since – except for one inhumation burial – none of them met the criteria of the CA. In the deepest grave 40/05, a 25–40-year-old woman was buried, crouched on her left side, with pottery and a grinding stone. As it was the only inhumation burial suitable for CA, its information value was very low. No significant similarities were recorded in the basic comparison with cremation burials which also contained grinding stones, as their grave goods were richer and more varied.

Example 2. Modłniczka 2 (Little Poland) – cremation cemetery of the LPC

Site 2 in Modłniczka (238 m a.s.l.) is located in the valley of the Wedonka River (a small tributary of the Rudawa) in western Little Poland (*Czekaj-Zastawny* et al. *2011.53*). The cremation cemetery (39 burials) was in a wet, seasonally watered part of the valley (*Czekaj-Zastawny, Przybyła 2012.Fig. 16; Czekaj-Zastawny 2008*). The burials were grouped on about 70 acres in the eastern part of the site (Fig. 4), earlier occupied by a settlement of the Zofipole phase. The graves did not form any bigger concentration, but were rather clustered in several places (*Czekaj-Zastawny, Przybyła 2012.Fig. 2, Plan 1*). A few graves were dug into the ditch linked with the early settlement. In 26 cases outlines of cremation pits were visible, and the others were marked by concentrations of artefacts and burnt bones.

Chronological context of the cemetery

Due to the relatively small amount of pottery in graves, the chronological position of the burial ground within the LPC is not very evident. Almost all pottery fragments found in graves were decorated with Music Note motives. Only grave 1109 contained fragments with engraved lines and single Želiezovce notches. Considering this, graves equipped with stone artefacts only or not equipped at all may also come

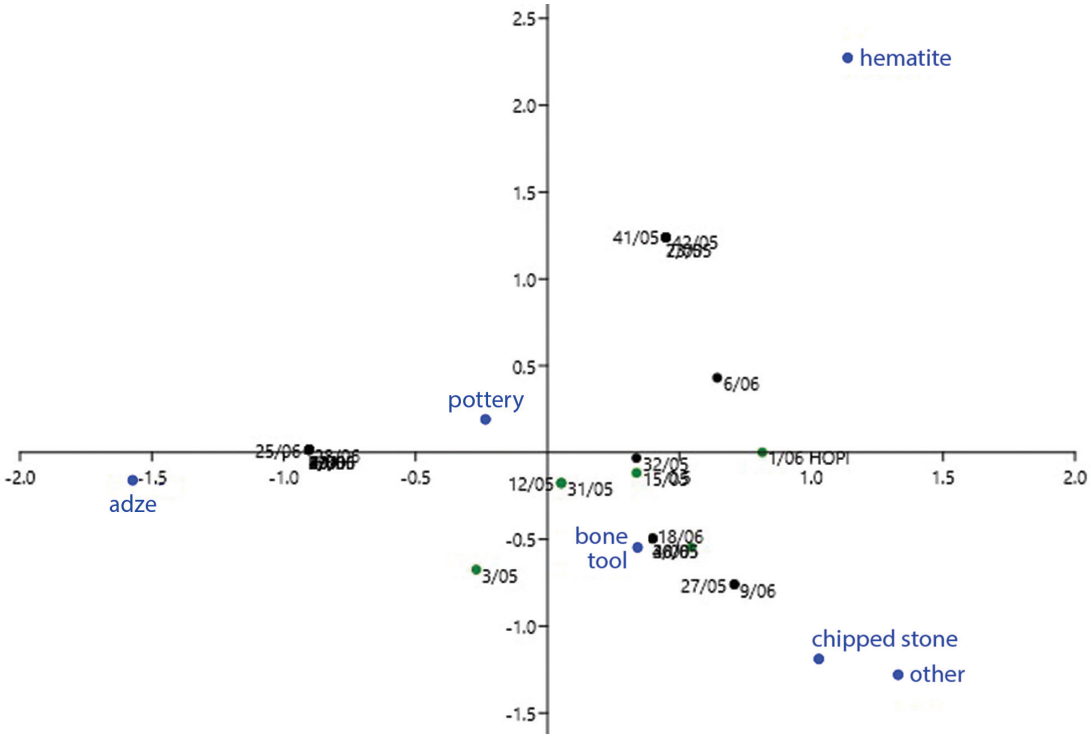

Fig. 3. Correspondence analysis plot of Kralice na Hané cremation burials, on 1. and 3. principal axes (child – green; adult – black).

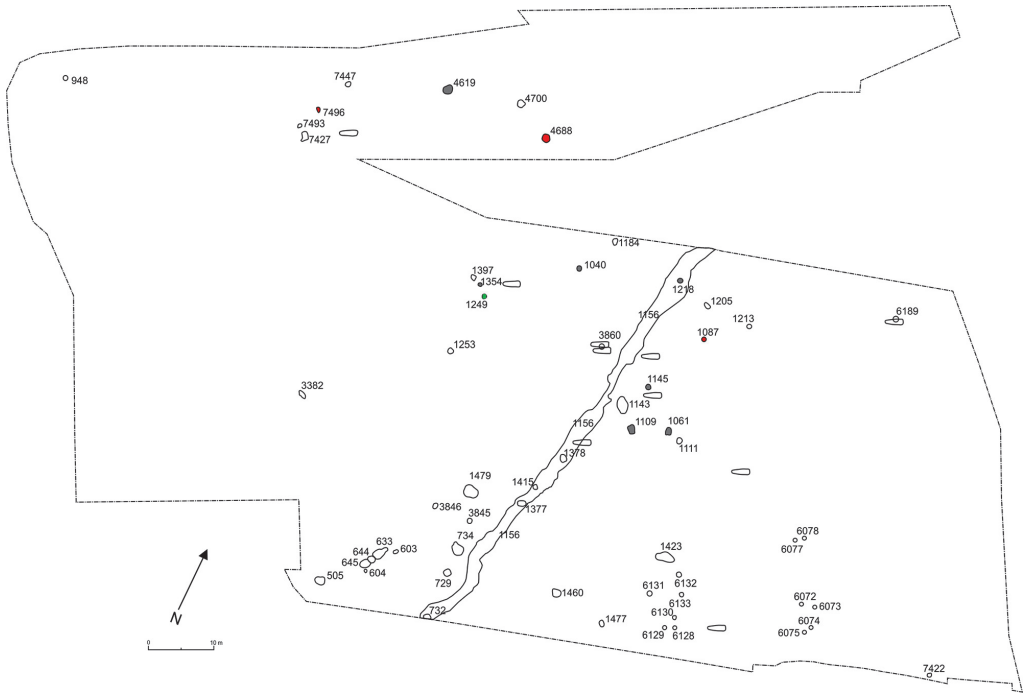

Fig. 4. Modłniczka, Site 2, Little Poland. Cremation cemetery. Location of LPC graves (after* Czekaj-Zastawny, Przybyła 2012.Fig. 2*). Colour-coded graves suitable for correspondence analysis (child – green; adult – black; male, adult – red).

from the Music Note phase (*Czekaj-Zastawny, Przybyła 2012.42–44*).

The cremation cemetery in the eastern part of Site 2 in Modlniczka was possibly linked with the settlement dated to the Music Note phase and the turn of Music Note/Želiezovce phase located a few hundred metres apart (Modlnica, Site 5). It was situated on a loess elevation on a slope of the low river terrace, and two contemporary inhumation burials were discovered there, too (*Czerniak 2010*). There are no visible relations between the cremation cemetery with the nearer settlement Modlniczka 2 from the Zofipole phase (*Czekaj-Zastawny, Przybyła 2012.31*).

Graves[3]

All cremation burials in Modlniczka are pit graves. The original shapes of the grave pits are very poorly preserved (*Czekaj-Zastawny, Przybyła 2012.Fig. 17–18*), although various outlines have been found: oval with dimensions 100–185x60–120cm, circular with diameters 40–90cm, or rectangular with dimensions 60–130x45–110cm. The preserved parts were up to 30cm deep. The cross-section of pits was in all cases basin-like. They were filled with grey, grey-brown, or black-brown sand with burnt human bones and remains of the funerary equipment. In better-preserved pits two fill layers were visible – slightly lighter sand with scattered bone fragments and very small charcoal pieces. Pieces suitable for palaeobotanical analyses were exceptional, including one oak (*Quercus* sp.) fragment from grave 1354. Original grave pits had small depressions into which the remains of the pyre had been placed, possibly in organic containers (small sacks?). Oval and quasi rectangular pits were in three cases orientated N-S, in other three cases E-W, in two cases NW-SE, and in one case NE-SW (*Czekaj-Zastawny, Przybyła 2012.56–62*).

Among 39 graves (*Szczepanek 2012.305–313*), the sex of buried individuals has been determined in six cases (one woman – grave 1205; five men – graves 1087; 1213; 1423; 4688; 7496) and age in seven cases (woman *Maturus*, two men *Adultus/Maturus*, man *Maturus*, man *Maturus/Senilis*, one *Adultus* of undetermined sex, and one *Infans*). The remains from 14 graves have been determined as belonging to adults. For 17 graves no information on the buried persons is available.

No links between age, gender and the size of the grave pit have been established. However, only one child was identified at the burial ground (grave 1249), and thus this claim is not generally valid. The

3 In the publication (*Czekaj-Zastawny, Przybyła 2012*), we noticed slight differences between the catalogue and the analytical parts. Thus, we follow exclusively the catalogue part when processing graves, their goods, dating and anthropological identification (*Czekaj-Zastawny, Przybyła 2012.96–129*).

adult woman (grave 1205) and the three grown men (graves 1087, 1213, 4688) were buried in smaller pits than the child. The largest grave pits were for adult individuals (graves 1061, 7427/7428) or adult men (grave 1423 and 7496).

No superpositions were documented at the burial ground. All burials were single graves, hence no grave included more than one individual (*Szczepanek 2012.305*).

Grave goods

Sixteen burials contained grave goods (*Czekaj-Zastawny, Przybyła 2012.96–129*). The other 23 graves were probably also equipped, but the goods were destroyed and poorly preserved. Generally, grave assemblages included adzes (13 graves), pottery (nine graves), and flint artefacts (nine graves). Altogether, 78 pottery fragments were recovered from grave pits (*Czekaj-Zastawny, Przybyła 2012. 38*). Nine graves were equipped with pottery (23%). In four cases (graves 1145, 1354, 7422, 7496) potsherds came from one vessel, in other cases from up to 11 vessels (grave 1109). In grave 7427/7428 were altogether 35 potsherds (of which 14 fragments were from one vessel, 15 fragments from another vessel, four fragments from a third). All fragments found in the graves were either thin or medium-thick. For the most part, they were decorated. Whole vessels have not been documented. No traces of fire have been observed on potsherds.

Fourteen burials were equipped with stone tools. There were 17 adzes, four adze fragments, and 3 hoes (*Czekaj-Zastawny, Przybyła 2012.41, 42*). Most of these were made of amphibolite, probably from the Sudety Mts. Only two tools from graves 1218 and 1354 are of feldspar (*Trąbska 2012*). Almost all adzes are burnt, usually on two-thirds of the length (from the blade). The grave inventory usually contained one or two adzes (*e.g.,* grave 1423, determined as a man), or one adze and a pot (*e.g.,* grave 7496, determined as a man). The male grave of *Adultus/Maturus* (feature 1087) contained three items: an adze, a hoe, and a trapeze – functionally an arrowhead. The richest and most diverse equipment was found in grave 1061 (adult of undetermined sex): three whole adzes and one shoe-last tool fragment, one hoe, three flint artefacts, one obsidian artefact and 9 potsherds (*Czekaj-Zastawny, Przybyła 2012.96–98, Pls. 29–31*).

Nine graves were equipped with flint or obsidian (one case) artefacts (*Trela-Kieferling, Zając in press*), ranging from one to eight of these (in grave 1061). Twelve artefacts were of the Cracow Jurassic flint, one of obsidian, and one of undetermined burnt rock. The obsidian artefact (from feature 1061) is a small single-platformed core for blades. The assemblage of tools includes a combined tool (burin + perforator) and a retouched blade from feature 1109, a trapeze (arrowhead) from feature 1087, a double truncated blade with sickle gloss from feature 1218, and a burin on truncation from feature 1249. The last mentioned example is a child grave, and the burin was in the grave together with an adze.

In grave 4688, identified as the burial of male aged *Maturus/Senilis*, apart from a hoe, four flint artefacts, and four potsherds, there was a unique perforated stone fragment of an oblong polished object made of white aplite, oval in cross-section (*Czekaj-Zastawny, Przybyła 2012.105, 124, Pl. 42.2*). It has a small opening (diameter approx. 5mm) in half of its length, bored from both sides.

Correspondence analysis

Eleven graves with grave goods met the CA criteria (Fig. 4). Since this is a small ensemble with unique graves, several divergences could be tracked (Fig. 5).

In any combination of main axes, the grave 4688, which has several distinctive attributes, was set apart from the others. It is the burial of the only male aged *Maturus/Senilis*, and apart from other grave goods he had a unique perforated stone artefact in the whole cemetery – a pendant(?). A separate position is also noted for the male *Adultus/Maturus* grave 1087, with a trapeze arrowhead combined with an adze and a hoe. Nearby is the richest grave 1061 of another adult individual, which, in addition to a combination of adzes, hoes, obsidian core and flint tools also contains potsherds.

Smaller clusters form graves without potsherds containing a combination of adzes and flint tools such as a burin and blades (child grave 1249; adult grave 1218; adult grave 1040).

Another cluster is made of possible adult male graves 1109, 1354, 4619. These have in common a combination of potsherds, adzes and flint tools and a larger grave pit.

Discussion

The LPC cremation cemeteries presented in this study were certainly used for regular burials of peo-

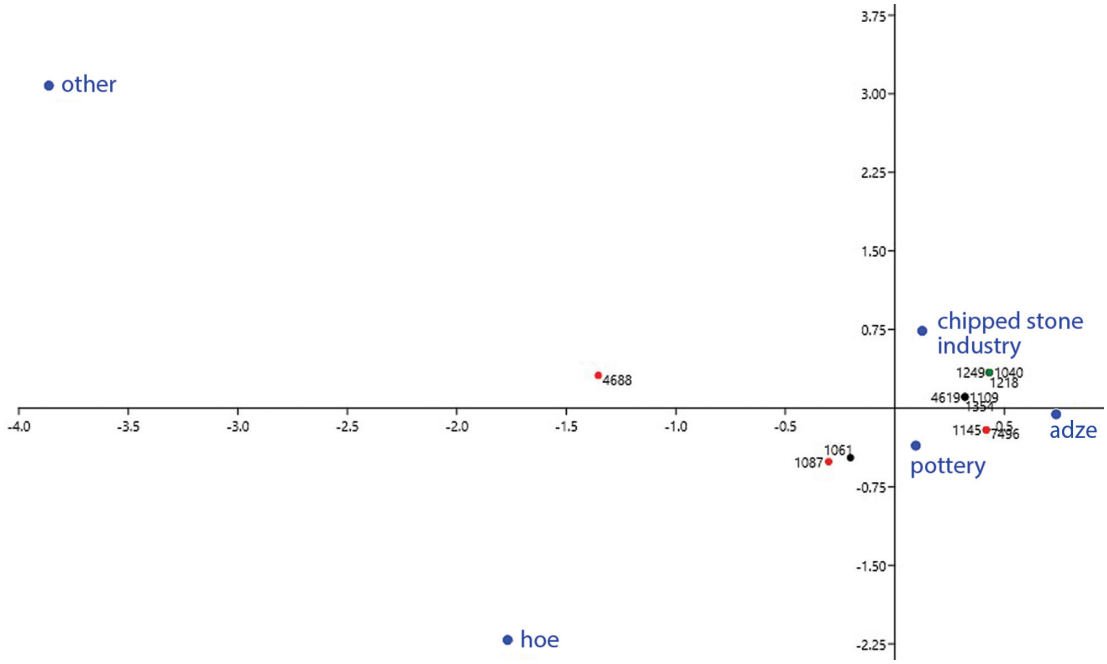

Fig. 5. Correspondence analysis plot of Modlllniczka, Site 2 cremation burials, on 1. and 3. principal axes (child – green; adult – black; male, adult – red).

ple from contemporary settlements. The cemetery in Kralice na Hané was in the immediate vicinity of a settlement. The neighbourhood whose inhabitants probably buried their dead in the cemetery in Modłniczka, Site 2, was only a few hundred metre from their last resting place. The cemeteries were used at least from phase LPC II to LPC II/III. During this period, biritual burials were used. In Kralice na Hané, human skeletons were recorded not only at the biritual burial ground, but also in pits right at the nearby settlement (*Šmíd 2012.110*). In Modłniczka, Site 2, only cremation burials were uncovered. Nevertheless, two contemporary inhumation burials were found at the nearby settlement of Modłniczka, Site 5 (*Czerniak 2010*). This funerary tradition documents the considerably diverse spiritual world of the LPC communities. Biritual burying in Kralice na Hané was probably not used until the end of the cemetery's existence, and it seems that cremation prevailed here in the later period as well. In both cases, however, we must bear in mind that only a small part of the original sacred area has been studied. Despite this, the burial grounds maintained their status as important places in the landscape for a long time, and they were used repeatedly. The progression from high quantities of inhumations in the east to their decline in the west in favour of cremations was also seen as chronological development at Aiterhofen-Ödmühle (Lower Bavaria). Cremations are here likewise believed to be a younger phenomenon (*Nieszery 1995. 89; Hahnekamp 2021.982, 983*).

The fact that the burials found at both the above analysed sites were mostly undisturbed or not destroyed in the LPC period is important. Therefore, we can assume a certain form of indication of graves or long remaining memory of the buried individuals (see *Chapman 2000.46*). Naturally, we cannot be sure about the relations between the graves or between the burying and the buried without an exact chronology of the place (cemetery and the related settlement). Previous sequences of ceramic decoration are insufficient for revealing chronological developments, and thus more radiocarbon and genetic studies are suggested.

Superpositions were recorded only in two cases in Kralice na Hané. The reuse of old funerary spots maintains community ties and may represent a link between generations. The use of the same location for cremation remains (grave 30/05) and inhumation (grave 33/05) in Kralice na Hané (*Šmíd 2008. 251*) and traces of fire detected on the vessel deposited next to the skeleton might indicate the traditional use of fire at the funerary rite. More information in relation to this hypothesis could be brought by detailed DNA analyses of both dead people, which has so far not been possible.

With regard to burial practices, there are no distinct differences between burials of adult women or men and children. The presented burial grounds reflect the demography of the population. The right and

possibility of being buried at the burial ground were not denied to neither sex nor any age category. Nevertheless, there are also some exceptions. In some cases, whole groups of graves are excluded from the burial ground, and sometimes there are no female, male, or child graves within a given site (*Chapman 2000; Wunn 2001*). Such localization of graves can be observed in the Vedrovice – Široká u lesa LPC cemetery (*Podborský 2002*). Selected clusters can also be divided by sex, with one group of graves being populated exclusively by females and the other one by men, children, and anthropologically undefined individuals (*Podborský 2002.301, Fig. 2*).

Grave goods in cremations do not show any significant differences at both analysed sites. They were placed in graves of adult men, women, and children. Grave goods specific for sex (*e.g.,* occurrence of adzes and hoes with men) are an exception. Numerous experts have pointed out that LPC adzes appear to have conveyed social, or even status, differences also in relation to the LPC inhumation burials (*Jeunesse 1997; Nieszery 1995; John 2005; Mandák Niklová, Mandák 2020*). For example, in Vedrovice wealthy burials including prestige items such as adzes were only associated with men (the only exception was a child grave 39) (*Květina 2004.385*). Regarding social hierarchy exceptionally wealthy male burials, comprising older individuals (matures, senilis) were therefore attributed to chieftains, big men or elders (*Květina 2004.387*). The increased frequency of polished stones in cremations at Aiterhofen-Odmühle also indicate a predominating presence of men, with half of the provided ones confined to adzes as the only gift (*Hahnekamp 2021.979, 982*). The difference in grave goods equipment between inhumations and cremations is thus seen here as potentially signifying gender distribution inequalities. Moreover, adult men buried with polished adzes in certain sites (Aiterhofen-Ödmühle, Vedrovice, and Nitra) have a higher protein intake of animal origin (^{15}N) so it seems that this social group has certain privileges such as a richer nutrition and a stable residence (*Augerau 2021.959*).

In burial contexts, no symbolic elements associated with the female gender are found. It seems that women have no gendered tools, and their adornments (if they have any) are not specific. However, there might be a preservation issue, therefore we must remember that some grave goods are possible not so visible in the archaeological record. Members of the Linear Pottery population who cremated their dead may have considered the act of burning itself to be significant, reducing the need of specific assemblages to identify the deceased's social standing or sex and instead focused on fewer but meaningful burial goods. Alternatively, a variety of organic material might have been burnt at the funeral, resulting in their absence in the grave-pit. Stone tools and remains of former – often unidentifiable – tools (fragments of chipped industry) represent an important tradition in grave goods and point to the everyday work of the inhabitants. Three bone tools (awls) and grinding stones can be considered representatives of human activities in Kralice na Hané, although two of the grinding stones found in cremations were without traces of any activity whatsoever.

Pottery was represented by the highest number of artefacts (as for fragments) which occurred in cremation burials. It was preserved mainly in fragments or as damaged vessels. The shape in which they were deposited in the graves, however, can reflect a different form of burial traditions. From the aspect of the rite of passage, for instance, intentional damaging of things (*e.g.,* breaking a vessel) might symbolize the dying of things so that they can further be used by the dead person (*Lutovský 1998.256*).

Unlike Modłniczka, Site 2, three graves in Kralice na Hané contained complete vessels. It could suggest a different function of pots and fragments deposited in graves. All this pottery is probably for the serving and to a lesser extent storing food and drink. Whether they were part of a funerary ritual involving the mourners eating and drinking at the grave, or whether they were placed in the grave for the deceased's use in the afterlife is open to debate. In this context, the fact that the presence of animal bones in cremation graves was minimum is very important. Unique burned bones (rabbit and sheep/goat) that might indicate adding meat to graves were identified only in two cremations in Kralice na Hané.

We must not overlook the significant fact that there is generally no indication of urn burials in the LPC (as well as in the studied sites). Vessels are placed deposits (grave goods) to the burial or used to cover cremated remains. In this context, it would be appropriate to regard the vessel as an upside-down urn?

A funeral pyre has not been recorded at any of the burial grounds. They were possibly at some distance from the burial ground. Transporting pyre remains into graves probably followed specific rules. In Modłniczka, Site 2, was observed that human bones, often with flint artefacts, were placed first, then – on

the same level or slightly above – adzes and pottery. Many stone and flint artefacts are burnt, but no traces of fire have been documented on potsherds. It suggests that broken vessels might have been placed directly into the pit (*Czekaj-Zastawny, Przybyła 2012.38–42*).

Certain differences and variations occurring among graves are a result of other factors – hidden in archaeological records – which could point to the status of an individual and/or a family (?), to wealth, and they could have been inherited, as children's graves rank among the richest ones from the aspect of typological diversity of grave goods. They include *e.g.,* grave 15/05 and 1/06 HOPI in Kralice na Hané and grave 1249 in Modłniczka, Site 2.

A certain change in the number of grave goods can be noticed when comparing older and newer graves. The youngest grave 9/06 (LPC phase IIc/III) belonged to the richest graves in the cemetery in Kralice na Hané. In the grave, three vessels, chipped lithic industry and a sandstone grinding stone were found. The youngest grave 1109 (Želiezovce phase) in Modłniczka, Site 2 also ranks among the richest ones discovered at the site with its inventory.

It was noticed in the past that cremation played various roles in various territories. In some regions, it was almost as common as inhumations, regardless of a chronological phase, in others much less frequent (*Czekaj-Zastawny, Przybyła 2012.49, Fig. 31*). We can also add – based on the above-presented facts – that it depends mainly on the state of research, not the regional tradition.

Conclusion

When considered alongside the small sample size, the potential of CA did not seem promising. Nevertheless, the use of CA in this contribution was intended to be exploratory and, in this case, it served its purpose. As we see the CA results brought not hidden, previously unrecognized data, but rather highlighted certain facts. We intended to find out what cremation says about the buried individual and if the burial method reflects the deceased person's social identity.

In the first place, we can confirm that any attempt to extrapolate a relationship between age and the use of cremation is frustrated by the low rate of success in identifying the cremations. Secondly, there seems to have been no association between sex or age and the type of burial used. Naturally, as the bodies were burnt, age and sex determinations are missing for the most part. There are also several aspects of burial practice that seem to have been 'cross-regional'. For example, the grave goods in cremation did not differ significantly from grave goods in inhumation burials, including exceptionally furnished burials of wealthy adult men or the presence of ochre in burials of adult individuals. These are LPC practices that occur across Europe and may point to shared understandings or values. It is especially relevant in addressing the mainstream ideology in the LPC society (*Augereau 2021*). However, this pattern does not characterise the whole LPC burial practice. Indeed, in the case of placing commodities at the funeral pyre together with the dead, unification does not apply, thus the ideology of cremation in the LPC culture was probably different or expressed in a different way, not perceptible in the funerary data.

Thirdly, a key issue in understanding the LPC sites is time. Unfortunately, all the sites with cremations in Central Europe are lacking a refined chronology, and the burials at the cemeteries have not been radiocarbon dated. Chronologies of the cemeteries discussed above were only broad phases based on typologies. And as the analysis of František Trampota and Petr Květina (*2020*) showed changes in the original material culture do not necessarily occur on a time axis. Hence more refined chronologies, such as whether a burial group/row was added to in a particular direction, or whether one area was finished before another came into use, do not yet exist. It is therefore impossible to follow the burial practice, in our case cremation, more closely in time. However, summarizing the current facts on cremation burials in Central Europe, their beginnings and gradual establishment in the Neolithic, we can state that their origin no longer needs to be sought in distant and more developed regions. In the LPC, cremation funerary rite becomes 'domesticated'. The rite itself cannot be associated with ethnicity and probably not with the social status of individuals either. However, cremation can be considered a common burial custom spreading simultaneously with inhumation since the Neolithic. This fact is documented also by recent excavations at biritual cemeteries in Central Europe. They gradually open the way to a better understanding of this funeral tradition and objective evaluation of the situation in a wider territory.

At the beginning of the millennium, we learned about cremation in LPC based on data from west-

ern Europe. New excavations and published data in the studied territory point to the fact that cremation was represented at cemeteries to a much greater extent as assumed. Therefore, we can state that cremation in the LPC was not limited territorially, chronologically, or demographically and it was used parallelly with inhumation also in Central Europe. Although cremations are still far less numerous than inhumations, they occurred in significant numbers depending on region and site, and thus must have played an important role in Linear Pottery funerary rites and might have reflected changes in notions of the afterlife. For example, at Vedrovice, Kleinhadersdorf and Nitra, cremations are scarce to absent, while they predominated in sites such as Kralice na Hané and Modłniczka, Site 2. All of these features point to dynamic and adaptable funeral practices and norms rather than fixed systems. The mode of body disposal could be affected by social organization, hierarchies, family, economic factors, religious beliefs, and by the individual preferences of the deceased or their survivors, and other factors not apparent in today's ideology.

The act of cremation can be associated with the purifying power of fire. The ritual aspect of the cremation process was a strong spiritual experience for the people attending a funeral (*Schlentner 1960; Ucko 1969*). The practical aspect of cremation is presented by the effort of the survivors at the creation of a funeral pyre, as well as reduced requirements for the deposition space. All these facts might have played equally important roles in deciding on the funerary rite. We also agree with the idea that the funerary treatment represents a chronological act expressing idealized social identities (more details in *Fowler 2013*), *i.e.* the archaeological remains are not an *a priori* reflection of a current social organization – they present a deeper view of the world of the contemporary community (family of the deceased person).

Since only a fraction of the living population was being buried in cemeteries, there will always be doubts about what could be considered a mortuary norm and exception (*cf. Boyadžiev 2009; Perlès 2001.274*). Nevertheless, the known data provide information on the religious, ritual, and social tradition, but these aspects can constantly change and vary in everyday practice. The presented examples confirm that the burial customs of individual communities primarily reflect domestic traditions and rules. A good example in cremation can be seen in the various compositions and ways of depositing grave goods – either on a pyre or in a grave intermingled with the burnt remains on variable sites.

As for the future of excavations of cremations and cremation cemeteries of the LPC, there are several determining factors, including localization of cemeteries in inundation areas or floodplains where settlement and associated activities are not expected or have not been searched by survey activities so far. The second determinant is the high proportion of destroyed graves which is associated with their smaller and shallower grave pits being disturbed or completely damaged by (not only) recent activities. Bearing this fact in mind, we must pay more attention to targeted searches and exact documentation of find contexts, which are unique testimonies of the LPC funerary rite.

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Some Balaton-Lasinja graves from Veszprém-Jutasi út and an outline chronology for the earlier Copper Age in western Hungary

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ABSTRACT – *A handful of new radiocarbon dates from three Balaton-Lasinja culture graves at the site of Veszprém-Jutasi út in western Hungary form the starting point for formal models for late Lengyel and post-Lengyel chronology in that region. The graves date to the later fifth millennium cal BC. They provide the opportunity to put the earlier Copper Age Balaton-Lasinja culture of Transdanubia into its regional and wider context, and to highlight both gradually improving understanding of its character and remaining problems of chronology and classification. The Balaton-Lasinja culture was part of a whole series of regional shifts in settlement and society connected to the end of the Neolithic and the demise of major settlement aggregations which had dominated lifestyles in previous centuries. This study indicates how much further detailed research continues to be needed to get fully to grips with this set of important changes, which run on into the Copper Age. Contrasts are drawn between western and eastern Hungary, and the uncertainties surrounding the chronology of the fourth millennium cal BC, including for the Furchenstich pottery style, are emphasised.*

KEY WORDS – *western Hungary; Late Neolithic and Copper Age; post-Vinča development; Balaton-Lasinja culture; radiocarbon dating; Bayesian chronological modelling*

Nekaj grobov kulture Balaton-Lasinja iz najdišča Veszprem-Jutasi út in oris kronologije starejše bakrene dobe na zahodnem Madžarskem

IZVLEČEK – *Novi radiokarbonski datumi iz treh grobov kulture Balaton-Lasinja v Veszprém-Jutasi út na zahodu Madžarske predstavljajo izhodišče za izdelavo formalnih pozno lengyelskih in postlengyelskih kronoloških modelov v regiji. Grobovi so datirani v pozno peto tisočletje pr. n. št. Omogočajo umestitev zgodnje bakrenodobne Balaton-Lasinja kulture v Transdanubiji v regionalni in širši kontekst in pomagajo pri boljšem razumevanju njenega značaja, kronoloških težav in klasifikacije. Kultura Balaton-Lasinja je del vrste regionalnih poselitvenih in družbenih premikov na koncu neolitika, povezanih z razpadom večjih poselitvenih območij, ki so prevladovala v prejšnjih stoletjih. Študija kaže koliko detajlnih raziskav je še potrebnih, da bi razumeli spremembe, ki so se nadaljevala*

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v bakreno dobo. Predstavljamo kontraste med zahodno in vzhodno Madžarsko in opozarjamo na nezanesljivo kronologijo četrtega tisočletja pr. n. št., tudi lončarskega sloga brazdastega vreza.

KLJUČNE BESEDE – *zahodna Madžarska; pozni neolitik in eneolitik; post-Vinča razvoj; lasinjska kultura; radiokarbonsko datiranje; Bayesovo kronološko modeliranje*

Introduction: aims and contexts

This paper presents a handful of new radiocarbon dates from three Balaton-Lasinja culture graves at the site of Veszprém-Jutasi út in western Hungary, as well as a series of formal models for late Lengyel and post-Lengyel chronology of that region based on the small number of existing dates. The graves date to the later fifth millennium cal BC. They provide the opportunity to put the middle Copper Age Balaton-Lasinja culture of Transdanubia into its regional and wider context, and to highlight both gradually improving understanding of its character and remaining problems of chronology and classification. The Balaton-Lasinja culture was part of a whole series of regional shifts in settlement and society connected to the end and aftermath of the Neolithic and to the demise of major settlement aggregations, including tells, which had dominated lifestyles in previous centuries. This study indicates how much further detailed research continues to be needed to get fully to grips with this set of important changes, which run on into the Copper Age. The immediate focus here is on western Hungary, but there are implications for other neighbouring regions as well.

From the Late Neolithic to the Copper Age in western Hungary and beyond

There has long been an imbalance in studies of the Neolithic and the Copper Age in Hungary between its eastern and western parts (*Kalicz 1991; Bánffy 1994*). This applies not least to the end of the Neolithic, broadly in the middle of the fifth millennium cal BC. This period is represented by a series of changes in eastern Hungary that are archaeologically well documented, like the abandonment of tell settlements and the appearance of new pottery styles. A significant shift in subsistence strategy has also been noted, with more reliance on stockbreeding and pastoralism in emerging Early Copper Age communities (*Bánffy 1995*). The Copper Age of eastern Hungary was already well-investigated by the mid-late 1950s (*Kutzián 1955; Banner, Bognár-Kutzián 1961*), and even underpinned by some reliable stratigraphic observations (*Kalicz 1958*). Its presumed cultural and chronological sequence (from Tiszapolgár to Bodrogkeresztúr to Baden), was established in the early 1960s, but has been severely questioned more recently (*Raczky, Siklósi 2013; Siklósi, Szilágyi 2021*; and see below), allowing considerable overlap between Tiszapolgár and Bodrogkeresztúr.

In contrast, research on the same times in Transdanubia in western Hungary has historically lagged behind. One obvious gap here was between the Late Neolithic Lengyel culture and the Late Copper Age Baden culture. From the 1970s onwards (*Raczky 1974*), the late phase of the long-enduring Lengyel culture, Lengyel III, was seen to persist in the period that was traditionally called the Early Copper Age in the central Carpathian basin, contemporary with Tiszapolgár in the previously accepted cultural scheme for eastern Hungary (*Raczky, Siklósi 2013; Siklósi, Szilágyi 2021*).

Just as there was historically uneven knowledge of Lengyel settlement in Transdanubia – whilst large settlements and cemeteries were found and excavated in east Transdanubia, including the eponymous site (*Wosinsky 1889; 1891*) and a recent site with more than 2000 burials at Alsónyék (*Osztás* et al. *2016*), data from the western Lengyel complex is characterised by smaller, dispersed settlements, with almost entirely 'Sonderbestattungen' or unusual graves – very little was known about late Lengyel settlement before 1974 (*Raczky 1974*) and more robust settlement data followed only in the 1990s (*Bánffy 1995*), with subsequent insights into changes in subsistence strategy in favour of stockbreeding (*Bánffy 1994; 1995; Barna* et al. *2019*). According to current knowledge, the Lengyel III horizon can be divided into two typo-chronological phases, IIIa and IIIb. The latter was taken to represent the gradual adoption of more elements common in the subsequent Balaton-Lasinja culture (*Kalicz 1991; Bánffy 1994*). As part of a larger cultural formation already described in Croatia, Slovenia and eastern Austria, the Balaton-Lasinja culture was initially supposed to be the result of a massive migration into southern Transdanubia (*Kalicz 1969*), based on the work of Josip Korošec (*1958*) who summarised its

principal characteristics in the late 1950s, and on 25 sites of the Lasinja culture published by Stojan Dimitrijević (*1961*), who considered them to be part of the suite of post-Vinča phenomena.

The Balaton-Lasinja culture

One of the earliest identifications of the Balaton-Lasinja culture resulted from systematic work on the archaeological topography of Hungary in the early 1960s. Volumes 1 and 2 were published on results from the Balaton Uplands in County Veszprém, where surface collections were complemented by small excavations (*Bakay* et al. *1966; Éri* et al. *1969*). The similarity of some assemblages to recently published Slovenian and Croatian material led to the definition of the Balaton group in 1969 by Nándor Kalicz, who stressed the dominance of southern traditions in its early phase of its development, while also emphasising central European ties both in the ceramic assemblages and in the metallurgy of its later phase (*Kalicz 1969*). Soon after, ceramics were already being classified as Balaton-Lasinja I, II and III types (*Kalicz 1973*). They became Balaton-Lasinja I and Balaton-Lasinja II-III cultures by the early 1980s in a further comprehensive survey, in which Kalicz discussed the dynamics, the cultural connections and the metallurgy of the period (*Kalicz 1982*). The label of 'Furchenstich' was also proposed for the more recent pottery assemblages in this proposed typo-chronological sequence. Related cultural groups are also known with many different names in adjacent regions (such as Retz-Gajary in Croatia, Bajč-Retz in Slovakia and Mondsee in Austria).

Kalicz went on to distinguish Balaton-Lasinja III as the Protoboleráz horizon, with some sites in eastern Hungary as well (*Kalicz 1991; 2001*). In this system, Lengyel III was set to be contemporaneous with Tiszapolgár, and Balaton-Lasinja with Bodrogkeresztúr, in eastern Hungary, and with Ludanice in the north-central part of the Carpathian basin; Furchenstich was seen as parallel to the Hunyadihalom group (Bodrogkeresztúr B). Protoboleráz already marked the emergence of Late Copper Age cultural groupings, such as Boleráz and Baden.

Although meticulous studies of typo-chronology were the principal focus for decades, architecture, settlement structure, burials, subsistence strategy and metallurgy also received attention. Two major types of houses of the Lengyel III and Balaton-Lasinja periods can be distinguished. Bipartite houses, with a larger northern and a smaller southern room, proved to be very characteristic for the period. No tra-

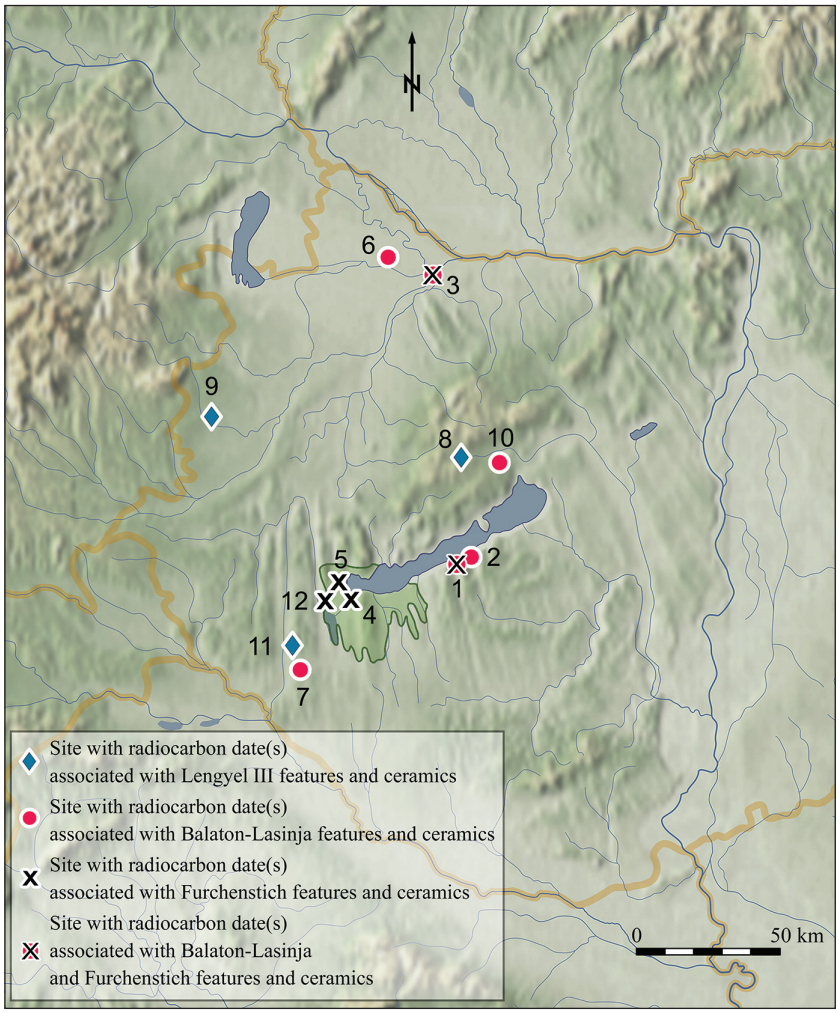

Fig. 1. Radiocarbon dated earlier Copper Age sites in western Hungary:* 1 *Balatonőszöd-Temetői-dűlő;* 2 *Balatonszárszó-Kis-erdei-dűlő;* 3 *Győr-Szabadrétdomb;* 4 *Keszthely-Fenékpuszta, Halászrét-Nádgazdaság agyagbányája;* 5 *Keszthely-Fenékpuszta, Vasúti őrház;* 6 *Mosonszentmiklós-Pálmajor;* 7 *Nagykanizsa-Sánc;* 8 *Szentgál-Teleki dűlő;* 9 *Szombathely-Metro;* 10 *Veszprém-Jutasi út;* 11 *Zalaszentbalázs-Szőlőhegyi mező;* 12 *Zalavár-Mekenye.

ces of internal division and just a single row of postholes in the position of the ridge purlin were observed in other buildings, which were extremely variable in shape and size. Some further constructions are more like Neolithic Lengyel houses with a single cross-row of heavy posts in their interior. Bedding trenches usually mark the walls of the houses. The exceptional visibility of the house plans, comparable only with those of LBK buildings, is due to these features. Different house types were dated to both the late Lengyel and Balaton-Lasinja periods, and no strict architectural sequence could be distinguished (*Virág 2003; 2005; Virág, Figler 2007; Oross* et al. *2010*).

Balaton-Lasinja settlement layouts are clearly looser than those of the densely built-up extended Neolithic sites of the LBK and the Lengyel periods. Small clusters of houses and a limited number of buildings have been discovered at sites such as at Zalavár-Basasziget and Balatonszárszó-Kis-erdei-dűlő (*Virág 2003; Oross* et al. *2010*). Archaeozoological and especially archaeobotanical evidence has remained extremely scarce. In sharp contrast to the extended extramural cemeteries of the earlier phases of the Copper Age in eastern Hungary, only single burials and small grave groups have so far been discovered on contemporaneous Transdanubian sites.

Metallurgy in western Hungary does not present the abundance of large copper axes and the series of other different artefacts known from eastern Hungary that reveal close ties with the Balkans. Attributed to a central European tradition, hooked copper spirals, so-called glass-shaped spirals, and different kinds of copper wire belong to repertoires recovered in the western Carpathian basin. However, the so-called Csáford-Stollhof type gold discs form a very spectacular and characteristic group of objects that have their close counterparts in the adjacent central European regions, sometimes also made from copper, and rarely from silver (*Korek 1960; Bóna 1963/1964.33–37; Makkay 1976; Kalicz 1982. 10–16*).

The Balaton-Lasinja graves at Veszprém-Jutasi út

During the excavation of the Neolithic and Copper Age site of Veszprém-Jutasi út in 2003, some Balaton-Lasinja graves in the southern and eastern parts of the excavated area were recorded. Settlement features related to the graves could not be observed on the site, although Balaton-Lasinja pottery occurred in the Lengyel pits, into which Copper Age graves were cut. Balaton-Lasinja pottery was found in a well-defined small area around the graves, and the situation can be interpreted as relating to burial ritual. The scattering of broken vessels into graves is a phenomenon known in other Balaton-Lasinja graves.

Veszprém-Jutasi út (earlier called Felszabadulás út) is a well-known site of the Lengyel culture, entering the literature as the first known settlement of the late Lengyel period (*Raczky 1974*). The western edge of the site was investigated during the excavation in 2003, and mainly the early stage in the settlement's life (*Regenye 2004; 2006; 2007; Regenye, Biró 2014; 2019*). Based on previous research, we know that the Lengyel site includes an extended Lengyel III settlement in the eastern direction as well; the centre of the site shifted eastward over time. The Balaton-Lasinja graves were located in a group on the westernmost edge of this large Lengyel III settlement.

The graves excavated in 2003 are mostly dated to the Lengyel culture. Eight burials can be listed here. These graves are located in a group. Four more graves (9, 13, 14, and 15), about 90m away from this group, were interpreted as burials of the Balaton-Lasinja culture (*Regenye 2006*). One of these, grave 15, an unfurnished burial, was subsequently shown by radiocarbon dating to be of Lengyel date (SUERC-54643; *Regenye* et al. *2020.Tab. 2*).

So only three graves of the Balaton-Lasinja culture are securely recorded. Grave 9 is that of a child (of Infans II age) lying on its right side in a contracted position, the skeleton oriented east–west. Grave 13

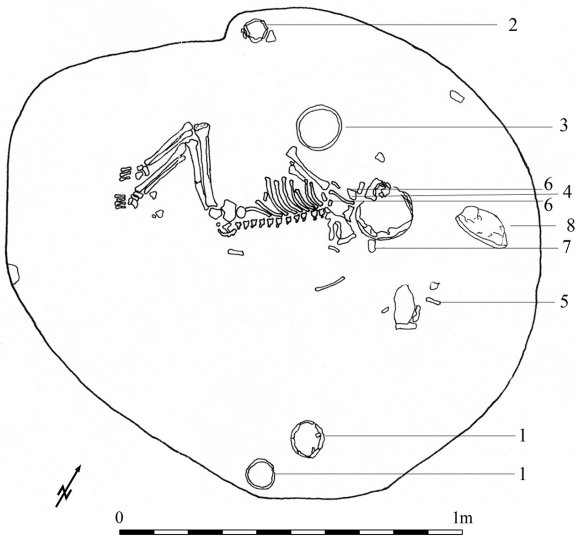

Fig. 2. Veszprém-Jutasi út, grave 9.

is that of an adult man, lying on his right side in a contracted position, his skeleton oriented southwest–northeast. Grave 14 is that of an adult woman (of Maturus-Senilis age, *Köhler 2006*), her upper body lying in supine position, the legs bending to the left, and skeleton oriented south-southeast–north-northwest.

The grave pit could be observed only in the case of grave 9, which was roughly round, 1.2m in diameter. The other two graves were buried into a Lengyel III pit; the form of the graves could not be determined.

All three burials are inhumations, but their orientation varies. Grave 9 has an east–west layout; the orientation of graves 13 and the 14 varies slightly from south–north. Two of the skeletons (9, 13) lie on their right side and the third turns to the left. The location of the two graves in a pit roughly parallel to each other may suggest a linked burial. Grave 14 was covered with irregular large limestone blocks which extended partly to grave 13. There was a possibility of post-depositional manipulation or disturbance in the case of grave 14, the left arm being separated between the two skeletons and covered by the stones.



Fig. 3. Veszprém-Jutasi út, pots from grave 9.

Two of the three graves had grave goods. Ceramics, ornaments and several stone implements are included in the child's grave, but only one of the adult graves had a single vessel. Both the composition of the grave goods and their placement in the grave follow Lengyel traditions in the case of the child's grave. One vessel was placed behind the head, two in front of it. At the neck were pieces of shell ornaments, in the form of rectangular flat beads (two intact, with three fragments, with two drilled holes at the top) made from river shells, and an unworked shell. The stone tools were placed around the head: a core in front of the neck, a core-flake behind the head, and a polished basalt axe preform above the head.

Three out of four vessels were in grave 9 (that of the child) and the fourth in one of the two adults, in grave 13. In that grave fill there were two more pots, incomplete pieces of a pedestalled vessel and a jug. These are not included in the grave furniture. Together with the fragments of different pots found in the grave fill beneath the stone deposit and under the legs of grave 14, they may have been placed in the grave as part of the funerary rite.

Both the graves had a pedestalled bowl with a bell-shaped base; in grave 9 there were also a biconical bowl and a small cup. The vessels are typical forms of the Transdanubian Copper Age (*Kalicz 1995b. 75–76; 2003.14*); both the biconical bowl and the bell-shaped pedestal are basic forms, just like the pedestalled bowl in grave 13 (*cf. Kalicz 1995a.Fig. 3, 12*). The biconical bowl with a short upper part is a frequent type deriving from the Lengyel culture, but the decoration of the upper part, typical of the Balaton-Lasinja culture, is missing here. The bowl on a pedestal ornamented with four drop-shape knobs fits well into the repertoire of both the Balaton-Lasinja (*Horváth, Simon 2003.Figs. 21.9,24.3*) and the Ludanice culture (*Virág 1995.Abb. 2, 10*). The little biconical cup is not characteristic of the Balaton-Lasinja culture, lacking decoration or handle.

The four pots found in the two graves show strong Lengyel traditions. The vessel forms are typical of the Balaton-Lasinja culture, but the characteristic channelled decoration is missing. Based on these characteristic features, these ceramics can be related to the material of the north Transdanubian sites.

Radiocarbon dating

New radiocarbon measurements were obtained on three human skeletons from the Balaton-Lasinja graves at Veszprém-Jutasi út as part of the *Times of Their Lives* project (see Acknowledgements, and Table 1).

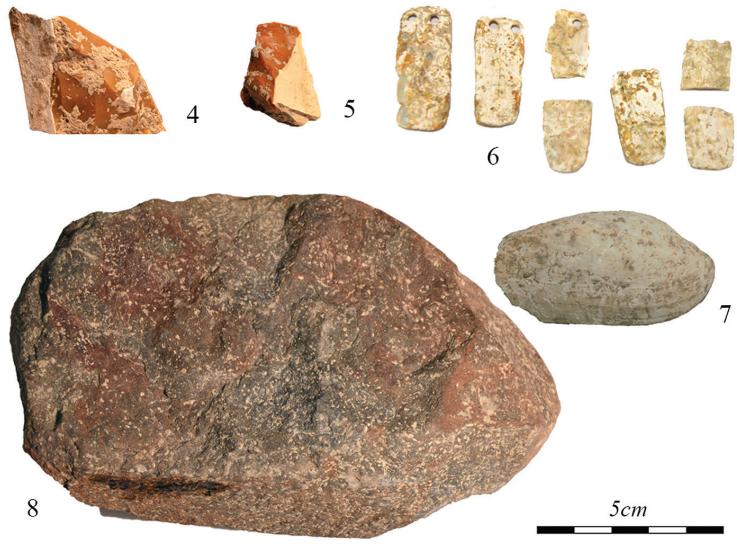

Fig. 4. Veszprém-Jutasi út, lithic artefacts and shell finds from grave 9.

The samples dated at the Curt-Engelhorn-Zentrum Archäometrie (CEZA), Mannheim (sample identifiers 'MAMS'), were prepared by gelatinisation and ultrafiltration (*Brown* et al. *1988*), combusted in an elemental analyser, graphitised and dated by Accelerator Mass Spectrometry (AMS) (*Kromer* et al. *2013*). The samples dated at the Scottish Universities Environmental Research Centre (sample identifiers 'SUERC'), East Kilbride, were also gelatinised, ultrafiltered and then graphitised and dated by AMS (*Dunbar* et al. *2016*).

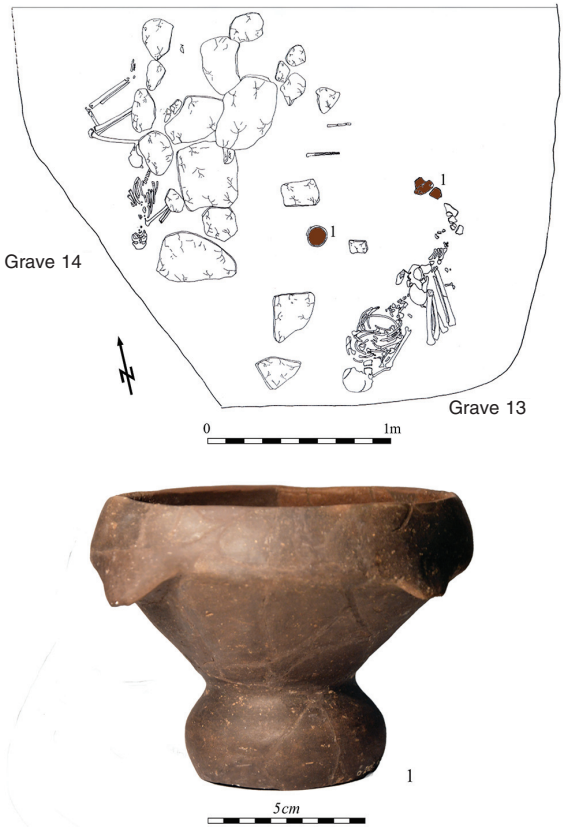

Fig. 5. Veszprém-Jutasi út, graves 13 and 14.

These measurements are conventional radiocarbon ages (*Stuiver, Polach 1977*). At CEZA they have been corrected for fractionation using $\delta^{13}C$ values measured by AMS. These values can include an element of fractionation introduced during the preparation and measurement of the samples in addition to the natural isotopic composition of the sample, and so they are not suitable for dietary analysis. For this reason, where sufficient material was available, subsamples of the dated gelatin prepared at MAMS- were analysed for $\delta^{13}C$ and $\delta^{15}N$ using IRMS at the Isotrace Facility, University of Otago Chemistry Department, using methods outlined by Beavan Athfield *et al.* (*2008.3*). At SUERC, $\delta^{13}C$ and $\delta^{15}N$ samples were prepared and analysed from sub-samples of the dated gelatin as described by Kerry Louise Sayle *et al.* (*2014*), and these $\delta^{13}C$ values were used for age calculation.

Groups of replicate radiocarbon measurements are available on two skeletons, both of which are statistically inconsistent at the 5% significance level (*Ward, Wilson 1978*) (Tab. 1). Those for Ve-9 are statistically consistent at the 1% significance level and have been combined before inclusion in the chronological models, but those from Ve-13 are significantly divergent. This degree of replication arises from attempts to resolve some differences between replicate measurements reported in August 2014 by Mannheim (MAMS-21328–41) and East Kilbride (SUERC-54631–4, SUERC-54638–44 and SUERC-54648–9) and is discussed further by Judit Regenye *et al.* (*2020.24*). Although the $\delta^{13}C_{AMS}$ value for MAMS-14829 is unusually depleted, the remaining three measurements are still significantly divergent (T'= 22.0, $T'(1\%)$=11.3, ν=2) and so, in the absence of contextual information suggesting which results may be in error, we have again incorporated a weighted mean of the results in our modelling.

Details of existing radiocarbon measurements from settlement features associated with ceramics of the Balaton-Lasinja phase are listed in Table 2, those of the preceding Lengyel III ceramic phase in Table 3, and those of the succeeding, related, Furchenstich phase in Table 4.

Laboratory number	Grave/Sample number	Material and context	Radiocarbon Age (BP)	$\delta^{13}C$ (‰) [AMS]	$\delta^{13}C$ (‰) [IRMS]	$\delta^{15}N$ (‰)	C:N ratio
MAMS-21338	Ve-9	Human bone, left femur from 8–9-year-old child inhumation in grave 9 with three diagnostic pottery vessels	5307±33	−18.4			
MAMS-23171	Ve-9	Replicate of MAMS-21338	5406±27	−19.6			
MAMS-14828	Ve-9	Replicate of MAMS-21338	5418±29	−24.7			
^{14}C age: 5384±17 BP, T'=7.4, T'(5%)=6.0, ν=2							
SUERC-54641	Ve-13 (i)	Human bone, right femur from 23–40-year-old male inhumation in grave 13 with one diagnostic pottery vessel and cut into feature 348, a settlement pit containing Lengyel III ceramics	5431±33		−19.2±0.2	10.1±0.3	3.2
MAMS-21339-1	Ve-13 (ii)	Replicate of SUERC-54641	5251±21	−19.6	−19.6±0.11	10.0±0.13	3.3
MAMS-21339-2	Ve-13 (ii)	Replicate of SUERC-54641	5279±26				
MAMS-14829	Ve-13	Replicate of SUERC-54641	5213±31	−30.4			
^{14}C age: 5281±14 BP, T'=27.9, T'(5%)=7.8, ν=3; $\delta^{13}C$: −19.5±0.1‰, T'=3.1, T'(5%)=3.8, ν=1; $\delta^{15}N$: +10.0±0.12‰, T'=0.1, T'(5%)=3.8, ν=1							
SUERC-54642	Ve-14	Human bone from grave 14 with diagnostic sherds in the fill, lying parallel with grave Ve-13 and cut into feature 348, a settlement pit containing Lengyel III ceramics	5384±33		−19.6±0.2	10.0±0.3	3.3

Tab. 1. Radiocarbon and stable isotopic measurements for Balaton-Lasinja graves from Veszprém-Jutasi út.

Radiocarbon calibration and reservoir corrections

Radiocarbon ages from fully terrestrial samples have been calibrated using IntCal20 (*Reimer* et al. *2020*).

The measurement on mussel shell from Balatonőszöd-Temetői-dűlő (KI-16690) probably has a freshwater reservoir effect derived from the nearby Lake Balaton. Unfortunately, no data are currently available for the freshwater reservoir in the lake, and so we use a value of 540±70 BP as calculated for Schela Cladovei on the Danube at the Iron Gates (*Cook* et al. *2001*).

Human bone can also exhibit a reservoir age, if people ate foods that did not derive entirely from the terrestrial biosphere. Accurate calibration in this case requires the proportions of different diet-sources in each individual to be estimated. This allows a mixed-source calibration curve to be constructed for each person, which incorporates the aquatic reservoir in the appropriate proportion for that individual. For this reason, source-proportional dietary modelling was undertaken for the dated human skeletons in this study. Existing pairs of radiocarbon measurements on human and animal bone from Neolithic and Copper Age graves in this region, however, are statistically consistent, suggesting that consumption of non-terrestrial foods by the population was probably negligible (*Bayliss* et al. *2016.Tab. 1; Jakucs* et al. *2016.Tab. 1; Raczky, Siklósi 2013. Tab. 1*). This does not mean, however, that particular individuals might not have consumed a larger component of freshwater resources.

Proportional dietary analysis for the Balaton-Lasinja skeletons from Veszprém-Jutasi út

The $\delta^{13}C$ and $\delta^{15}N$ isotopic values for burials Ve-13 and Ve-14 are from replicate measurements, and the weighted means (*Ward, Wilson 1978*) (Tab. 1) have been used in the analysis. As no stable isotopic values have been measured from Ve-9, the proportional diet estimates have been derived from the mean FRUITS (Food Reconstruction Using Isotopic Transferred Signals; *Fernandes* et al. *2014*) estimates for Veszprém burials for which there are stable isotope values (*Regenye* et al. *2020.Tab. 4a*).

The individual mixed-source calibration curve for each of the Veszprém burials incorporates the aquatic reservoir in the proportion suggested by the dietary estimates provided by the Bayesian mixing mo-

Laboratory number	Site	Material and context	Radiocarbon Age (BP)	δ13C (‰) [AMS]	δ13C (‰) [IRMS]	δ15N (‰)	C:N ratio	References
OxA-13784	Balatonszárszó-Kis-erdei-dűlő	Disarticulated *Sus scrofa domesticus*, right ulna, from feature B-5713, internal posthole of house A43	5356±34		−19.8±0.3	9.95±0.4	3.2	*Oross* et al. *2010.392*
deb-13379	Balatonőszöd-Temetői-dűlő	*"Pit 1099. Well 1: Grave 70, human (Boleráz) skeletons in fill of the well of the Balaton-Lasinja culture"*	4480±70		−20.6			*Horváth* et al. *2008. Tab. 1*
VERA-4806	Balatonőszöd-Temetői-dűlő	Unidentified animal bone from pit B-432	5000±40	−26.8±0.9				*Horváth* et al. *2014a. Tab. 2*
deb-2171	Győr-Szabadrétdomb	Unidentified animal bone from feature 29	5160±60		−20.25			*Figler* et al. *1997.Tab 2*
Bln-1206	Nagykanizsa-Sánc	Sample material and context unknown	4940±80*					*Kalicz 1995a.41*
Bln-1207	Nagykanizsa-Sánc	Sample material and context unknown	4990±80					*Kalicz 1995a, 41*
MAMS-44913	Mosonszentmiklós-Pálmajor	Cattle tibia, found in a closed assemblage including a clay horn which can be played as a musical instrument, several intact vessels and an intact cattle femur squeezed into the horn	5387±25	−21.1			3.2	*Bánffy, Egry forthcoming*

* Bln-1206–7 were published by Kalicz (*1995.41*), following information from a letter by Hans Quitta, with neither standard deviations, details of the material dated nor contextual information. Kalicz (*1982.10*) writes that radiocarbon dates for the Balaton-Lasinja culture are between 3040–2980 uncal bc ±80 y. Footnote 38 makes clear that this is based on the dates reported from Nagykanizsa-Sánc in Quitta's letter. We infer from this information that the quoted error on these measurements may have been ±80 BP.

Tab. 2. Radiocarbon and stable isotopic measurements associated with Balaton-Lasinja settlement features.

del FRUITS vβ2.0. FRUITS produces estimates of the mean percentage (and standard deviation) for each of the possible food sources making up the diet for each consumer.

To estimate the relationship between an individual's isotopic profile and the food sources that were likely available, we first create a FRUITS model starting with the 'baseline' isotopic values for foods from the isotopic averages of each likely food source. The FRUITS proportional dietary estimates were modelled on two diet proxies ($\delta^{13}C$ and $\delta^{15}N$) for the average isotopic data and its associated mean error for each of three general food sources – cereals, terrestrial herbivores and omnivores (cattle, sheep, and pigs), and freshwater fish. The cereals baseline used carbon and nitrogen values for archaeobotanical samples of wheat (n=12) and barley (n=6) from Nives Ogrinc and Mihael Budja (*2005*), and emmer wheat (n=1) and barley (n=3) from Amy Bogaard *et al.* (*2013*), producing mean cereal values and errors of –24.6±0.3‰ ($\delta^{13}C$) and +5.0± 0.4‰ ($\delta^{15}N$). The food baseline data are particularly robust for animal protein sources, as the data are drawn from sites within approximately 1000km of Veszprém-Jutasi út. Baseline values for terrestrial animals (pig, sheep, cow, n=89; $\delta^{13}C$ –20.3± 0.2‰ and $\delta^{15}N$ +6.9±0.2‰) are from faunal materials in the Starčevo, Sopot, and Lengyel sites at Alsónyék-Bátaszék (including 27 sets of analyses on terrestrial fauna provided by the Bioarchaeology Workgroup Mainz; *Bayliss* et al. *2016*). These values for terrestrial fauna complement mean isotope ranges cited from sites within 250km of our study area (*cf. Gamarra* et al. *2018; McClure* et al. *2020*), extending the potential geographical relevance of the baseline terrestrial fauna isotope values in this study. Isotopic values for archaeological freshwater fish were drawn from Olaf Nehlich *et al.* (*2010*; n= 3), Dušan Borić *et al.* (*2004*; n=12), and Alexandra Bayliss *et al.* (*2016*; n=4) and were further supplemented with six sets of carbon and nitrogen values on fish from Alsónyék-Bátaszék, also provided by the Bioarchaeology Workgroup Mainz. This

Laboratory number	Site	Material and context	Radiocarbon Age (BP)	$\delta^{13}C$ (‰) [IRMS]	References
deb-10274	Szengál-Teleki dűlő	Unidentified animal bone from pit 1, Lengyel III	5530±60	–20.3	*Regenye 2011.43*
deb-3365	Zalaszentbalázs-Szőlőhegyi mező	Unidentified charcoal from feature 5/2, –45cm	5728±58	–25.3	*Bánffy 1995*
deb-3378	–//–	Unidentified charcoal from feature 2, –80cm	5767±70	–25.8	*Bánffy 1995*
deb-3385	–//–	Unidentified charcoal from feature 4/2, –100cm	5720±71	–24.9	*Bánffy 1995*
deb-3379	–//–	Cattle tibia from feature 4, –85–90cm	5682±57	–21.8	*Bánffy 1995*
deb-3380	–//–	Cattle from feature 4, –90cm	5614±70	–20.8	*Bánffy 1995*
deb-8408	Szombathely-Metro	Unidentified animal bone, from foundation trench of house 1	5520±60		*Ilon 2004.27, Fig. 26*
deb-8486	–//–	Unidentified animal bone, feature 35	5590±60		*Ilon 2004.Fig. 26*
deb-8518	–//–	Unidentified animal bone, feature 19	5450±90		*Ilon 2004.Fig. 26*

Tab. 3. Radiocarbon and stable isotopic measurements associated with Lengyel III ceramics.

group of samples provided a final freshwater fish baseline value of $\delta^{13}C$ of –21.4±0.2‰ and $\delta^{15}N$ of +8.7±0.2‰.

The FRUITS proportional diet model also uses the metabolic enrichment of stable isotope values that occur in the course of building consumer tissue. This is known as an 'isotopic offset' between diet and consumer. We used an isotopic offset in the FRUITS model of 4.8±0.2‰ for $\delta^{13}C$ (*Fernandes* et al. *2014*), and for 6.0±0.5‰ for $\delta^{15}N$ (*O'Connell* et al. *2012*). The FRUITS dietary model also allows for further constraints on the calculations from *a priori* observations in the archaeological record and logical considerations. We had observed in a previous dietary analysis of populations at Alsónyék-Bátaszék (*Bayliss* et al. *2016.40–46*) that there was a possibility for the consumption of freshwater resources. We ran tests of the FRUITS model first using no prior information, and then with prior information weighting terrestrial protein over fish. The final version of the FRUITS model was modified, incorporating prior information that the proportion of terrestrial protein was greater than that of cereals which added weight

Lab. number	Site	Material and context	Radiocarbon Age (BP)	$\delta^{13}C$ (‰) [IRMS]	References
Bln-500	Keszthely-Fenék-puszta, Vasúti őrház	Charcoal (*Quercus* sp.), from pit Objekt 2, at 1.5m depth. Finds include lots of sherds of Gajary-type assigned by Kalicz (*1982.10, fn39*) to Balaton-Lasinja II–III group	4780±80		*Quitta, Kohl 1969. 241*
Bln-501	Keszthely-Fenék-puszta, Halászrét-Nádgazdaság agyagbányája	Charcoal (*Quercus* sp.), from big, multi-part pit complex. Sample at 1m depth in pit sector 2. Lower part of pit currently below water table. Finds include lots of sherds of Gajary-type assigned by Kalicz (*1982.10, fn39*) to Balaton-Lasinja II–III group	4890±80		*Quitta, Kohl 1969. 242*
Bln-502	Zalavár-Mekenye	Charcoal (*Abies* cf. *alba* Mill.), from settlement pit 13, lower down in fill at 1m below surface. Finds include white-painted late Lengyel sherds and undecorated sherds and associated copper smelting debris.	5400±80		*Quitta, Kohl 1969. 247*
KI-16690	Balatonőszöd-Temetői-dűlő	Mussel from pit B-1984	5210±40	–10.3±0.3	*Horváth* et al. *2014a.Tab. 2*
deb-2196	Győr-Szabadrétdomb	Unidentified animal bone from feature 251	4650±60	–20.89	*Figler* et al. *1997. Tab. 2*
deb-2194	–//–	Unidentified animal bone from feature 251	4850±60	–19.49	–//–
deb-2178	–//–	Unidentified animal bone from feature 510	4730±60	–20.81	–//–
deb-2213	–//–	Unidentified charcoal from feature 510	4630±60	–26.27	–//–
deb-2095	–//–	Unidentified animal bone from feature 589	4820±60	–20.11	–//–

Tab. 4. Radiocarbon and stable isotopic measurements associated with Furchenstich features and ceramics.

Grave	Sex	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Cereals	Terrestrial protein	Freshwater fish
Ve-9	Unknown	8–9 years	–	–	48.3±1.1%	50±1.2%	1.7±1.7%
Ve-13	Male	23–40 years	–19.5±0.1*	+10±0.21*	48.4±1.1%	49.9±1.2%	1.7±1.7%
Ve-14	Female	over 40 years	–19.6±0.2*	+10±0.3*	47.9±1.5%	49.9±1.5%	2.2±2.2%

Tab. 5. Proportional dietary estimates for the dated burials from Veszprém-Jutasi út, derived from the FRUITS analysis (*mean of values from Table 1).

to the higher $\delta^{15}N$ contribution of terrestrial meat in the diet.

The results of the FRUITS analysis for the individuals from Veszprém-Jutasi út indicates the population all had diets that were made up almost entirely of cereals and terrestrial protein, and that freshwater fish are a negligible contribution to the diet (Tab. 5).

Chronological modelling

The Bayesian chronological modelling has been undertaken using the program OxCal v4.4 (*Bronk Ramsey 2009*). The algorithms used are defined exactly by the brackets and OxCal keywords on the left-hand side of Figures 6 and 8 (http://c14.arch.ox.ac.uk/). The posterior density estimates output by the models are shown in black, with the unconstrained calibrated radiocarbon dates shown in outline. The other distributions correspond to aspects of the model. For example, the distribution "*start Veszprém Lengyel*" (Fig. 6) is the posterior density estimate for the start of Lengyel burial at Veszprém. In the text and tables, the Highest Posterior Density intervals of the posterior density estimates are given *in italics*.

Furnished inhumation burials from Veszprém-Jutasi út

The first model examines the dating of furnished inhumation burials at Veszprém (Fig. 6). Five furnished Lengyel graves have been dated (*Regenye* et al. *2020.Tab. 2*), four of which have been included in the correspondence analysis of Lengyel funerary ceramics (*Regenye* et al. *2020.Fig. 2*). Ve-5 is allocated to phase 2 of that seriation, and ve-2, ve-3, and ve-7 to phase 3. One further, dated but unfurnished, grave appears to belong to this period of activity (*Regenye* et al. *2020.Fig 5*).

The model illustrated in Figure 6 suggests that Lengyel burial at Veszprém began in *4950–4710 cal BC* (*95% probability; start Veszprém Lengyel*) (Fig. 6), probably in *4830–4725 cal BC* (*68% probability*). It ended in *4695–4485 cal BC* (*95% probability; end Veszprém Lengyel*) (Fig. 6), probably in *4670–4575 cal BC* (*68% probability*), having been used for a period of *30–245 years* (*95% probability; duration Veszprém Lengyel*) (Fig. 7), probably for *65–180 years* (*68% probability*). There was then an extended gap with no furnished burial on the site, which endured for a period of *20–490 years* (*95% probability; gap Veszprém Lengyel/Balaton-Lasinja* (Fig. 7), probably for *200–435 years* (*68% probability*).

Only three Balaton-Lasinja graves from Veszprém have radiocarbon dates, two of which are furnished with diagnostic pottery. The other has Balaton-Lasinja sherds in the grave fill, and is parallel to one of the furnished graves. The model shown in Figure 6 suggests that this period of burial began in *4565–4160 cal BC* (*93% probability; start Veszprém Balaton-Lasinja*) (Fig. 6) or *4150–4115 cal BC* (*2% probability*), probably in *4370–4180 cal BC* (*68% probability*). It ended in *4235–3575 cal BC* (*95% probability; end Veszprém Balaton-Lasinja*) (Fig. 6), probably in *4215–4010 cal BC* (*68% probability*), having been used for a period of *1–215 years* (*93% probability; duration Veszprém Balaton-Lasinja* (Fig. 7) or *230–260 years* (*2% probability*), probably for a period of *10–130 years* (*67% probability*) or *155–165 years* (*1% probability*).

The earlier Copper Age in western Hungary

The second model explores the context of the Veszprém cemeteries within the ceramic sequence of the earlier Copper Age in western Hungary (Figs. 8–11).

First, we consider the relationship between the end of Lengyel furnished burial (which is largely restricted to the eastern part of this region) and the start of Lengyel III ceramics, which do not appear in graves and are restricted to settlement contexts. Regenye *et al.* (*2020.Figs. 11–12*) present a model for a three-phase seriation of Lengyel graves, which we have recalculated using IntCal20 (*Reimer* et al. *2020*). This suggests that Lengyel furnished burial started to decline in *4770–4560 cal BC* (*95% probability; start end Lengyel 3*) (Fig. 11), probably *4750– 4635 cal BC* (*56% probability)* or *4610–4580 cal BC* (*12% probability*), and finally ended by *4605– 4460 cal BC* (*95% probability; end end Lengyel 3*) (Fig. 11), probably *4575–4505 cal BC* (*68% probability*).

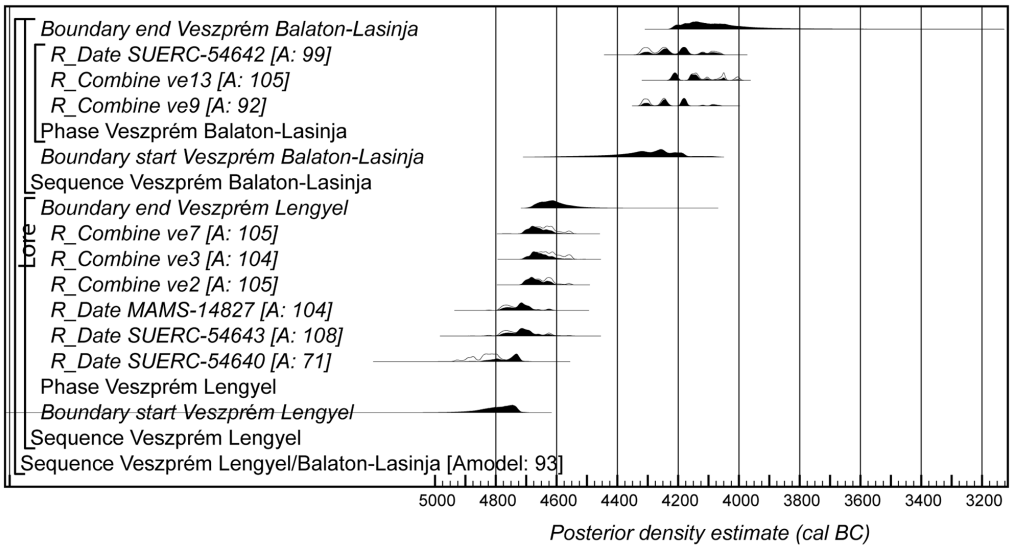

Fig. 6. Probability distributions of dates from inhumation burials at Veszprém-Jutasi út. Each distribution represents the relative probability that an event occurred at a particular time. For each of the dates two distributions have been plotted, one in outline which is the result produced by the scientific evidence alone, and a solid one which is based on the chronological model used. The other distributions correspond to aspects of the model. For example, "start Veszprém Lengyel" is the estimated date when the Lengyel cemetery was initiated. The large square brackets down the left-hand side of the figure along with the OxCal keywords define the overall model exactly.

There may then have been a short gap of *–55 –210 years* (*95% probability; gap Lengyel furnished graves/Lengyel III*; Fig. 10), probably of *30–155 years* (*68% probability*)[1].

The model shown in Figure 8 suggests that Lengyel III ceramics appeared in western Hungary in *4570–4360 cal BC* (*95% probability; start Lengyel III*; Fig. 8), probably in *4490–4390 cal BC* (*68% probability*). They were last used in *4445–4300 cal BC* (*95% probability; end Lengyel III*; Fig. 8), probably in *4415–4335 cal BC* (*68% probability*), having been used for a period of *1–155 years* (*95% probability; duration Lengyel III*) (Fig. 9), probably for *1–70 years* (*68% probability*). This apparently relatively short phase was succeeded by Balaton-Lasinja ceramics, probably with little or no gap: *1–165 years* (*95% probability; gap Lengyel III/Balaton-Lasinja*) (Fig. 10), probably *1–85 years* (*68% probability*).

The model suggests that Balaton-Lasinja pottery first appeared in *4400–4190 cal BC* (*95% probability; start Balaton-Lasinja*) (Fig. 8), probably in *4360–4255 cal BC* (*68% probability*). It ended in *3895–3585 cal BC* (*95% probability; end Balaton-Lasinja*) (Fig. 8), probably in *3790–3625 cal BC* (*68% probability*), having been used for a period of *280–610 years* (*95% probability; duration Balaton-Lasinja*; Fig. 9), probably for *355–540 years* (*68% probability*). This extremely long tradition was succeeded by a related pottery style, the Furchenstich. Again, there was probably little or no gap: *1–275 years* (*95% probability; gap Balaton-Lasinja/Furchenstich*) (Fig. 10), probably *1–140 years* (*68% probability*).

The Furchenstich style first appeared in *3770–3520 cal BC* (*92% probability; start Furchenstich*; Fig. 8) or *3460–3405 cal BC* (*3% probability*), probably

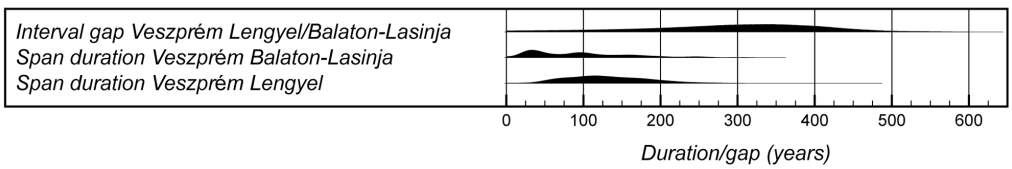

Fig. 7. Probability distributions of the durations of the cemeteries at Veszprém and the interval between them, derived from the models defined in Figure 6.

1 The negative part of this range reflects the *10% probability* that *start Lengyel III* was before *end Lengyel 3*, and thus that there was a period of overlap rather than a gap between these ceramic phases. It should be noted that our sample of radiocarbon dates for the Lengyel III phase (Tab. 3) is pitifully small and that these derive from only three sites. In these circumstances, the potential gap may be an artefact of our current dataset.

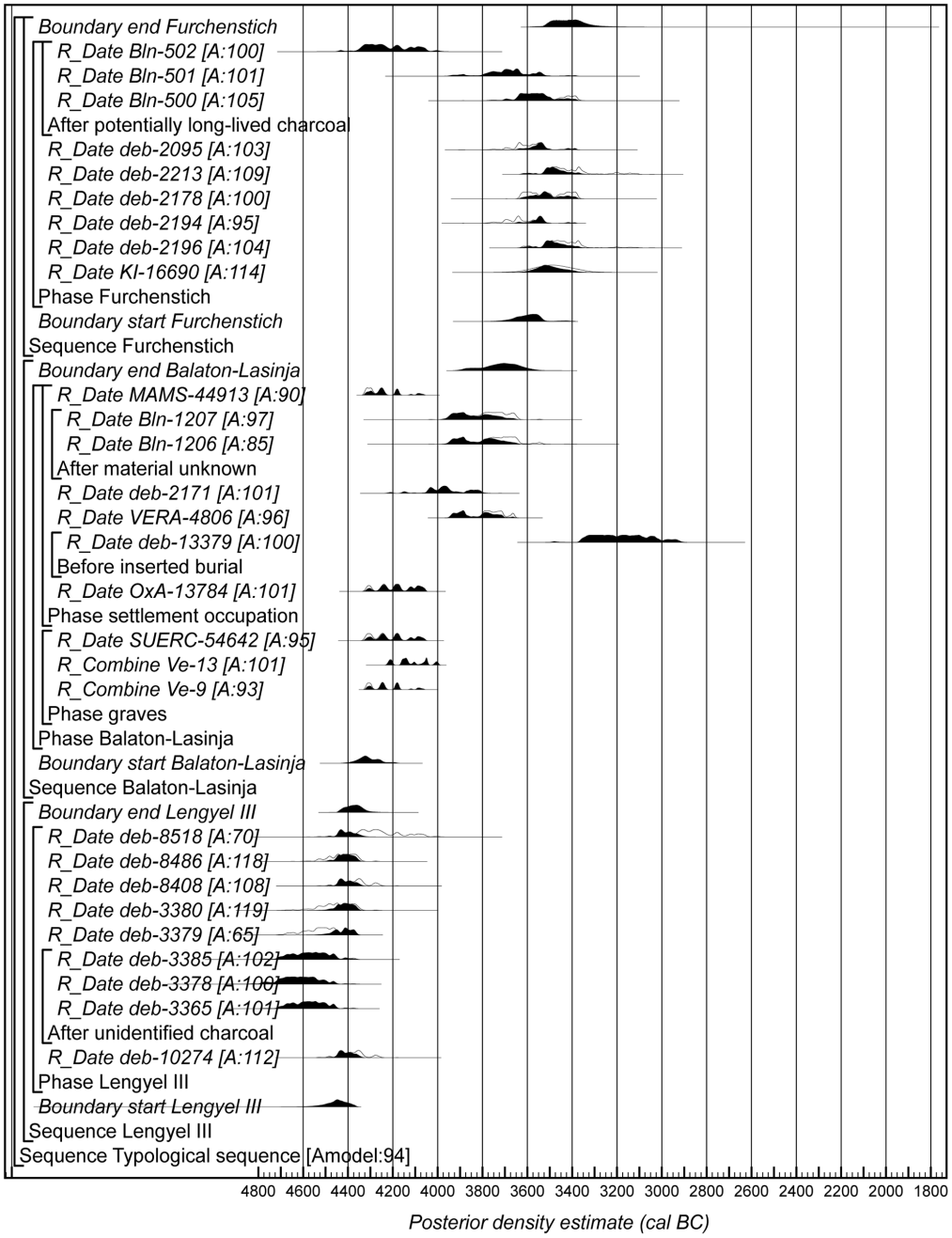

Fig. 8. Probability distributions of dates from the earlier Copper Age ceramic sequence in western Hungary. The format is identical to that of Figure 6. The large square brackets down the left-hand side of the figure along with the OxCal keywords define the overall model exactly.

in *3670–3545 cal BC* (*68% probability*). It ended in *3545–3125 cal BC* (*95% probability; end Furchenstich*) (Fig. 8), probably in *3485–3320 cal BC* (*68% probability*). Overall Furchenstich pottery was used over a period of *1–265 years* (*95% probability; duration Furchenstich*) (Fig. 9), probably for *60–210 years* (*68% probability*). Given the small number of radiocarbon dates currently available associated with the Furchenstich style, this ending may fall within the earlier part of this date range and is then compatible with the suggestion that this ceramic style was replaced by Boleráz pottery *c.* 3500 cal BC (*Furholt 2008*).

Figure 11 illustrates the outline chronology for the earlier Copper Age ceramics in western Hungary. These traditions span more than a thousand years, which brings into sharp relief the small number of radiocarbon dates on which this chronology is based. Nonetheless, it is striking that the Balaton-Lasinja tradition appears to have endured for much longer than the other ceramic styles.

Discussion

Great changes occurred across big swathes of Europe in the mid-fifth millennium cal BC. In the Carpathian basin, the previous system of tells and large agglomerated flat settlements came to an end. In the Vinča orbit, this process had probably begun around 4700 cal BC, as seen for example in the sequence of the Uivar tell in western Romania (*Draşovean* et al. *2017; Draşovean, Schier 2020; Bayliss* et al. *2020*). The great tell of Vinča-Belo Brdo itself was probably the latest tell in its area to be abandoned, around 4500 cal BC (*Tasić* et al. *2016; Whittle* et al. *2016*). In the Lengyel sphere of Transdanubia and beyond, the major settlement aggregations with substantial houses and large grave groups had also largely ended by the middle of the fifth millennium cal BC (*Bánffy* et al. *2016; Regenye* et al. *2020*). The largest known Lengyel aggregation, at Alsónyék-Bátaszék, had reached its peak size around 4700 cal BC, declining steadily from then until probably the 45th century cal BC (*Osztás* et al. *2016; Bánffy* et al. *2016*). In the broad, so-called Danubian distribution of the LBK and post-LBK, longhouses and longhouse settlements also largely came to an end in the mid-fifth millennium cal BC. One regional study, in Lower Alsace in the upper Rhine valley, suggests that the last longhouses there belonged to the Rössen phase, dating probably to the 46th–45th centuries cal BC (*Denaire* et al. *2017*). In another region, that of the Polish lowlands, the last longhouses were in use till the turn of the millennium (*Czerniak* et al. *2017*). These worlds have traditionally been studied by separate research communities, and as a result, while there are plenty of hypotheses about the causes of such changes, there has been little discussion about the convergent timings.

In the aftermath of these changes, a different lifestyle came into existence. This can be broadly characterised by a more dispersed settlement system, the existence of generally smaller settlements (in modern terminology hamlets rather than villages), often smaller groups of graves or cemeteries, less obvious

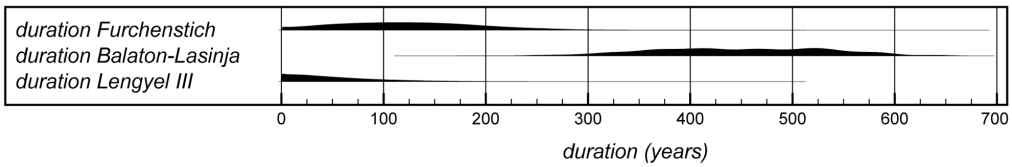

Fig. 9. Probability distributions of the durations of the earlier Copper Age ceramic traditions of western Hungary, derived from the model defined in Figure 8.

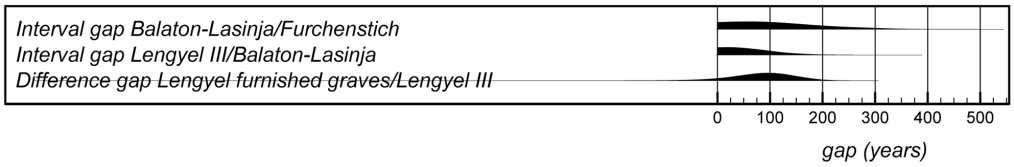

Fig. 10. Probability distributions of the gaps between the earlier Copper Age ceramic traditions of western Hungary, derived from the model defined in Figure 8.

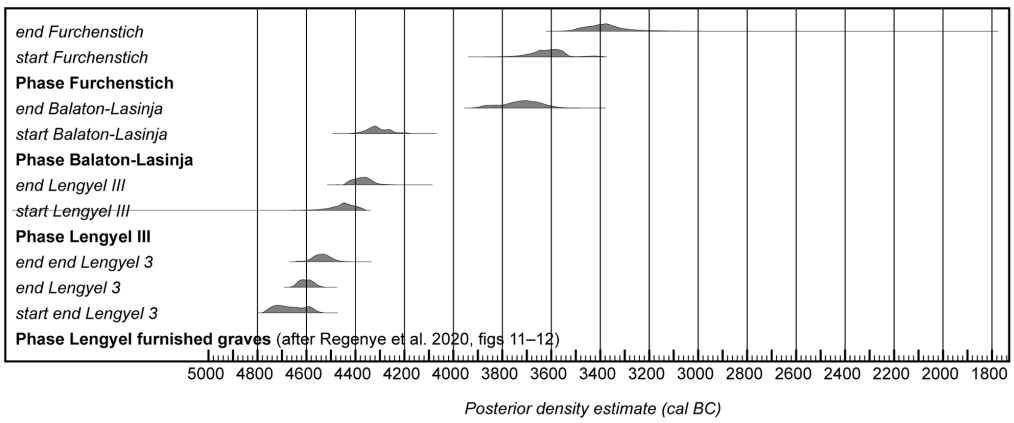

Fig. 11. Probability distributions of the key parameters for the earlier Copper Age ceramic traditions of western Hungary, derived from the models defined in Figure 8 and* Regenye *et al. (*2020.Figs. 11–12*; recalculated using IntCal20).

social differentiation, and finally an often less ostentatious material culture (*Parkinson 2006; Yerkes* et al. *2009; Siklósi, Szilágyi 2021.585*). There was, however, considerable variability across east-central, central and western Europe, perhaps hardly surprising given the size of the area. In some regions, houses remained a visible and frequently detected feature of settlements, while in others a more elusive pattern of pits and other remains is met with, for example across many parts of the TRB distribution. On the Great Hungarian Plain, cemeteries became a notable feature, seemingly supplanting the graves previous intermingled in tells and flat settlements; the grave ground of Tiszapolgár-Basatanya remains the largest (*Siklósi, Szilágyi 2021*), perhaps serving as some kind of regional centre (*Chapman 2020*). There are signs of differentiation within the grave goods at that cemetery (*Chapman 2020; Sofaer Derevenski 2000*), and further north there has been a long debate about the character of megalithic and related constructions. While a shift to plainer, or less exuberantly decorated, pottery characterises many regional sequences, the increasing appearance of copper and gold should be noted (*Siklósi, Szilágyi 2021.585*), and the production and distribution of jadeitite continued in the second half of the fifth millennium cal BC in western Europe (*Pétrequin* et al. *2012*).

From this deliberately broad perspective, the results presented here for Veszprém-Jutasi út and the post-Lengyel sequence in western Hungary contribute in the first place to the better establishment of more robust local and regional detail, mirroring the progress towards the same end being made on the Great Hungarian Plain (*Yerkes* et al. *2009; Siklósi, Szilágyi 2021*). It is, however, important to stress the varied quality of the dating samples currently available. The date estimates from Veszprém-Jutasi út and for the regional west Hungarian post-Lengyel sequence (Figs. 6–11) may suggest gradual change from the peak of earlier Lengyel activity (again, as seen at Alsónyék-Bátaszék), and then apparent considerable longevity for the Balaton-Lasinja phenomenon; the estimate for its duration, lasting several centuries (Fig. 9), is particularly striking. Although clearly incomplete and in need of much further research, the settlement record suggests much smaller settlement units than in the Lengyel heyday in Transdanubia, especially in its southeastern part. Interestingly, individual houses may not have been substantially smaller than in Lengyel times, and are archaeologically recognisable and visible. It is hard to quantify settlement density, but Balaton-Lasinja sites have been recurrent finds in both surveys and rescue excavations and appear to have existed in significant numbers. Finally, the contents of Balaton-Lasinja graves do not obviously suggest major social differentiation, though the presence of gold is again to be noted.

By way of contrast, the situation on the Great Hungarian Plain was different. According to recent analyses (*Raczky, Siklósi 2013; Siklósi, Szilágyi 2021*), the Tiszapolgár and Bodrogkeresztúr ceramic traditions probably overlapped in time, rather than being successive as previously thought; there may also be regional variation within the Plain (*Siklósi, Szilágyi 2021.622*). Associated material, such as heavy copper items and gold ornaments in Bodrogkeresztúr contexts (*Siklósi, Szilágyi 2021.585*), should therefore have been unevenly available or accessible across the communities of the Plain. The cemeteries themselves, though the majority are clearly much smaller than that of Tiszapolgár-Basatanya, are more prominent than those in the Balaton-Lasinja orbit, and might speak for local social differentiation, in the form say of established places for the dead of prominent social status. Date estimates currently available suggest that some of the smaller cemeteries at least were much shorter-lived than the long span originally attributed to Tiszapolgár-Basatanya (*Siklósi, Szilágyi 2021.586*). In these ways potentially less stable than the Balaton-Lasinja phenomenon, the emergent situation on the Plain may have also been shorter-lived than the Balaton-Lasinja sphere, with the Tiszapolgár-Bodrogkeresztúr phenomenon ending by the turn of the millennium (*Siklósi, Szilágyi 2021.619*). A possible contrast of this kind, however, will depend on the chronology of Transdanubia being confirmed and refined in the future.

The existing absolute chronological evidence reinforces earlier assumptions about the use of the Furchenstich pottery style as a phenomenon succeeding the Balaton-Lasinja era in western Hungary. That is, moreover, at a surprisingly late period, virtually in the second third of the fourth millennium cal BC. This conclusion must be tentative, however, until further radiocarbon dates are obtained on short-lived samples associated with Furchenstich pottery from a larger number of sites. Another significant implication is the apparent partial contemporaneity of Furchenstich with the Boleráz-Baden complex, over several centuries. The emergence of the Boleráz-Baden complex has been placed *c.* 3650 cal BC and the expansion of the Boleráz style *c.* 3500 cal

BC in the comprehensive study of Martin Furholt (*2008*). It must be emphasised here, however, that literally no scientific research targeting problems associated with communities using Furchenstich and related pottery styles has been carried out in Transdanubia in the past two decades. The only exception is probably the long-lasting settlement at Balatonőszöd-Temetői-dűlő where an abundance of features and finds represented the Baden complex, while the earlier Copper Age occupation was only a limited part of the prehistoric assemblage (*Horváth* et al. *2014a*). As a consequence, reliable radiocarbon dates associated with this kind of occupation are scarce. Therefore, only a very tentative picture can be presented of the development and the dynamics of early and mid-fourth millennium cal BC communities in the region. By contrast, large cemeteries of the Boleráz-Baden complex such as from Budakalász-Luppacsárda (*Bondár, Raczky 2009*) and Pilismarót-Basaharc (*Bondár 2015*) and extended sites like the afore-mentioned Balatonőszöd-Temetői-dűlő (*Horváth* et al. *2014b*) have been published, including statistically modelled series of radiocarbon dates.

Further research needs therefore to continue to pick away at these local and regional differences within the post-Lengyel and post-Vinča worlds. In the future, we need to expand our focus to neighbouring regions as well. A lot of new data have been obtained during rescue and other excavations in Croatia and Slovenia in the last decade. These have contributed greatly to the refinement of the Neolithic-Copper Age sequence in this region (*e.g., Balen, Drnić 2014; Čataj 2014; 2016; 2020; Kramberger 2014; 2020; McClure* et al. *2020*).

Finally, it is worth considering whether the emerging conditions of the later fifth millennium cal BC, seen here through the particular lens of Veszprém-Jutasi út, contribute to a better understanding of the circumstances in which the previous system of major settlement aggregation came to an end. That process has of course been much debated (among a host of others, see for example, *Tringham, Krstić 1990; Chapman 2000; 2020; Tripković 2010; Porčić 2011; Crnobrnja 2011; Müller* et al. *2013; Borić 2015; Bánffy* et al. *2016; Whittle* et al. *2016*), and many factors have been suggested. This is not the place to re-air all the issues, but it is an opportunity to reflect briefly on how what came after may enable further insight into some of the processes perhaps at work; a small-scale situation like Veszprém-Jutasi út may be valuable in this quest. Clearly, it is unlikely that the system of major aggregations just petered out, though it is the case that a gradual decline in numbers at Alsónyék-Bátaszék has been carefully documented (*Osztás* et al. *2016; Bánffy* et al. *2016*). It is much more likely that there was something unstable, with high social costs, making the maintenance of prominent places and large aggregations unsustainable in the long run. A favourite idea has been the rise of the individual household at odds with the wider community (for example, *Tringham, Krstić 1990; Borić 2015*), though the overt evidence for difference is generally hard to find, not helped by the lack of cemeteries in the Vinča culture or by the apparent paucity of signs of violence on the more than 2000 skeletons from Lengyel Alsónyék-Bátaszék (*Osztás* et al. *2016; Bánffy* et al. *2016*); successive burnings at the top of Vinča-Belo Brdo (*Tasić* et al. *2015*), or through the sequence at Uivar (*Draşovean, Schier 2020*), however, should be remembered. Perhaps situations like Veszprém-Jutasi út in Transdanubia help to support the idea of the importance of the single (if not necessarily autonomous) household, showing more individual social units in smaller and potentially simpler social settings. The apparent durability of the Balaton-Lasinja phenomenon may also indicate the success of this resolution of putative former social tensions. The situation on the Great Hungarian Plain, however, as described briefly above, may suggest that competition and local or regional rivalries had not entirely disappeared.

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Prehistoric stone disks from entrances and cemeteries of north-eastern Adriatic hillforts

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ABSTRACT – *The paper presents a group of four, approximately 0.5m large, stone disks from entrances or cemeteries of two protohistoric hillforts of north-eastern Adriatic. The disks, having a sparse chronology with the exception of one dated to the Middle Bronze Age, show flat and plain surfaces or covered with sub-circular depressions. One disk shows two larger cup-marks at the centre of both faces. They are interpreted as ritual artefacts based on the association with sacred settlement locations and comparisons with similar coeval stones found mainly close to citadel entrances, burials and thresholds in the Aegean area and Anatolia.*

KEY WORDS – *north-eastern Adriatic; hillforts; stone disks; cup-marks; SfM photogrammetry; Bronze Age religion*

Prazgodovinski kamniti diski z vhodov in grobišč na gradiščih na severovzhodnem Jadranu

IZVLEČEK – *V prispevku predstavljamo štiri približno 0,5 m velike kamnite diske z vhodov oziroma grobišč na dveh prazgodovinskih gradiščih na severovzhodnem Jadranu. Diski so, razen enega, ki sodi v srednjo bronasto dobo, slabo datirani. Vsi so ploščati z gladkimi površinami ali prekriti s polkrožnimi vdolbinami. Na enem sta v sredini ploščatih delov kroglasti vdolbini. Interpretirani so kot obredni predmeti, povezani s svetim mestom naselbine. Primerjamo jih s sočasnimi kamni, najdenimi blizu vhodov v citadele, grobove in prehode v Egejskem prostoru in v Anatoliji.*

KLJUČNE BESEDE – *severovzhodni Jadran; gradišča; kamniti diski; kroglaste vdolbine; SfM fotogrametrija; bronastodobna religija*

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Introduction

The Karst plateau and Istrian peninsula at the north-eastern shore of the Adriatic Sea (Fig. 1) are marked by the presence of hundreds of protohistoric settlements, generally located on hilltops. These sites, protected by dry-stone walls, locally called *castellieri, gradine* or *gradišča*, featured clear originality and cultural unity in pottery production, architectural models, defensive systems and funerary practices. They were settled for a very long time, spanning from the late Early Bronze Age (EBA), approximately between 1800 and 1650 BC, to the late Iron Age (IA; *Mihovilić 2013; Borgna* et al. *2018*). The formation and rising of *castellieri* chronologically corresponds to the EBA II in the Italian relative chronological system (*Cardarelli 2009*) and to the BZ A2 in the Central-Europe Reinecke's system (*Hänsel 2009*). Their origin is still debated. The complex fortified entrances, the inner-space subdivision and settlement layout of some of them, *e.g.*, Monkodonja/Moncodogno (hereafter Monkodonja) hillfort in Istria, together with some peculiar ceramic and metal artefacts, such as pottery tripods and bronze knives with two rivet holes, suggest that the first Istrian settlements had direct contacts with the eastern Mediterranean (*Hänsel* et al. *2015*). However, other archaeological artefacts, such as the so-called enigmatic tablets, defined also as *Brotlaibidole*, and some types of pottery vessels, show that Istria was also connected to the Pannonian-Carpathian area (*Hänsel* et al. *2015; Borgna* et al. *2018*). Other pottery materials suggest connections with northern Italy and Apulia, too (*Hänsel* et al. *2015*).

Considering the funerary practices, small cemeteries close to or within the hillfort fortifications and burial mounds are the main funerary contexts at least from the EBA to the later Bronze Age phases. In more detail, single or small groups of burials have been identified next to the gates of settlements and/or within the ramparts. Recent radiocarbon dates obtained from two individuals buried in a small monumental cemetery found next to the main fortified entrance at Vrčin/Mt. Orcino (hereafter Vrčin) in southern Istria (the so-called *sepolcreto gentilizio*, consisting of about 20 cist tombs) point to a time span approximately between about 1700 and 1200 BC (*Battaglia 1958; Cupitò* et al. *2018*). Cist tombs included within stone platforms very similar to those from Vrčin are known from the Gradina hillfort on Veliki Brijun/Brioni Maggiore island (hereafter Veliki Brijun; *Vitasović 2002; 2005; Buršić-Matijašić, Žerić 2013*). At the Monkodonja hillfort, two cist tombs of similar chronology have been identified next to the western entrance (*Hänsel* et al. *2015*). The radiocarbon dating of some of the human remains from Monkodonja covers approximately the period between 1900 and 1600 BC (*Hänsel* et al. *2015*). A similar cist tomb has been discovered at the Gradac-Turan hillfort located along the eastern Istrian coast (*Mihovilić 1997; Buršić-Matijašić, Žerić 2013*).

Burial mounds have been found in the Karst and Istria in the surroundings of several hillforts, such as the tumuli of Mušego near the settlement of Monkodonja (*Mihovilić* et al. *2012*), those close to the Vrčin hillfort (*Battaglia 1958*) or the one excavated close to Barbariga (*Codacci-Terlević 2012*). Generally, as for burial mounds excavated in other part of Istria, they feature one or more depositions within stone cists covered by earth and stone caps.

In this contribution, using structure from motion (SfM) photogrammetric techniques, we present a group of four stone disks associated with entrances or Bronze Age cemeteries of two hillforts, Rupinpiccolo and Gradina, on Veliki Brijun, located in the Trieste Karst (Italy) and in the Brijuni/Brioni islands facing the southern Istria (Croatia), respectively (Fig. 1).

Rupinpiccolo/Repnič hillfort

The Rupinpiccolo/Repnič hillfort is located in the southern side of the central Karst ridge, which develops through the Karst plateau with a Dinaric orientation and approximately marks the border between Italy and Slovenia (Fig. 1). The area belongs to the Cenomanian to Turonian Repen Formation consisting of bedded and massive, partly re-crystallized, limestone containing chert and with displaced, locally broken and rounded rudist shells (*Jurkovšek* et al. *2016*).

The ruins of its massive defensive structures were already noticed at the beginning of last century (*Marchesetti 1903*). The first archaeological investigations were carried out several decades later in 1965, 1970–1974, 1986 and 1988 (*Cannarella 1970; 1975; Maselli Scotti 1988*), making it possible to uncover the entire surviving fortification system. The site, built along the slope of a modest hill, shows a sub-rectangular plan but its western side has been destroyed by a modern quarry. It was defended by a massive rampart, up to 7m tall, built with two main external stone alignments with the intervening space filled with smaller stones and partially supported

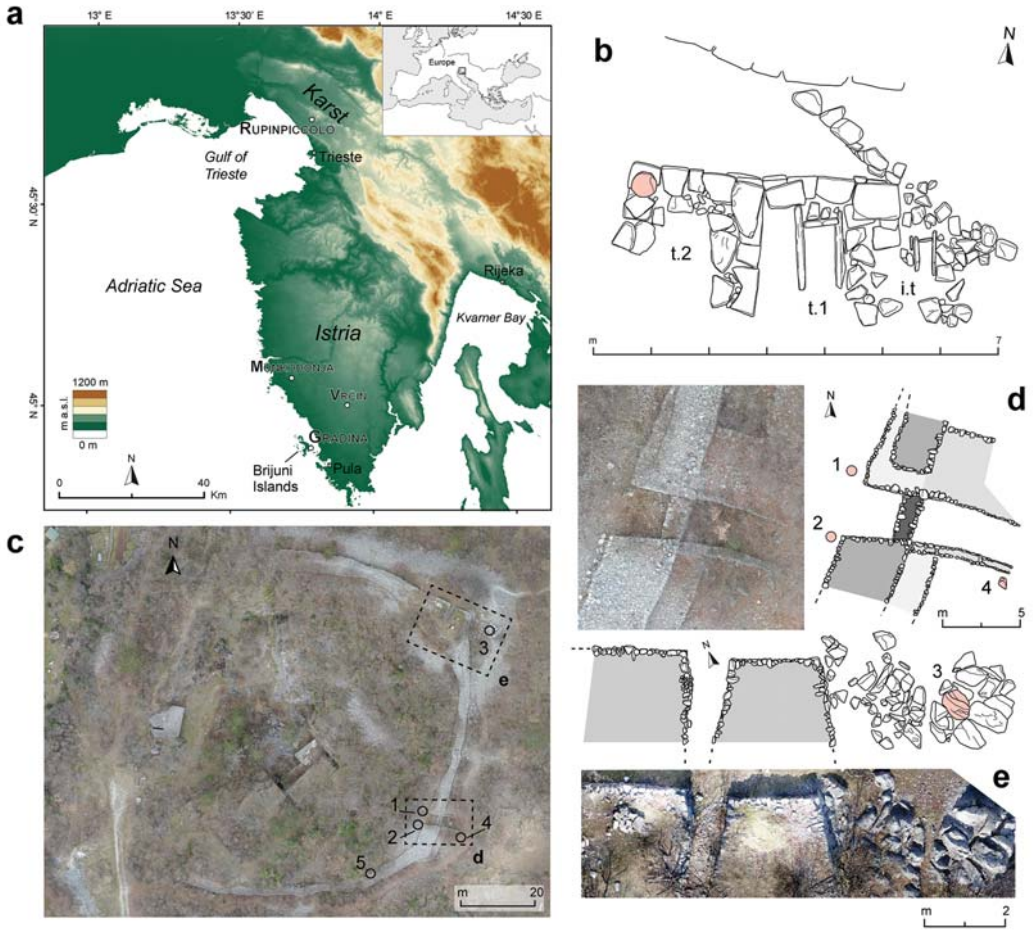

Fig. 1. The Rupinpiccolo and Gradina on Veliki Brijun hillforts.* a *Position of Rupinpiccolo and Gradina on Veliki Brijun hillforts and other main sites mentioned in the text.* b *Plan of the Bronze Age cemetery (t1-t.2, tombs 1-2; i.t., infant tomb) of Gradina on Veliki Brijun hillfort with the Gradina disk 2 in light red.* c *Drone-derived orthophoto of the Rupinpiccolo hillfort with the position of the stone disks (1–2), ancient quarrying sites (3–4) and a block of the rampart with a wedge hole (5).* d-e *south-eastern and north-eastern gates of Rupinpiccolo, respectively.

by lower stone reinforcements. Two entrances have been discovered approximately at the north-eastern and south-eastern corners. The first one is located on the hilltop and is about 2m tall, while the southern one is larger, about 3.2 m, externally delimited by a corridor-like structure and walled up in ancient times. Remains of four inner transversal terraces, probably built to support the dwellings, have been identified.

According to available data, the stones used to build the fortification, including massive blocks up to about 3m wide, were taken from the local limestone outcrop which is broken in many parts, just outside the rampart. In addition, chisel marks and a wedge hole were identified a few meters east of the north-eastern corner of the fortification (*Priuli 1977*). The use of such huge blocks is not reported in other sites of the Trieste Karst, and makes Rupinpiccolo a unique context.

Based on the typology of ceramic finds, Rupinpiccolo was firstly dated to the IA (*Cannarella 1975*), then to a period spanning from the Late Bronze Age (LBA) to the advanced IA (*Maselli Scotti 1982; 1983*). However, Bronze Age materials were only partially published, and our revision of pottery finds has allowed to identify pottery shards dating back to the EBA/initial Middle Bronze Age (MBA; see *infra*). No traces of a later Roman occupation of the site have been identified (*Cannarella 1975*). Archaeological survey (*Bernardini 2012*) and airborne laser scanner investigations (*Bernardini* et al. *2013; Vinci, Bernardini 2017*) have revealed that Rupinpiccolo is not isolated, but is part of a small-scale cluster of four hillforts.

Gradina on Veliki Brijun/Brioni Maggiore

The Gradina hillfort, also known as Monte Castellier, is located on the eastern side of the Veliki Brijun is-

land in front of southern Istria (Fig. 1). Veliki Brijun is part of the Upper Albian to Middle Cenomanian carbonate succession of southern Istria (*Tišljar* et al. *1998*).

The hillfort is composed of three concentric ramparts extending over a surface of more than seven hectares (*Vitasović 2002; 2005*). Already recognized more than a century ago (*Puschi 1898; Marchesetti 1903*), it was investigated by Anton Gnirs (*1925*), who identified an entrance in the north-western part of the upper rampart and, later, by Boris Baćić and Anton Vitasović (*2002; 2005*). These last researchers excavated the entrance previously identified, revealing a complex structure designed to defend the access to the site. They also investigated other structures and a small cemetery next to the external side of the upper rampart, composed of a few cist tombs within platforms divided by low walls (Fig 1B; *Vitasović 2002; 2005; Buršić-Matijašić, Žerić 2013*). The Gradina entrance finds significant comparisons in Bronze Age hillforts of Istria, such as Monkodonja (*Hänsel* et al. *2015*), while the small cemetery is very similar to the Vrčin necropolis, recently radiocarbon dated to between about 1700 and 1200 BC (*Cupitò* et al. *2018*). The available data suggest that the Gradina on Veliki Brijun was settled for a long time span, at least from the late EBA and the IA (*Vitasović 2002; 2005*).

Materials and methods

Identification of the stone disks and related archaeological evidence

The stone disks 1 and 2 from Rupinpiccolo were uncovered during the excavations carried out in the 1970s close to the inner side of the south-eastern entrance (*Cannarella 1970; 1975*), but they were not recognized as valuable artefacts and were left on site (Fig. 1). Since the identification of the disks by Federico Bernardini, all the area has been carefully and repeatedly surveyed, in order to identify possible chisel marks and wedge holes on blocks of the rampart, similar to those identified on the disks (see *infra*) and on the karst outcrops just next to it. This research confirmed the presence of chisel marks and a wedge hole on the hilltop (*Priuli 1977*) (Fig. 1 and supporting Fig. 1A) and led to the identification of wedge hole remains on the karst outcrop next to the southern wall of the corridor-like structure in front of the south-eastern entrance (Fig. 1 and supporting Fig. 1B) and on a block of the rampart (Fig. 1 and supporting Fig. 2). The outcropping rocks with traces of wedge holes and chisel marks on the hilltop and close to the entrance were buried under the ruins of the rampart and brought to light by the archaeological excavations (*Priuli 1977*).

Stone disk 1 from Gradina on Veliki Brijun was discovered during the excavation of the entrance of the upper rampart and was preliminarily described and recognized as an artefact with a probable ritual value (*Vitasović 2005*). Stone disk 2 was identified during a visit to the small Bronze Age cemetery of the hillfort in 2019 by Federico Bernardini. It lies on the eastern side of the low wall that delimits a tomb (Fig. 1B).

Drone structure from motion photogrammetry

A drone survey of the whole Rupinpiccolo site was performed in 2017 in order to produce orthophotos and plans of the site, taking advantage of the low and sparse vegetation (*Eltner* et al. *2016*). Two separate flights, with the camera aligned perpendicular to the flight path and with a tilt angle of 45 degrees, respectively, were planned with FlightPlanner software (AeroScientific, Blackwood, Australia) to maintain a constant ground sample resolution (GSR) and optimize the area coverage. Drone pictures were taken using a DJI Mavic drone (DJI, Nanchan District, Shenzen, China) capable of providing 12Mp files with a zoom lens equivalent to 24–48mm. Working with a medium-long focal lens instead of a wide angle allowed us to perform higher flights above the vegetation and maintain a high ground resolution (12.7mm/pixel) over an area of 46 953m^2. In order to reduce the flight time, jpeg files were saved, cloudy days were preferred and almost no shadows were registered. A total of 414 orthogonal images and another series of 94 images with the same focal length but different angulations and ground resolutions were taken and processed using Agisoft Metashape (Agisoft LLC, St. Petersburg, Russia, 2019). The images were aligned, and a sparse point cloud generated using high quality settings. Thickening the cloud was done using the Dense Cloud algorithm, which was run at high resolution to provide a large number of points, suitable for DEM generation.

Such an approach was not applied at Gradina on Veliki Brijun because the area is covered by dense evergreen vegetation.

Terrestrial structure from motion photogrammetry

The terrestrial structure from motion (SfM) approach was applied to produce a plan of the Gradina on Veliki Brijun cemetery and high-resolution 3D models

of the stone disks (*Verma* et al. *2019; Porter* et al. *2016*), a Rupinpiccolo rampart block with wedge-hole remains, the Rupinpiccolo quarrying sites and a block from the Bronze Age Vrčin cemetery in Istria (Croatia). A full frame 21 megapixel camera was used with a 17mm lens, and raw format images were taken in order to produce files with low contrast capable of generating point clouds of even dark spots.

A total of 56 images of the Gradina on Veliki Brijun burial site, 270 images of the Rupinpiccolo quarrying site east of the north-eastern gate, 91 images of the Rupinpiccolo rampart block with two symmetrical half-wedge holes and 65 images of the block from Vrčin cemetery were acquired.

For the stone disks, two series of pictures representing both sides of the artefacts and their edges were taken to ensure the correct alignment. When necessary, a flashlight was used to achieve better visibility in the shadows and avoid uneven lighting (*Menna* et al. *2016*). Finally, a colour reference was used to calibrate colours during postproduction and to scale the model. A total of 98 and 96 images of Rupinpiccolo stone disk 1 faces, 104 and 125 images of Rupinpiccolo stone disk 2 faces, 113 and 134 images of Gradina on Veliki Brijun stone disk 1 faces and 38 and 82 images of Gradina on Veliki Brijun stone disk 2 faces were taken.

All the acquired images were processed using Agisoft Metashape (Agisoft LLC, St. Petersburg, Russia, 2019), as described for the drone photogrammetry of Rupinpiccolo. In addition, to remove outliers and improve the overall quality of the models, after sparse cloud generation the gradual selection tool was applied to remove non-correctly aligned pictures. After separating the sparse and dense cloud generation of the stone disk faces, manual alignment of the two clouds selecting homolog points along the stone edges was performed just before the mesh generation and texturing.

The large number of pixels and the high dimensionality of the CCD sensor used provided high resolution models: Gradina on Veliki Brijun cemetery: 10.7 mm/pixel; Rupinpiccolo rampart block: 0.254 mm/pixel; quarrying site: 12mm/pixel; Vrčin block: 1.68

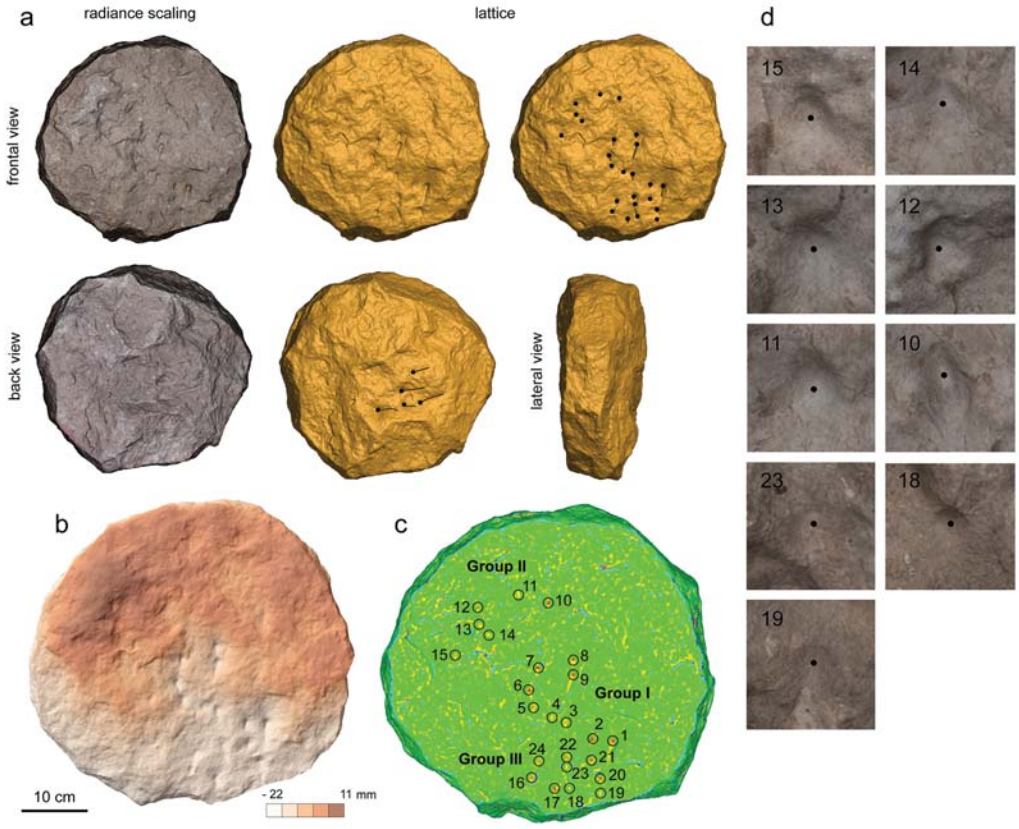

Fig. 2. Rupinpiccolo stone disk 1. **a** ***Radiance scaling and lattice visualizations of the disk with chisel marks highlighted in black (full circles correspond to the bottom of the chisel marks).*** **b** ***Digital elevation model of the frontal face of the disk.*** **c** ***Curvature map of the disk with chisel marks indicated by black circles and numbers. d Enlarged view of chisel marks 10–15, 18–19 and 23. The other chisel marks are clearly visible in Fig. 3.***

mm/pixel; Rupinpiccolo stone disks 1 and 2: 0.114 and 0.104mm/pixel, respectively; Gradina on Veliki Brijun stone disks 1 and 2: 0.111 and 0.627mm/pixel, respectively.

Elaboration of 3D models

The obtained 3D models were visualized and rendered by using MeshLab 2020.03 (*Cignoni* et al. *2008*) in order to enhance artificial features, such as chisel marks and wedge traces, and bioerosional evidence detected on the frontal face of the disk 1 from the Gradina on Veliki Brijun hillfort. Surface features have been enhanced applying radiance scaling, and/or lattice plugins. The radiance scaling technique makes it possible to enhance shape details such as convexities and concavities (*e.g., Vergne* et al. *2012*), while the lattice shader makes it possible to detect surface details by removing the colour and regulating the light direction (*e.g., Cassen* et al. *2014*). In order to enhance the bottom of the chisel marks of stone disk 1 from Rupinpiccolo, the plugin Colorize curvature (APSS) was applied using the default parameters, with the exception of the filter scale which was set at 4.

Typological analysis of Bronze Age pottery and initial occupation of Rupinpiccolo

Bronze Age materials from Rupinpiccolo have only been partially published and, for this reason, we have reviewed the pottery finds from the site kept in the Soprintendenza Archeologia Belle Arti e Paesaggio del Friuli Venezia Giulia.

Results

Rupinpiccolo stone disks

Two disks, carved from the local massive limestone belonging to the Repen Formation (*Jurkovšek* et al. *2016*), have been identified next to the south-eastern gate of the Rupinpiccolo hillfort (Trieste Karst, Italy) (Fig. 1).

Rupinpiccolo stone disk 1

The Rupinpiccolo disk 1, about 50cm wide and 20cm thick, was carved by using a metal point chisel and a hammer. Producing a rounded disk from very massive and compact limestone is not a simple task, since advanced stone-working skills are required. The stone has a relatively flat upper face showing numerous chisel marks arranged in patterns (Figs. 2–3). The depth of the chisel marks ranges from about 20 to 1mm in those more severely affected by weathering processes. The diameter of the chisel marks ranges from about 10 to 5mm with most of them being about 7mm. This suggests that the original point of the chisel was about 6–7mm in diameter.

The relatively flat morphology of the frontal surface of disk 1 was probably achieved by centripetal flaking using a precursor. The position of the chisel marks corresponds to limited portions of the disk upper surface, suggesting they were not due to surface flattening processes. This is also shown by the digital elevation model of the frontal surface of the disk (Fig. 2B), where some marks were produced on the highest portion of the surface but without making it flatter, and the others, located at the lowest portion of the stone, have produced an irregular depression. Moreover, the very small distance between some marks (*i.e.* less than 2cm) further supports the idea that they were intentionally created to reproduce a pattern.

The chisel marks are highlighted in the curvature map of the disk due to their hemispherical shape, which separate them well from the other surfaces of the disk (Figs. 2C and 3). They are iso-oriented and were likely created by a right-handed person holding an oblique metal chisel with the left hand and a hammer with the right one.

Considering the north-eastern Adriatic region, the use of bronze tools to work limestone is documented in the cemetery of Vrčin hillfort in Istria covering approximately a time span between 1700 and 1200 BC (*Battaglia 1958; Cupitò* et al. *2018*; see *infra*). Most of the cist tombs are included within platforms delimited by low walls made of well-shaped blocks which show clear marks produced by a metal point chisel (*Battaglia 1958*; supporting Fig. 3), similar to those found at Rupinpiccolo.

Rupinpiccolo stone disk 2

The Rupinpiccolo stone disk 2 was found close to stone disk 1 (Fig. 4). They share the same raw material, size (about 50cm large and 30cm thick) and shape, but its frontal surface is very flat and without any chisel marks (Fig. 4). To obtain such a flat surface a rock with a very regular bedding plane was selected, extracted and carefully worked. Unlike the other stone, disk 2 still has the remains of two different half-wedge holes that made it possible to shape the artefact. One of them, originally part of a complete hole with a triangular cross-section, is about 12cm wide and 6cm deep and still preserves faint parallel and oblique chisel marks on its surface (Fig. 4, black arrows and lines). It develops on the lateral

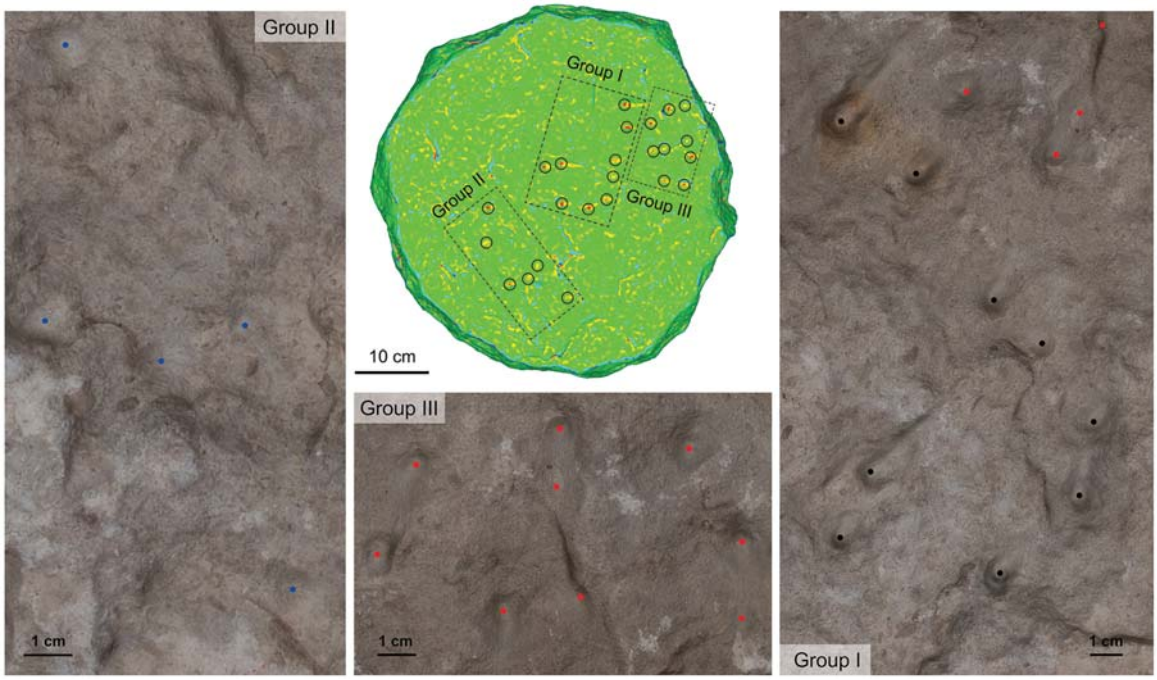

Fig. 3. Curvature map of the frontal face of the Rupinpiccolo stone disk 1 and enlarged views of the chisel marks divided in three groups (I-III). Chisel marks of Group I are indicated by black circles, those of group II (with the exception of one mark which is not shown) by blue circles and those of group III by red circles.

surface of the disk from the frontal surface towards the bottom of the disk. It was likely opened up to separate the block from the outcrop. The other half-wedge hole, about 15cm wide and 7cm deep, shares a similar cross-section and chisel marks but it is located on the bottom surface (Fig. 4, grey arrows and lines). It was opened to reduce the thickness of the disk. The presence of such wedge holes is significant, as it makes it possible to connect the disks with the quarrying sites used to build the rampart. After the production of the rough stone, it was carefully retouched by using a hammer to make the frontal surface round.

Typological analysis of Bronze Age pottery and initial occupation of Rupinpiccolo

Based on our review of the pottery assemblage from Rupinpiccolo, the initial occupation of the site is likely to be placed during the late EBA/MBA.

In particular, one elbow (*a piastra*) shaped handle with straight upper profile (Fig. 5.1), one fragment of handle with a large central impression (Fig. 5.2) and another *a lingua* pointing up handle (Fig. 5.3) all refer to typical *castellieri* types well attested in the Istrian peninsula, the Trieste Karst and Friuli between late EBA-initial MBA (*e.g., Urban 1993. Pl. 1. 2–3; Mihovilić 1997.Pl. 1.1 and 10; Hellmuth Kramberger 2017.Pl. 100.8–10*).

The base of a bowl decorated with rectilinear furrows on the external side (Fig. 5.4) points to a similar chronological span. This decoration refers to a cruciform-like set of motifs, probably recalling the solar symbolism associated with pottery finds (generally to the external base of bowls and cups) widespread in several coeval contexts from the North Adriatic (Trieste Karst, Istria and Kvarner), the Po plain and the adjacent peri-Alpine zone and the Pannonian-Danubian region (*Hellmuth Kramberger 2017. 161–168*). The best comparisons for the Rupinpiccolo base are found at the hillfort Gradac-Turan in Istria (*Mihovilić 1997.Pl. 1.3*).

A generic chronology pointing to the MBA can be proposed for some relatively small globular bowls and jars with everted rims, sometimes decorated with a circular knob under the rim (Fig. 5.5–7), well attested in the *castellieri* assemblages (*Cardarelli 1983.Pl. 17, type 71 and Pl. 18, type 6*) and very common at several sites in the Trieste Karst and Istria (*e.g., Hellmuth Kramberger 2017.Pl. 32.2*).

Finally, a carinated bowl (Fig. 5.8), a jar with a thick crown-like rim (Fig. 5.9) and a handle with a deep circular impression (Fig. 5.10) find good comparisons with types in use between the final MBA and the first centuries of the LBA (*Cardarelli 1983.Pl. 18, type 97a, Pl. 19, type 14; Hellmuth Kramberger 2017.Pl. 20.1*).

Chronology of Rupinpiccolo disks

The pottery assemblage from Rupinpiccolo shows that the hillfort was probably in use from about 1800/1650 to 400 BC. The disks can only be safely referred to this long time-span (the original finding context was not recorded in detail during excavations), but several data suggest they can be lined to an early building phase of the rampart. The half-wedge holes on disk 2 and chisel marks on disk 1 can be associated with identical stone-cutting marks identified next to the external face of the rampart (Fig. 1.C, locations 3–4) and in one large block of the rampart itself (Fig. 1.C, location 5). These stone-cutting marks do seem to be related to the building of the rampart itself.

● Location 3 of Fig. 1.C. East of the north-eastern gate of the Rupinpiccolo hillfort, an area covering about 16 square meters, that before excavations was buried under the ruins of the rampart, is characterized by outcropping rocks showing numerous fractures produced by the extraction of blocks to build the rampart (Fig. 1.C,E, location 3). Chisel marks, interpreted as a representation of a halberd (*Priuli 1977*), and a wedge hole were already identified on the face of a large outcropping rock in the 1970s (supporting Fig. 1.A). An accurate re-examination of the rock and the elaboration of its 3D model have made it possible to identify a line of additional chisel marks parallel to the handle of the putative halberd and many other previously unreported marks on the adjacent eastern rock face. The wedge-hole is complete and is identical to those identified on stone disk 2, showing a triangular cross-section and similar dimensions (about 20cm wide and 7cm deep). The chisel marks present on both wedge-holes and the other surfaces of the rock are comparable to those identified on the stone disks, likely produced by a point chisel. The position of chisel marks and wedge-hole suggest that all of them are related to an aborted attempt to extract a stone block after a first block was successfully obtained. The putative halberd, located opposite to the wedge-hole, seems more likely a quarry mark related to the extraction activity.

● Location 4 of Fig. 1.C. An additional half-wedge hole has been identified on an outcrop next to the southern wall of the corridor-like structure in front of the south-eastern entrance (Fig 1.C,D, location 4 and supporting Fig. 1.B). It is also very similar to those present on stone disk 2. Originally part of a complete hole with a triangular cross-section, it is larger (about 40cm wide and 20cm deep) and still preserves faint parallel and oblique chisel marks on its surface. This area was completely buried under the ruin of the entrance, testifying to its ancient origin.

● Location 5 of Fig. 1.C. Finally, a wedge-hole divided in two symmetrical parts has been identified on a large block broken in three big pieces, which belongs to the inner stone alignment of the rampart of Rupinpiccolo (Fig 1.C, location 5 and supporting Fig. 2). Three chisel marks and half-wedge hole have been recognized on the southern fragment of the block (supporting Fig. 2, black arrows and lines). The chisel marks are probably related to the preliminary operations aimed at the production of the hole. Just in front of this first half-wedge hole, another one originally belonging to the same hole has

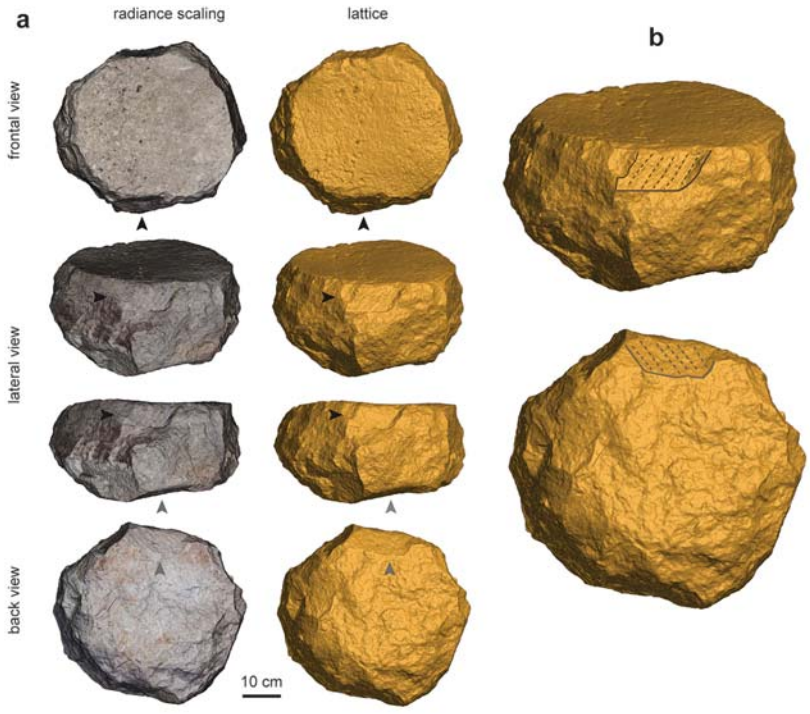

Fig. 4. Rupinpiccolo stone disk 2. **a** ***Radiance scaling and lattice visualizations of the disk with black and gray arrows showing lateral and bottom wedge hole traces, respectively.*** **b** ***Lateral and bottom lattice visualizations showing the wedge hole remains.***

been identified on the northern fragment of the block (supporting Fig. 2, white arrows and lines). The wedge-hole is about 18cm wide and 10cm deep and shows a triangular section but no parallel chisel marks, similar to those visible on the half-wedge holes of disk 2 and the outcropping rock close to the south-eastern entrance, are visible. This suggests that the block suffered higher levels of dissolution probably because it was not completely buried under the ruins of the rampart such as the stone disks and the outcropping rocks with quarrying traces.

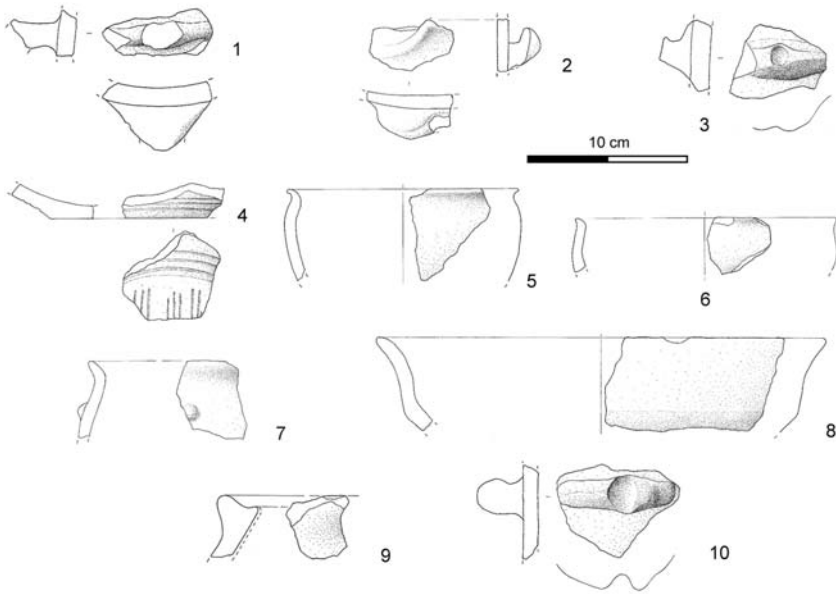

Fig. 5. Bronze Age selected pottery from Rupinpiccolo (drawings by G. Vinci and A. Fragiacomo).

At the macroscopic level, the original surfaces of the block and the wedge-hole faces appear much smoother than the fracture surfaces, suggesting the block was put in place after an aborted attempt to split it and broke up in recent times.

The ancient origin of the quarrying traces was ascertained based on the fact that they were covered by the massive ruins of the rampart and are located next to it. A possible later quarrying activity is unlikely, considering that the ruins of the rampart could easily provide abundant already extracted limestone blocks of different size. The identification of one of the newly identified wedge holes on one block of the rampart would further confirm such a hypothesis. Considering that the surviving rampart has been entirely excavated, and only one main building phase was recognized with some possible minor additions (*i.e.* rampart stone reinforcements and the corridor-like structure connected to the south-eastern gate; *Cannarella 1975*), its construction could have taken place during an early phase of the hillfort. Most of the large blocks used to build the Rupinpiccolo rampart were probably extracted levering along natural fractures in the local limestone outcrop, but, when necessary, wedge-holes produced by metal chisels were used to split the rock in absence of natural discontinuities by using wooden levers or wooden/stone wedges.

In Egypt, wedging was generally believed to be a quarry technique developed during the mid-1st millennium BC with the introduction of iron tools/wedges (*e.g., Harrel, Storemyr 2009*), but the identification of u-shaped holes in greywacke quarries of the Wadi Hammamat (eastern desert of Egypt) and

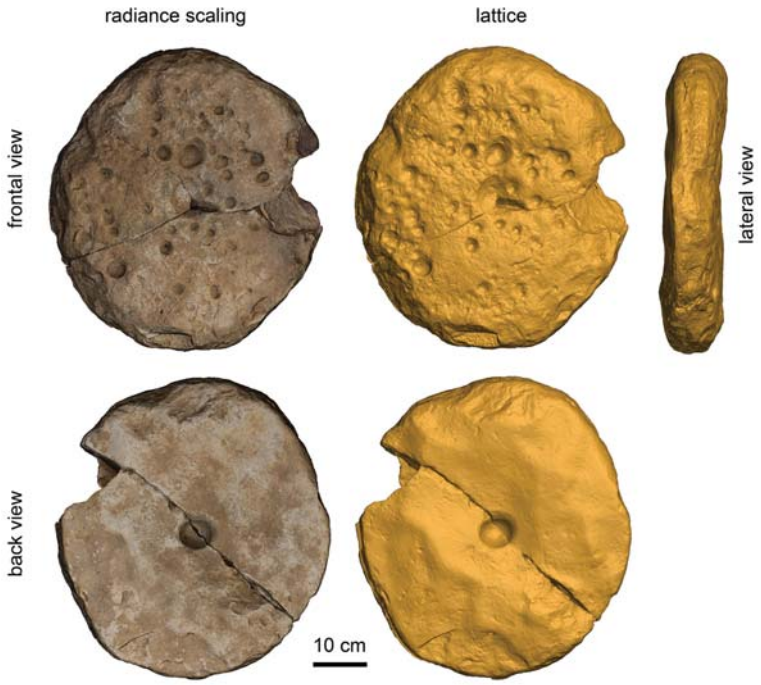

Fig. 6. The Gradina stone disk 1 from the upper entrance of Gradina on Veliki Brijun island.

stone wedges of the same rock type suggest that such technique was in use much earlier, probably since the Old Kingdom (mid-3rd millennium BC; *Bloxam 2015*).

Stone disks from Gradina on Veliki Brijun/Brioni Maggiore

The other pair of disks are from the Gradina hillfort (Veliki Brijun island, Croatia; Fig. 1), in use at least from the late EBA to IA.

Stone disks 1–2 from Gradina on Veliki Brijun
Gradina 1 is about 50cm wide and 10cm thick and was found next to the entrance of the upper rampart (*Vitasović 2005*). Both faces show a central artificial cup mark, 6cm wide, but only one face is covered with shallow hemispherical depressions, likely produced by marine bivalves (Fig. 6 and supplementary text), while the opposite one is flat (Fig. 6). The other disk, Gradina 2, has been identified in the Bronze Age cemetery next to the upper rampart (Figs. 1.B and 7), composed of a few cist tombs within platforms divided by low walls. Despite its slightly smaller size, with a diameter of about 44cm and without wedge holes, it closely resembles the Rupinpiccolo disk 2. Its frontal surface, partially damaged on one side, is very flat and without any chisel marks. It was obtained by selecting a stone slab with a regular bedding plane and through a careful retouching of the disk edges by using a hammer precursor.

Chronology of disks from Gradina on Veliki Brijun
Disk 2 gives very important clues to date the north-eastern Adriatic disks, since it is the only one belonging to a secure Bronze Age context. The disk comes from the small cemetery next to the upper rampart (Fig. 1.B), composed of three burials within platforms divided by low walls. The infant burial and burial 1 of Figure 1.B are characterized by a stone cist, not present in burial 2. Significant Bronze Age pottery was found in tombs 1 and 2. Both a hemispherical bowl characterized by a straight rim with an inwardly slanted edge (burial 2; *Vitasović 2002. Pl. 3.3*) and a cup with a raised triangular handle with a rounded end plate (burial 1; *Vitasović 2002.Pl. 5.1*) point to a MBA I-II chronology according to the Italian relative chronological system (*Cardarelli 2009; 1983.91, Pl. 17, type 15; 93, Pl. 18, type 65*) corresponding to the Bz III phase of the Istrian chronology (*Hänsel* et al. *2015*). They can be compared to similar artefacts from the recent phase of Monkodonja (roughly 1600–1450 BC; *Hellmuth Kramberger 2017.139, Fig. 110; 144, Fig. 115, variant a1; 324, Fig. 255 for the bowl; 84, Fig. 57; 89, 323, Fig. 254*).

Considering the stratigraphic relations, the platform of burial 2 was the first one to be built. The disk was found on the top of the low wall of the platform of burial 2, likely being visible when the burial was in use. The cemetery was uncovered by excavations which brought to light only Bronze Age materials.

Disk 1 can be generally attributed to protohistory and probably to the Bronze Age on the basis of comparisons with Gradina disk 2.

Discussion and conclusions

Structure from motion (SfM) photogrammetry has been proved to be a low-cost, effective and accurate method to document and represent in 3D the stone disks and related quarrying areas presented in this paper.

Gradina disk 2 can be safely dated to the Bronze Age and likely to the MBA on the basis of pottery find-

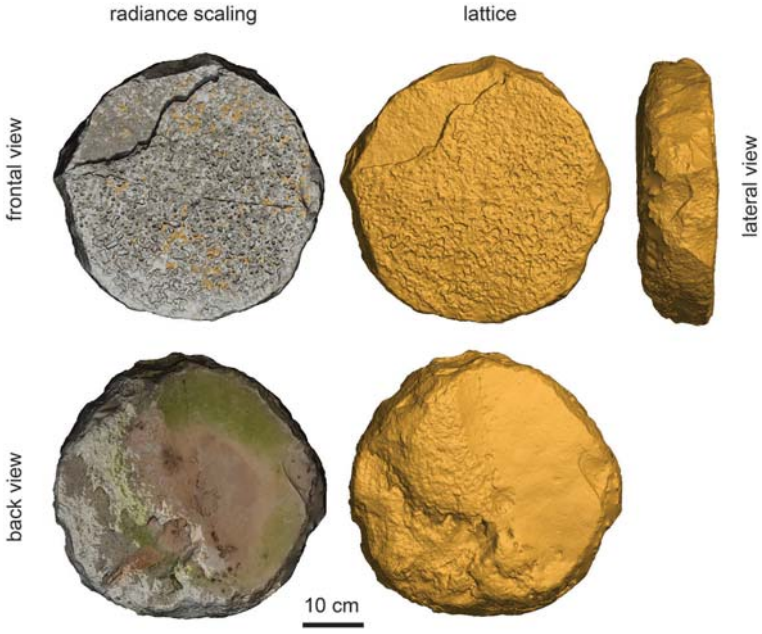

Fig. 7. Gradina disk 2 from the Bronze Age cemetery next to the upper rampart of Gradina on Veliki Brijun island.

ings; Rupinpiccolo disks could be related to an early building phase of the settlement that was likely established during the late EBA/initial MBA, while no precise contextual chronological data are available for Gradina disk 1, and a general protohistoric attribution can be proposed. However, considering their typological homogeneity and similar finding contexts – *i.e.,* entrances or cemeteries – all probably belong to a similar chronological horizon (*i.e.*, an early phase of the *castellieri* culture).

The disks show flat and plain surfaces or are covered with sub-circular depressions and without any macroscopic use-wear traces. Gradina disk 1 shows two larger cup-marks at the centre of both faces.

It is worth mentioning that simple slabs and blocks with cup-marks are reported from IA cremation cemeteries of Istria (*i.e.*, Nezakcij/Nesazio, Kaštel/Castelvenere and Limska gradina/Gradina di Leme), but at least some of them could originally belong to Bronze Age tombs (*Mladin 1964; Mihovilić 1996; 2014*). Cup-marks are, indeed, reported from a block belonging to tomb 2 of the Bronze Age cemetery of Gradina on Veliki Brijun itself (*Vitasović 2002.14*), where the Gradina disk 2 has been identified.

We propose to interpret the stone disks as ritual artefacts and/or possible cult representations based on the association of all disks with significant and sacred settlement locations (they could be related to some type of cult designated to protect the hillforts and/or connected to the dead and the afterlife), the absence of functional traces and comparisons with cup-marks from Istrian protohistoric cemeteries (see above), and similar Bronze Age stones covered with circular depressions found mainly close to citadel entrances in Anatolia and burial sites, entrances and thresholds in the Aegean area.

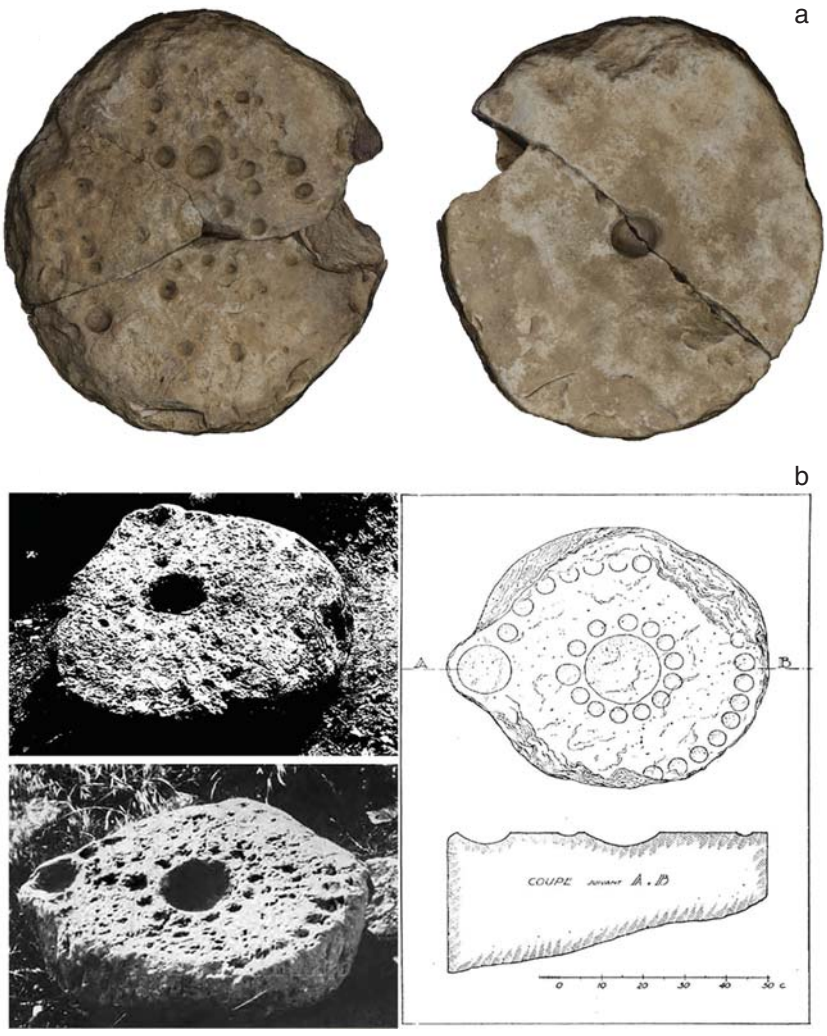

Fig. 8. Gradina disk 1 (*a*) compared to the Bronze Age offering table from Chrysolakkos (Crete) (*b*). Photo top left from de* Pierpont 1987*, the other photo and the drawing from* Demargne 1932 *(image modified from* Arcà 2015*).

In Anatolia blocks with cup-marks have been found in front of the gates of Troy, probably reflecting Anatolian religious elements before the end of the 2nd millennium BC (*Korfmann 1998*), in the city gates or funeral contexts of Boğazköy-Ḫattuša (*Neve 1977-78*), close to the north-west gate of Kuşaklı-Sarissa (*Mielke 2018. Fig. 6.6*) and in some 2nd-millennium BC citadels in the Marmara Lake basin of the Gediz Valley (*Luke, Roosevelt 2017*). They are generally interpreted as evidence of libation rituals (*Neve 1977–78; Luke, Roosevelt 2017*).

Other significant comparisons are cylindrical stones of similar size with a central large cup-mark but surrounded by circularly arranged circular depressions, defined as offering tables, known from protopalatial Crete, more precisely from the New Palace of Mallia (roughly 1700–1500 BC; *Chapouthier 1928; Cucuzza 2010.Fig. 1; Arcà 2015*) and Chrysolakkos (*Demargne 1932; de Pier-*

pont 1987; Arcà 2015). Similar circularly arranged cup-marks, mainly carved into steps and pavements and belonging to the same chronological horizon, are common in Phaistos and in other sites in Crete, where they have been variously interpreted as evidence of rituals or games, or both at the same time. Among other identifications, they are variably defined as stone *kernoi*, Minoan cup-holes, and stone slabs with depressions (*Whittaker 2002; Cucuzza, Ferrari 2004; Hillbom 2005; Cucuzza 2010; Arcà 2015*).

Gradina disk 1 is quite similar to the Crete offering tables from Mallia and Chrysolakkos due to the size, shape and presence of the central, quite large cup-marks (Fig. 8), but it differs because the smaller circular depressions around the central cup-marks are irregularly arranged and probably the result of marine bio-erosion.

Some chisel marks of Rupinpiccolo disk 1 show a sub-circular distribution which is, anyway, more irregular than in the *kernoi* from the Aegean area. Moreover, their dimeter is relatively small (5–10mm) compared to that of most *kernoi* (*Cucuzza, Ferrari 2004*). This leaves open the question as to whether the chisel marks of Rupinpiccolo disk 1 could have a different meaning and function.

Interestingly enough, disks with a plain face and no cup-marks similar to Gradina 2 and Rupinpiccolo 2 are so far unknown in the eastern Mediterranean. Considering their possible ritual meaning, stone disks with a plain face could perhaps be interpreted as a representation of the Sun. Solar motifs are in fact known from EBA/MBA pottery from the north-eastern Adriatic (*Hänsel* et al. *2015*), including Rupinpiccolo itself. Iconographic elements referring to the Sun and its cyclic movements spread out in Europe at least from the late Copper Age, probably in connection with the large-scale migrations from the Pontic steppe region to western Europe during the 3rd millennium BC (*Kaul 1998; West 2007; Kristiansen 2010; 2012; Allentoft* et al. *2015; Haak* et al. *2015; Kristiansen* et al. *2017*).

The bronze and gold chariot from Trundholm, Denmark, carries an elaborate image of the Sun of the 14th century BC (*Kaul 1998; West 2007*). Similar ornate gold disks have come to light in various parts of Europe and probably are deity representations. They were produced over a long time, between the late Copper Age and late Bronze Age (*Cahill 2015*).

The occurrence of two circular faces on the same artefact, such as at Veliki Brijun, or on two associated but separate objects, such as at Rupinpiccolo, is reminiscent of solar symbolic imagery of the European Bronze Age related to the representation of the Sun's daily journey from day to night (*Kaul 1998; West 2007; Pásztor, Roslund 2007; Kristiansen 2010; 2012*). If this interpretation is correct, the plain faces could be a representation of the Sun, while those covered with chisel marks of the night sky. Bronze Age representations of the night sky in the European Bronze Age are rare, and the Nebra disk from Germany is the most famous example (about 1600 BC; *Meller 2002; Schlosser 2002; Pásztor, Roslund 2007; Kristiansen 2010; Pásztor 2015; Pernicka* et al. *2020*).

In conclusion, we propose interpreting the disks from north-eastern Adriatic hillforts as Bronze Age ritual artefacts reflecting the position of north-eastern Adriatic regions between the Mediterranean and central Europe. They seem to be related to the solar symbolic imagery of European Bronze Age, but at the same time show strong connections with the eastern Mediterranean during an early phase of the

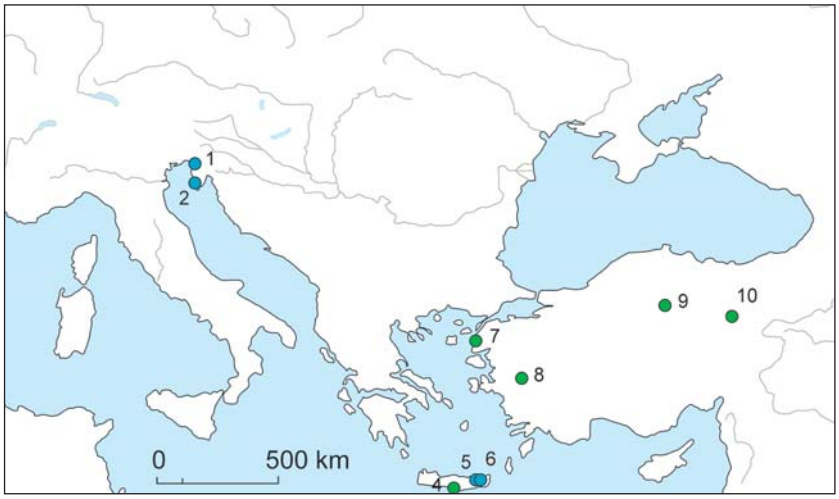

Fig. 9. Location of Rupinpiccolo and Gradina on Veliki Brijun hillforts (1 and 2 respectively) and other main sites where cylindrical offering tables (5–6) or blocks with cup-marks have been found close to citadel entrances, burial sites and thresholds both in the Aegean area (4) and Anatolia (7–10). 4 Phaistos; 5 Mallia; 6 Chrysolakkos; 7 Troy; 8 Marmara Lake basin; 9 Boğazköy-Ḫattuša; 10 Kuşaklı-Sarissa.

castellieri culture (Fig. 9). This is in line with the hypothesis – mainly based on specific types of pottery, metal artefacts and architectural models – that the first Istrian settlements had direct contacts precisely with this area (*Hänsel* et al. *2015; Hellmuth Kramberger 2017*). The stone disks would show that the inhabitants of north-eastern Adriatic regions not only shared some aspects of the material culture, but also common religious habits.

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Author contributions: F. B. identified the Rupinpiccolo stone disks and related quarrying traces, designed, initiated and led the study; F. B., G. V., V. M. produced photogrammetric data; G. V. produced plans of investigated sites; F. B., G. V. performed archaeological research; F. B., G. V., A. D. M., S. F. performed geomorphologic research; A. B. performed ichnological research; F. B. wrote the manuscript with significant input from G. V., A. B. and with contributions from all authors; all authors contributed to final interpretation of data.

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Appendix

Supporting information: Gradina stone disk 1

Both frontal and opposite faces show at their centre an artificial cup mark about 6cm wide but only the frontal one is covered with a network of slender pits (width: about 1–3mm) arranged in sub-linear sets (length: about 1–3cm; Fig. 6). This morphology is characteristic of the sponge boring *Entobia cateniformis*, consisting of cylindrical chambers arranged in coalescing sub-linear chains (*Farber* et al. *2016*). Clionid sponges produce incipient *Entobia* in the Adriatic Sea (*Bromley, D'Alessandro 1989*). *Entobia* is a proxy for marine rocky substrates (*Bromley, D'Alessandro 1989; Domènech* et al. *2001*).

On Gradina stone disk 1, *Entobia* crosscuts larger, shallow hemispherical depressions (diameter: about 0.5–3cm). Anton Vitasović (*2005*) considered these hemispherical depressions as artificial cup marks, but some of them are cut by the central cup mark or interrupted at the edge of the stone, implying they were already present when the disk was shaped. In addition, the observed cross-cutting relationships suggest that they were produced in marine environments as well as *Entobia*. This hypothesis is supported by the morphological correspondence with the boring *Gastrochaenolites*, which is produced by marine bivalves (*Donovan, Hensley 2006*). In fact, *Gastrochaenolites* is a clavate boring that is preserved as a hemispherical depression when truncated by physical and/or biological erosion (*Domènech* et al. *2001*). In the Mediterranean Sea, the bivalve *Rocellaria* (*Gastrochaena*) *dubia* produces incipient *Gastrochaenolites*, whereas the date mussel *Lithophaga lithophaga* is another important bivalve bioeroder (*Casolia* et al. *2016*).

The association between *Gastrochaenolites* and *Entobia* typically arises from long-term bioerosion, such as occurs on sediment-free submarine cliffs (*Entobia* ichnofacies *sensu Bromley and Asgaard 1993*). The Gradina borings are unfilled and therefore might have been produced few decades before being collected by humans. This hypothesis is supported by the relatively fast bioerosion rates observed in the Mediterranean Sea, *i.e. Entobia cateniformis* can be produced in two years whereas *Gastrochaenolites* requires longer (*Domènech* et al. *2001; Farber* et al. *2016*). The depth of penetration (tiering) of *Entobia cateniformis* is usually restricted to the first

centimetre within the substrate (*Farber* et al. *2016*). Therefore, the *Entobia* from Gradina could have been produced a short time after *Gastrochaenolites*. A similar explanation is provided by Rosa Domènech *et al.* (*2001*) for *Entobia-Gastrochaenolites* assemblages of Spain.

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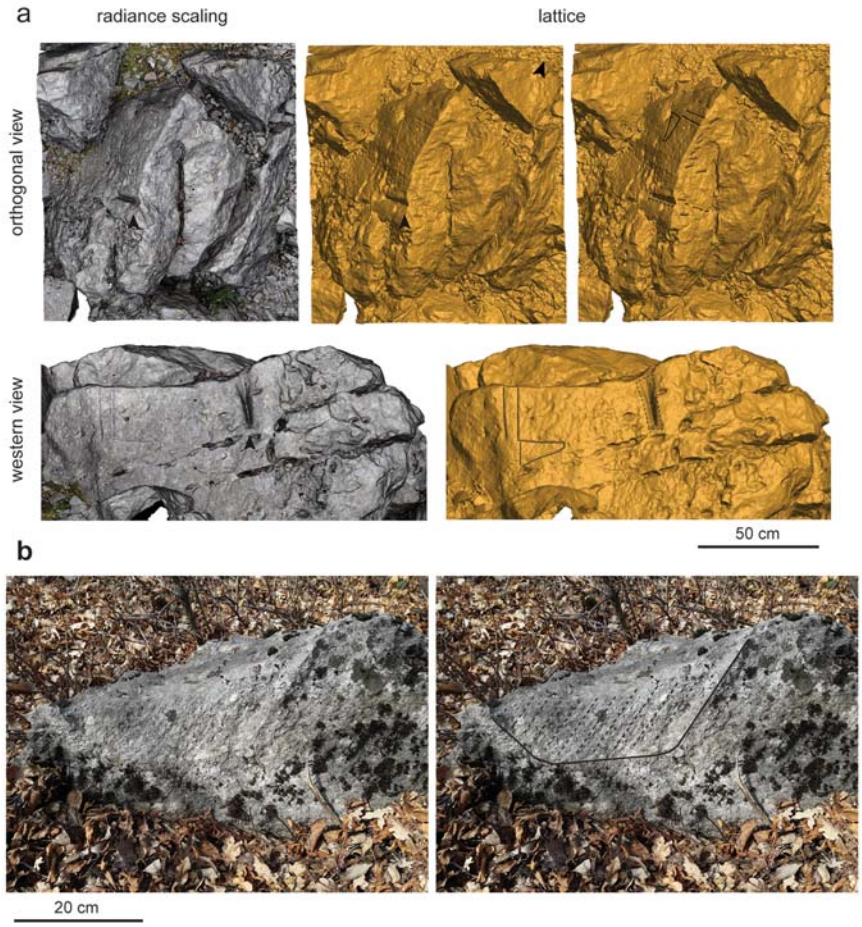
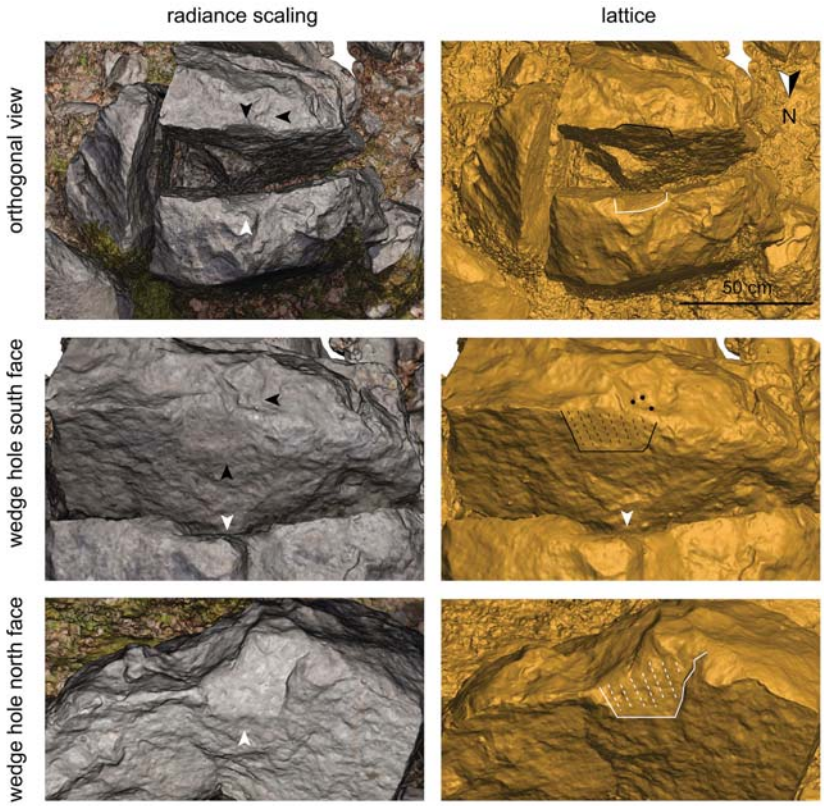
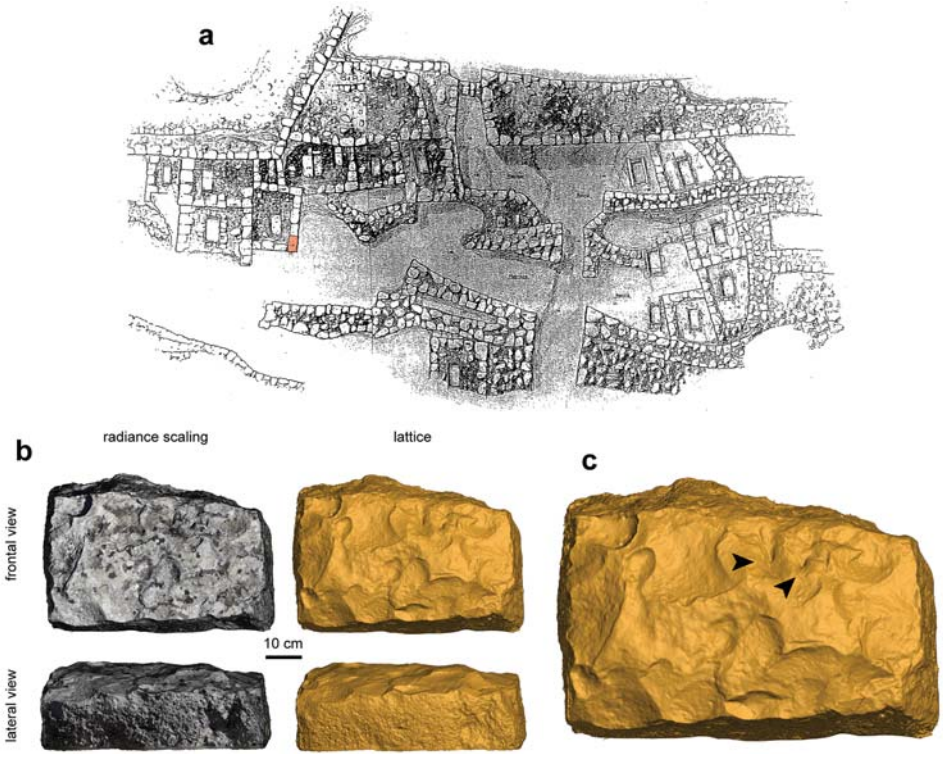


Supporting Fig. 1. Quarrying sites next to the Rupinpiccolo rampart. **a** ***Quarrying site east of the north-eastern gate of the rampart with short and linear chisel marks (black lines) and a wedge hole (dotted black lines).*** **b** ***Quarrying site next to the corridor-like structure in front of the south-eastern entrance.***



Supporting Fig. 2. Rupinpiccolo rampart block with two symmetrical half-wedge holes and a few chisel marks. The southern half-wedge hole and close chisel marks are shown by black arrows and lines; the northern half-wedge hole is shown by white arrows and lines.



Supporting Fig. 3. Block belonging to one of the platforms of the Bronze Age Vrčin cemetery in Istria with clear chisel marks. **a** ***Position of the block (in light red) in the cemetery; plan taken from Battaglia (*****1958*****).*** **b** ***Radiance scaling and lattice visualizations of the block.*** **c** ***Lattice visualization of the block with chisel marks indicated by black arrows.***

Analysis of Neolithic pottery technology along the Iranian Zagros foothills

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ABSTRACT – *The article presents the results of a technological analysis of the ceramic samples from Neolithic settlements of Ali Kosh, Mahtaj and Guran (the 7th mill. BC). The use of sheep and goat dung in the paste prevailed. While two-layer slabs were applied as the main construction method across the region, a few samples from Guran show the appearance of coil construction around the middle of the 7th millennium BC. First an overall coating with the same clay and red colouring appeared, and later a new type of red slip emerged – a mixture of clay with red pigment.*

KEY WORDS – *Zagros; Neolithic; pottery technology; paste composition; construction methods; slip*

Analiza tehnologije neolitske lončenine iz predgorja Zagrosa v Iranu

IZVLEČEK – *V članku predstavljamo rezultate tehnološke analize keramičnih vzorcev iz neolitskih naselbin Ali Kosh, Mahtaj in Guran (7. tisočletje pr. n. št). V lončarski masi prevladujejo ovčji in kozji iztrebki. V regiji pri izdelovanju posod prevladuje metoda dvojnih glinenih trakov, vendar se v Guranu sredi 7. tisočletja pr. n. št. uporablja tudi tehnika svaljkov. Posode so bile na začetku v celoti premazane z istim premazom rdeče barve. Kasneje se je pojavila nova vrsta premaza – mešanica gline in rdečega pigmenta.*

KLJUČNE BESEDE – *Zagros; neolitik; lončarska tehnologija; sestava lončarske mase; oblikovanje posod; premaz*

Introduction

The emergence of pottery has long been seen as an important technological innovation in human life. Across west Asia, the overall archaeological evidence suggests that the first unfired clay vessels appeared at the turn of the 9th to 8th millennia BC, as shown by the Ganj Dareh materials (*Darabi* et al. *2019*) while the earliest pottery vessels appeared at around 7000 BC (see *Le Mière 2017; Le Mière, Picon 1998; Nieuwenhuyse, Campbell 2017; Tsuneki 2017*). In the Zagros region, excavations at Ganj Dareh yielded two types of clay vessels, including large storage containers, sometimes attached to the wall of buildings, and samples from much smaller ones. They were mostly found in the burnt deposits known as layer D at the site (*Smith 1974; 1990*). This highlights the fact that Neolithic communities were long dealing with such unfired clay containers during the pre-pottery period as a direct predecessor to the fired pottery vessels in the 7th millennium BC. In addition, this important technological innovation should have been influenced by some other preceding items, such as stone vessels,

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white ware, and waterproofed mat containers, as well as pyro-technological experiments with making clay objects. In this regard, we also assume a technological correlation between the construction of *cob* walls and subsequent pottery vessels. Along the Zagros foothills and intermountain valleys, the earliest available pottery samples are dated to the turn of the 8th to 7th millennia BC (*Darabi 2018*). However, they were regionally variated, although later inter-regional interactions led to some stylistic similarity or uniformity. When it comes to Neolithic pottery in the Zagros (*Bernbeck 2017; Hole 2018; Matthews, Fazeli Nashli 2022.89*), the majority of scholarship has dealt with stylistic consideration of various types, in particular their form and decorative elements, while the composition of the pottery paste, construction methods, and firing of the early ceramics remain poorly understood. Previously, examinations by Frederick R. Matson (*1960*) and Pamela Vandiver (*1987*) presented some information on the Iraqi and Iranian Zagros, respectively. The Zagros region is formed of high intermountain valleys and plains or foothills at lower altitudes. This spectacular geomorphological feature has always played a major role in human life in the area, enabling the coexistence of local, regional and interregional cultural facts resulting from socio-economic interactions. Frank Hole (*2018*) recently pointed out the 'diversity' and local development of various types of Neolithic ceramics across the Zagros piedmont, in Deh Luran, Susiana, Hulailan, Mahidasht Fars. He thus refers to these internal ceramic trajectories as 'creative centuries'. According to Hole, due to the formidable Zagros heights the nearby lowlands, such as the Deh Luran Plain, and intermountain valleys or plains, such as Hulailan, show distinct ceramic trajectories during the Neolithic period. This claim can be assessed through investigating of a large body of various artefacts, including ceramics.

This article presents a comprehensive analysis of Neolithic pottery technology across the Iranian Zagros, with a focus on the samples recovered from three Neolithic sites of Ali Kosh, Mahtaj and Guran. The first two sites are located in the two corners of the lowlands of southwestern Iran, while the last lies at a small, closed intermountain valley, Hulailan, in the central Zagros. Such distinct natural settings may provide us with a better comparison of the Neolithic ceramics in the light of technological, not stylistic, matters. Moreover, both Ali Kosh and Guran represent the most common Neolithic ceramic types, which are ubiquitous on the lowlands and highlands, respectively (Fig. 1).

Materials and their chronology

As noted above, the pottery assemblages examined and presented here are some selected samples from the Neolithic sites of Ali Kosh and Guran, as well as few sherds from Mahtaj. All three sites contain both pre-pottery and pottery levels, though the last one lacks any *in situ* samples due to anthropogenic destruction (see below).

As a result of the stratigraphic excavation in 2017, a total of 227 pottery sherds were found from the upper levels of Ali Kosh, Deh Luran Plain (32°33' 28.14"N, 47°19'29.82"E, about 6km to the northwest of Mousian town, Ilam Province) (*Darabi 2018; Darabi* et al. *2017*). Following the early 1960s excavations, these levels were previously defined as the Mohammad Ja'far Phase in which three pottery types were recovered: Ja'far Plain, Ja'far Painted, Khazineh Red (*Hole* et al. *1969.113*). Accordingly, these are mostly chaff-tempered and burnished. Judging from the cracking and peeling of surface, the two former types (Ja'far Plain and Ja'far Painted) seem to have been covered with a "*wash of the same clay*" (*Hole* et al. *1969.115,117*). In relation to Khazineh Red, both 'slip' ("*as a fine solution of well-cleaned clay*") and 'self-slip' (formed during wet smoothing of the vessels) were applied. Only Ja'far Painted was decorated in geometric designs, such as chevrons, zig-zags and checkerboard (for further information see *Hole* et al. *1969.113–124*). Technological analysis was carried out on 31 fragments of ceramics (for basic information on the samples see Table 1 – the number and other information of the fragments associated with their figures is given by site in the corresponding tables), including 13 samples of the Ja'far Plain type, 12 samples of the Ja'far Painted type, and six samples of the Khazineh Red type. It's noteworthy that the last is not uniform in appearance, with a variation in the red colour on the outer surface. The Ja'far Plain type has a wall thickness between 0.6–1.2cm, predominantly 1.0–1.1cm. The thickness of the walls of Ja'far Painted and Khazineh Red is mostly less than 1cm (0.7–0.9cm). The diameter of the vessel rims of all types ranges from 15 to 25cm.

Chronologically, Hole (*1987*) attributed the pottery layers of Ali Kosh to 6300–6000 BC and the preceding pre-pottery layers (the Boz Mordeh and Ali Kosh phases) to *c.* 7500–6300 BC. Melinda A. Zeder (*1999; 2008*) dated the entire sequence to *c.* 7500–7000 BC. However, recent determinations placed the site within *c.* 7500–6500 BC, and proposed that the pot-

tery emerged from roughly 7000 BC onwards (*Darabi 2018*).

During the sounding at Tapeh Mahtaj, Behbahan Plain (30°38'7.64"N, 50°12'15.33"E, about 3km to the west of Behbahan city, Khuzestan Province), a few pottery fragments were recovered from the site. However, they were all intrusions from upper, destroyed levels. The site presents traces of some subsequent seasonal occupations spanning from the late 8th to early 7th millennia BC (*Darabi* et al. *2017; 2021*). If the upper levels had not been destroyed, the site could have helped with better understanding of the transition from the pre-pottery to pottery Neolithic in southwestern Iran. However, the two samples that were analysed for this research should be attributed to the early 7th millennium BC. They represent fragments of a vessel base, and provide adequate technological information (for basic information on the samples, see Table 2).

Our third assemblage comes from surface of Tapeh Guran (33°45'23.83"N, 47°05'51.90"E, about 4km to the west/northwest of Tohid town in the Hulailan valley, Ilam Province). Diachronically, the site presented various types of Neolithic pottery in the central Zagros: Greyish-brown ware (level S), Buff ware (levels R-D), Archaic Painted (levels R-F), Standard Painted ware (levels O-D), Sarab Geometric (level L-D)[1], and Red-slipped ware (*Mortensen 1972; 2014; Meldgaard* et al. *1964.116–117*) (Fig. 2).

Greyish-brown ware is the earliest type made of untempered pure clay, but later tiny pieces of chaff and husk appeared as inclusions. It is also wet-smoothed or slightly burnished, with incised lines and crescentic impressions from fingernails or the end of a bone tool. Variated grey and brown surface colours are the result of 'poor firing' (*Mortensen 2014.50*). The occurrence of such pottery is controversial, as it was also reported from Ganj Dareh (see *Smith 1976*), a site that has recently been dated to the pre-pottery Neolithic period (see *Zeder 2008; Meiklejohn* et al. *2017; Darabi* et al. *2019*). As the most common type at the site, Buff ware contains some limestone and sand, as natural inclusions of the clay, and tempered with tiny fragments of chaff in medium or large quantities. Some samples were reported to have contained dung as temper. The surface of the Buff ware is wet smoothed or slipped, often slightly burnished and ranges from buff to orange-buff. Standard Painted ware and Sarab Geometric style are tempered with tiny pieces of chaff, grits of limestone and small particles of sand, sometimes naturally added to the clay. They are also slipped and usually burnished, varying from buff to orange buff to reddish colour. In this regard, the inner layer is buff; the outer surface is slipped (light orange to red in colour) and usually burnished. The decoration is also painted in red ochre; though the Standard Painted has bobbled lines (tadpoles) and Sarab Geometric style is decorated with elements

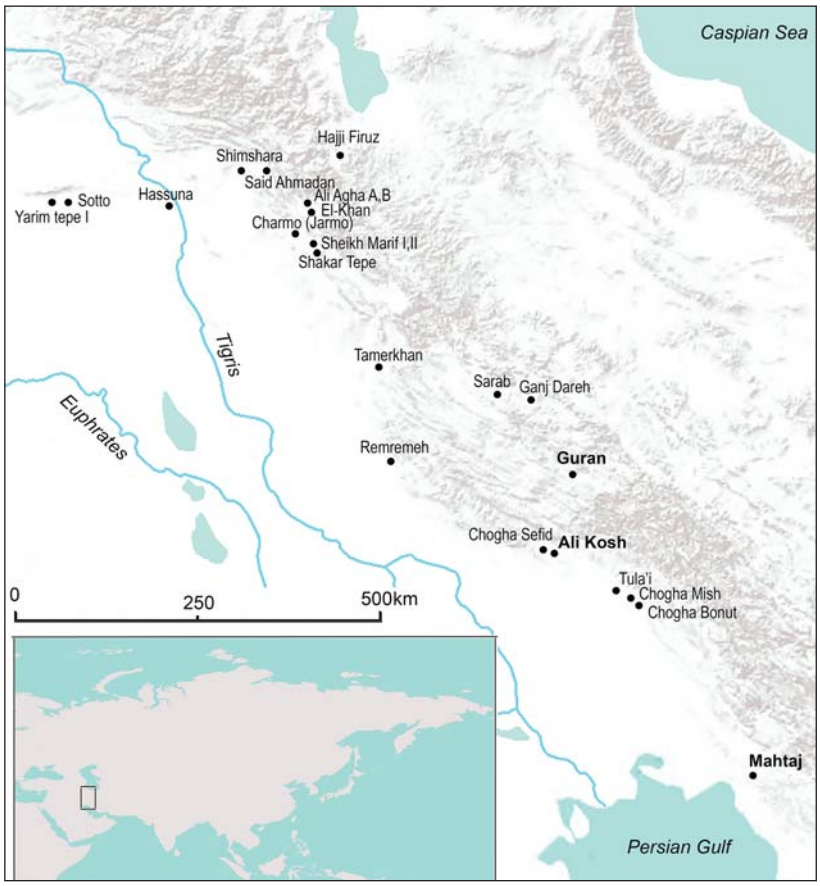

Fig. 1. A map showing the location of Ali Kosh, Mahtaj and Guran among some other key pottery Neolithic sites across Zagros.

1 This type was later re-classified by the site excavator as a sub-type (group d) of the Standard Painted (see *Mortensen 2014.59*), though they are obviously distinct in terms of their decorative elements.

such as chevrons, zig-zags and bands. Archaic Painted ware is usually burnished and heavily tempered with chaff and decorated with groups of vertical, oblique or horizontal lines. Red-slipped ware is also medium-heavily tempered with chaff and small particles of sand. Both outer and inner surfaces of the ware are slipped and burnished. The outer, and sometimes inner, surface is covered with a medium-dark red to orange-buff slip. In most cases, a grey or black layer is seen inside the fragments, which results from 'insufficient firing' (*Mortensen 2014.50–66*).

Peder Mortensen (*2014.17*) placed the site within *c.* 6700–5500 BC while Zeder (*2008*) suggested a time spanning *c.* 7300–6000 BC. Judging from a regional perspective, the latter seems to be more realistic. With regard to the current research, 22 potsherds were analysed. The available assemblage consisted of various types, with Standard Painted ware including the Charmo (Jarmo) style (one sample) and Guran style (one sample), Sarab Geometric (one sample), Buff ware (four samples) and Red-slipped ware (15 samples), while no samples associated with the Greyish-brown ware and Archaic Painted ware are investigated, as they were stratigraphically limited to the lower levels and hardly found on the surface (for basic information on the samples, see Table 3).

Methods

The ceramic technological analysis included the analysis of ceramics in terms of raw materials, pottery paste, and methods of construction, surface treatment and firing to study the stages of pottery technology. The technique applied is based on a binocular microscopy examination of technological traces on the surfaces and in fresh cross-sections of ceramic fragments,[2] as well as experimental modelling of individual elements of pottery technology to verify issues that arose in the microscopic analysis (*Bobrinsky 1978; 1999*).

Raw materials

In order to reconstruct the knowledge of the potter about the kind of clay to be used for making a desired pottery, the clay ferrugination, qualitative composition of natural inclusions, their dimensions and concentrations were recorded. The clay ferrugination was determined by re-firing samples in a muffle furnace at a standard temperature of 850°C. The concentration of natural inclusions was also measured in comparison with the special tables, previously obtained as a result of the data of numerous experiments (*Bobrinsky 1999.35–40*). Based on the presence of natural sandy inclusions, the used clay can be divided into low sandy, medium sandy and high sandy groups. Low sandy clay contains single grains that are mostly fine (0.1–0.25mm) and sometimes medium-grained sand (0.25–0.5mm) in a concentration of 1:10 (sand:clay). High sandy clay contains very fine (0.05–0.1mm) and fine sand grains (0.1–0.2mm) in a concentration 1:5–1:1 (sand:clay). The larger sand grain inclusions are usually rare (*Lopatina, Kazdym 2010*).

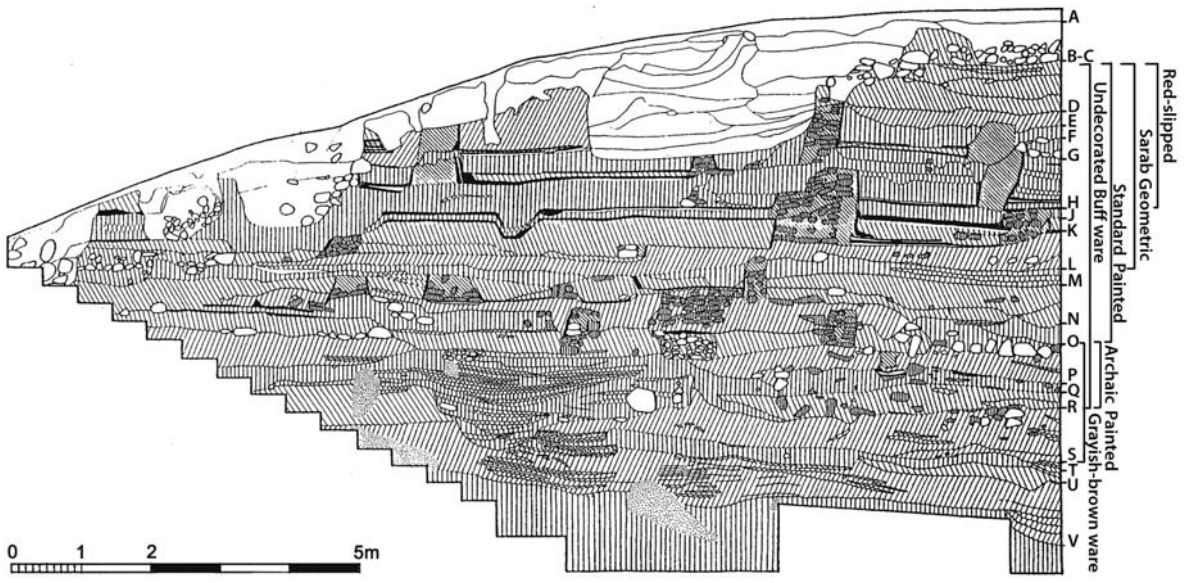

Fig. 2. Archaeological layers at Tapeh Guran showing their related pottery styles (modified by H. Darabi after* Meldgaard *et al.* 1963.109, Fig. 9*).

2 Carl Zeiss 2000-C stereo microscope.

Pottery paste

The qualitative composition of intentionally added inclusions, their dimensions and concentrations were determined. Archaeological samples were compared with experimental samples containing various types of organic inclusions: fresh grass, hay, straw and dung of cattle, sheep and goats (*Bobrinsky 1999.18–19,32–33,41–44,86; London 1981; Rice 1987.82; Tsetlin 2003*). The dung in pottery paste is represented by prints of small plants and sometimes the remaining residues, 0.2–1mm wide and up to several centimetres long, with pointed or rounded tips. In particular, there are a lot of highly degraded particles (0.1–0.2mm wide, less than 1mm long) in the dung of sheep and goats. In case of using fresh dung a strong curvature of small plants is seen in the pottery paste. Experiments show that an admixture of straw, crushed by any type of grinding or by impact, has uneven stepped edges (along the fibres), along with the splitting of the stems along the fibres and the falling of individual plant fibres. Only when cutting is an even cut fixed without splitting into individual fibres. Plant residues (imprints) are not bent and do not break at the bend. The concentration of organic inclusions was examined in comparison with experimental samples (*Petrova 2012.78; 2019; in preparation*).

Construction methods

The construction methods were examined on the basis of studying the vertical and horizontal cross-sections of ceramic fragments, which would attest to the presence of junctures at the places of joints of sequential "*clay building elements*" and the orientation of pores (*Bobrinsky 1978.174–184; Albero Santacreu 2014.78; Roux,Courty 2019.164– 166; Rue 1981; Shepard 1956.184; Vandiver 1987.30–31*). Analysis of the shape, size and direction of the junctures in the sherd allows us to find out from which sequential elements (slabs, coils, bands) the vessel was made. There are two known methods for gluing slabs: unsystematically and along circular horizontal zones. It is possible to assess the construction method by the presence of traces of some action that occured during the forming sequence that were left unsmoothed, changes in the relief and thickness of the vessel walls at the places of joints of sequential elements on the outer and inner surfaces of the ceramic fragments, and the presence of a mould connected with slabs (*Bobrinsky 1978; Rice 1987.125; Vasil'eva, Salugina 2010.72–87*). With regard to the slab construction, the vertical and horizontal cross-section is divided by junctures into many separate parts. The coil construction can be detected by the extended horizontal line of juncture at the horizontal cross-section of the vessel wall. In a vertical cross-section, in the case of coils, the wall is divided into many separate parts by horizontal or oblique junctures (Fig. 3).

Surface treatment

The surface treatment is assessed through analysing the micro-traces left on the surface. To verify the presence of a clay covering, we conducted experiments using different clays to make a basic paste and other types with the addition of various pigments. A full study of all the features of the clay coating is still ongoing. At present, however, it can be noted that at least in the case of applying an additional clay coating (including the slip) before firing, characteristic rounded (micro) cracks and chips appeared on the surface of the vessels, as noted in other studies (*Rue 1981.41,54; Shepard 1956.67*). This resulted from uneven shrinkage of the clay that was used in the basic paste composition and coating.

With regard to the clay covering, we need to clarify the concepts used in our research. We divided the concept of 'slip' into two types: "*coating with the same clay*" – a type of very thin or watery clay similar to the main raw material from which the vessel was made without using additional admixtures; and 'slip' – the application of clay composed of the same or different clay material mixed with a pigment. This is necessary to show the development of idea of the 'slip covering', which will be shown below.

In addition, the traces left by the tools used for smoothing the surface of the vessels were studied and compared with our experimental observations.

Firing

The firing regime, its duration and temperature are determined based on the thickness of the oxidized and un-oxidized layers and the quality type of the transition of margin between them (sharp or gradual) in the cross-section, as well as changes in the form of intentionally added or naturally occurred inclusions (*Bobrinsky 1999.93–95; Rue 1981.118; Volkova, Tsetlin 2016*).

Analyses

Clay raw materials

With regard to the Ali Kosh ceramics, a wet clay with varying degrees of ferrugination was used: medium (19 fragments), high (12 fragments), and low (one fragment). In all the three pottery types recovered



Fig. 3. Experimental samples. **a,b** ***slabs construction (a free modelling on the flat,*** **b** ***construction with using mould);*** **c,d** ***coil construction (experimental samples and photos made by N. Petrova).***

from the site, the clay contained an insignificant concentration of sand (no more than 1:10), which is a natural rounded admixture of sand (with a particle size of 0.2–0.5mm) and a fine admixture of limestone (0.2–0.5mm) in an even lower concentration. The samples of Mahtaj are made of low-ferruginated, low sandy clay (sand particle size 0.2–0.5mm, concentration less than 1:10). At Guran, medium (14 samples) or low ferruginous (eight samples) and low sandy clays are seen. Red-slipped ware, in the overwhelming majority of cases, shows the use of medium ferruginous clay (13 samples), while the Buff ware was only made of low ferruginous clay. In all the samples the clay contains very fine natural sand (0.2–0.5mm) at a concentration of less than 1:10, and there are sporadic larger grains of sand. Limestone was also found in only two fragments in insignificant amounts.

Pottery paste

An examination of the paste of the Ali Kosh ceramics showed different scales of organic prints and residues: very small plants (0.1–0.2mm wide, ≤1mm long) remaining from sheep and goat dung with pointed (needle shape) (Fig. 4.a.23) or rounded ends (Fig. 4.a.2) in wet condition, as evidenced by curved long (Fig. 4.a.15) and very small compressed plant prints (Fig. 4.a.10); coarse plant residues (≤ 0.5mm wide, often ≤1mm long) in a dry state with straight (cut) ends characteristic of mechanical crushing (Fig. 4.b.12). The presence of grain husk residues is also possible (Fig. 4.b.6). It is not clear whether coarse plant admixture was added intentionally or was associated with the dung pellets (like the remnants of undigested fodder, or occurred accidently when the dung was collected or picked up from the ground). However, we may assume that in low concentrations (5–10%) large plant inclusions resulted from dung, while in higher amounts (≥30%) they were added intentionally. The presence of husks can be indicative of adding chaff to the pottery paste, but it is not clear as not enough evidence is available yet.

Ja'far Plain ceramics present the highest concentration of organic admixture – approximately 50% of the volume of the pottery paste – which was recorded in two fragments recovered from the lowest layer of the phase (in one case only coarse plants, and in the other a mixture of dung and larger plants, probably added separately from the dung). A fragment containing only dung was also found in the same layer. Upper layers yielded samples that show only dung or plant inclusions. However, the concentration of organic impurities decreased over time. In terms of Ja'far Painted, except for one fragment with only coarse plant inclusions all the ceramics presented a pure admixture of dung. In general, the concentration of organic admixture in this type of ceramic is less than that in the Ja'far Plain samples. It seems that its amount remained stable, as represented by two values: 10 and 30%. In the Khazineh Red samples the presence of dung is ubiquitous. Both Khazineh Red and Ja'far Painted types show a significant amount – up to 30% – in the lower layers, while only an impurity of dung in a small concentration – up to 10% – is seen in the upper layers. In the remaining two pieces of Khazineh Red, dung forms approximately one-third of the total volume of the pottery paste. In general, we recorded organic admixtures in the ceramics of Ali Kosh which may have resulted from the use of sheep and goats dung and especially crushed, coarse plants (possibly chaff). The highest density of organic impurities (~50%) is seen in the Ja'far Plain samples that were recovered from the lowest layer, where dung was also deployed as temper, whether added to the plant inclusions or specifical-

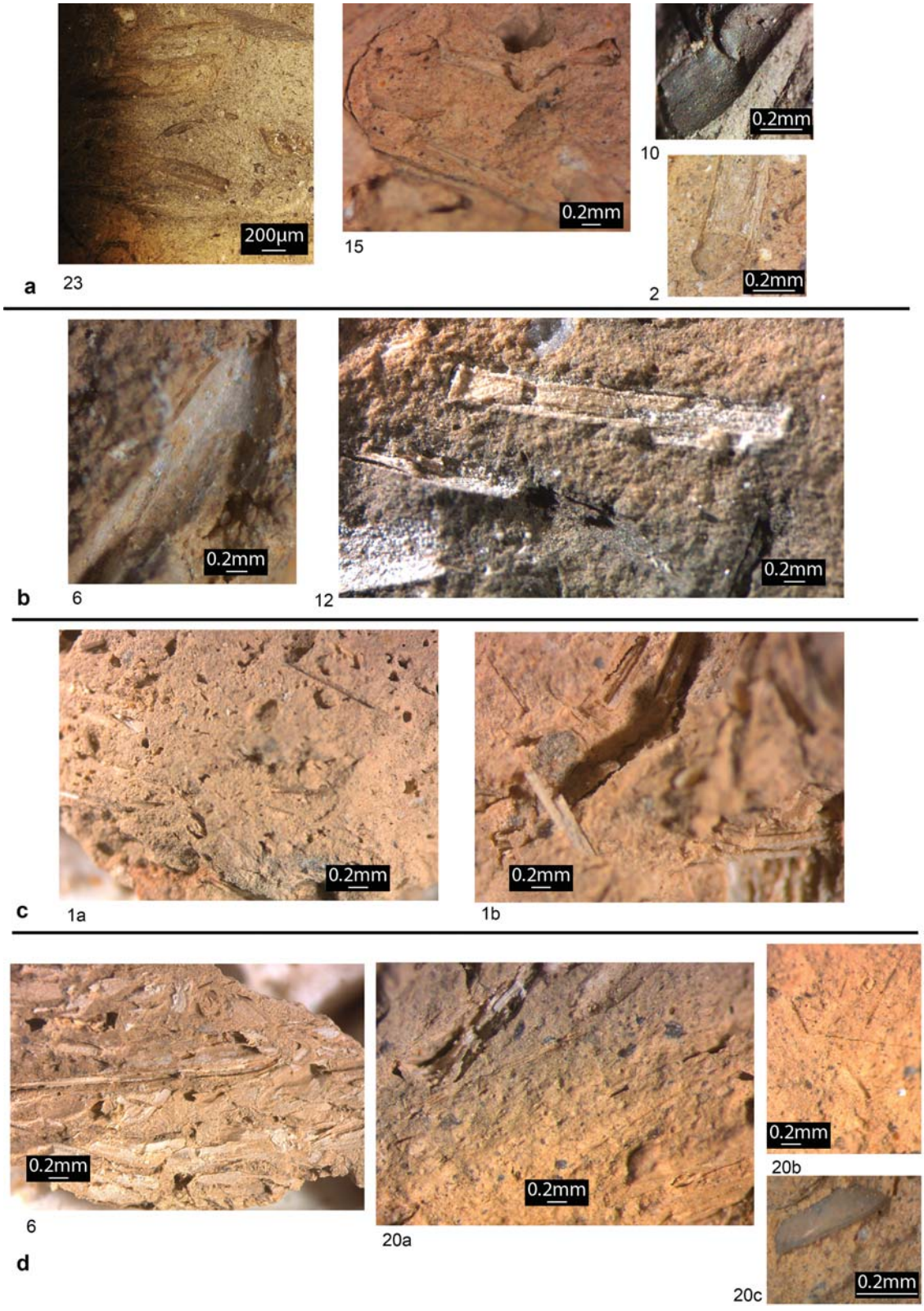

Fig. 4. The composition of pottery paste at Ali Kosh, Mahtaj and Guran (photos made by N. Petrova). **a** ***Ali Kosh, plant prints, dung-related:*** **23** ***general view of dung (pointed ends of prints),*** **15** ***curved plant prints,*** **10** ***compressed plant prints,*** **2** ***rounded end of plant print;*** **b** ***Ali Kosh, plant prints, not related to dung:*** **6** ***probably husk imprint;*** **12** ***straw imprint with straight (cut) ends;*** **c** ***Mahtaj, plant prints, dung-related.*** **1a,b** ***general view;*** **d** ***Guran, plant prints, dung-related.*** **6,20a,b** ***general view,*** **20c** ***shell chip, presumably dung-related. The number of fragments here and below are given by number in the corresponding (by sites) tables (see Tabs. 1–3).***

ly used. In the later layers, ceramic fragments with only dung or large plants or a mixture of both components in the pottery paste are common. The latter two types of admixtures dominated the Ja'far Plain ceramics. There is a general tendency toward decreasing the concentration of organic temper over time: from 30 to 50% in the lower layers to 10–30% in the upper ones.

In the composition of the samples selected from Mahtaj both dung in a wet and dried state and coarse plant imprints and residues were recorded in approximately the same concentrations. In general, the organic admixture to the clay makes up to at least 50% of the total volume of the pottery paste (Fig. 4.c.1a,b).

Regarding Guran, the addition of dung as temper is seen in all the ceramic types (Fig. 4.d.20a,b). The admixture of dung is represented by the predominance of very small (<0.1–0.5mm wide) plant imprints with pointed (needle) ends in the cross-sections (Fig. 4.d.6). In addition, a fragment of a mollusc shell (0.3mm long) was encountered, which is also most likely connected with dung. The shell of the mollusc is highly thinned and transparent. On its surface, there is absolutely no surface pattern typical for the outer layer of the shell, possibly indicating only the inner, pearlescent layer. In this regard, it can be assumed that it had gone through a process of digestion (Fig. 4.d.20c).

The dung was added both in lightly wet (Fig. 4.d. 20a) and dry (Fig. 4.d.6) condition, as shown by the form of plant prints (lightly curved or straight). Sometimes larger plant prints (>1mm wide) are also seen, but in low concentration. Their presence is also most likely connected with dung. In most cases the dung of goats or sheep was added (Fig. 4.d. 20a,b). The concentration of dung varies between 10–50%. In the earlier sub-type of Standard Zagros – Jarmo style – dung consisted of around 50% of the total pottery paste, while in the Guran and Sarab Geometric styles this decreased to about 30%. In the Buff ware, dung mostly presented in a concentration of about 30% (four samples), but in one case it was 10–15%. In the Red-slipped ware it varied much more, from 10 to 50% (Fig. 4).

Forming techniques

The features of the sequential construction of clay building elements were recorded in the cross-section of the Ali Kosh samples. Owing to the very small size of the available fragments, there is not enough information to distinguish the details by ceramic type. In most cases, slab construction was used in making vessels (Fig. 5). The clay slabs were joined sequentially along a horizontal circular path. This can be seen in only one large example of Ja'far Painted type (Fig. 5.a.13a) showing horizontal zones bounded by deepened lines. In the vertical and horizontal cross-sections joints of these zones are visible. They divide this horizontal zone into elements (slabs) (Fig. 5.a.13b,c). Layering of slabs divided horizontal and vertical cross-sections of sherds into two parts, inside of which joins are located at a short distance from each other (Fig. 5.a,b,c). In all cases, the clay slabs were elongated (approx. 2 x 3cm in size) and placed horizontally. In most of the ceramic fragments, there is a two-layer sequential slab construction.

Two-layer slab construction is also visible in the cross-sections of the two bases from Mahtaj in the way that slightly-deformed and elongated slabs are evident (1.2cm height, 3cm wide, 4.2cm long) (Fig. 6).

Sequential slab construction is also present in all the analysed samples from Guran (Fig. 7). The Jarmo style ceramics are made of two-layer slabs and, possibly, the same can be assigned to the fragment of the Guran style vessel (Fig. 7.a.1). In most of the Red-slipped samples two-layer slabs were also used (Fig. 7.a.6,13,14). In the horizontal and vertical cross-sections of the vessel walls, the junctions are located a short distance from each other and at a large angle to the walls of the vessel, creating layering. The slabs have a horizontal elongated shape. However, in two cases we can assume the construction of vessels from coils – in horizontal cross-section – due to the extended horizontal line of juncture, parallel to the vessel walls, in vertical cross-section, and the division into many separate parts by junctures (Fig. 7.b.4,10). Such a construction method is also seen in three fragments of Buff ware (Fig. 7. b.19).

Surface treatment and decoration

With regard to the Ja'far Painted (Fig. 8) and Ja'far Plain (Fig. 9) types at Ali Kosh, the outer and inner surfaces in all cases are covered with an additional dense layer, most likely of the same clay as the main raw material but without any organic temper, as suggested by the smooth surface of most fragments without plant imprints. Almost all ceramics with preserved coating have some loss of the upper layer (for example see Figs. 8.5a,b,6,7b, 8,9; 9.a.16b,18b,20) and cracks (Fig. 9.c.6c), which can be associated

with uneven shrinkage of the coating clay and the basic composition of the pottery paste. However, on some ceramic fragments with a destroyed surface this slightly ferruginous clay is visible in large amounts under a layer of clay covering (Fig. 9.a. 14,15,19). In some cases, over the clay, the surface of the vessels with varying degrees of wetness has been smoothed with a hard tool, probably made of bone or pebble (Figs. 8.a.3b; 9.b.25a).

The geometric designs, presumably painted with red ochre, are seen on the outer surface of all the Ja'far Painted vessels. Hole also mentioned the use of a specular hematite in one case (see *Hole* et al. *1969.117*). Under magnification, the paint showed a grainy texture, and it was applied unevenly (Fig. 8.a.11b).

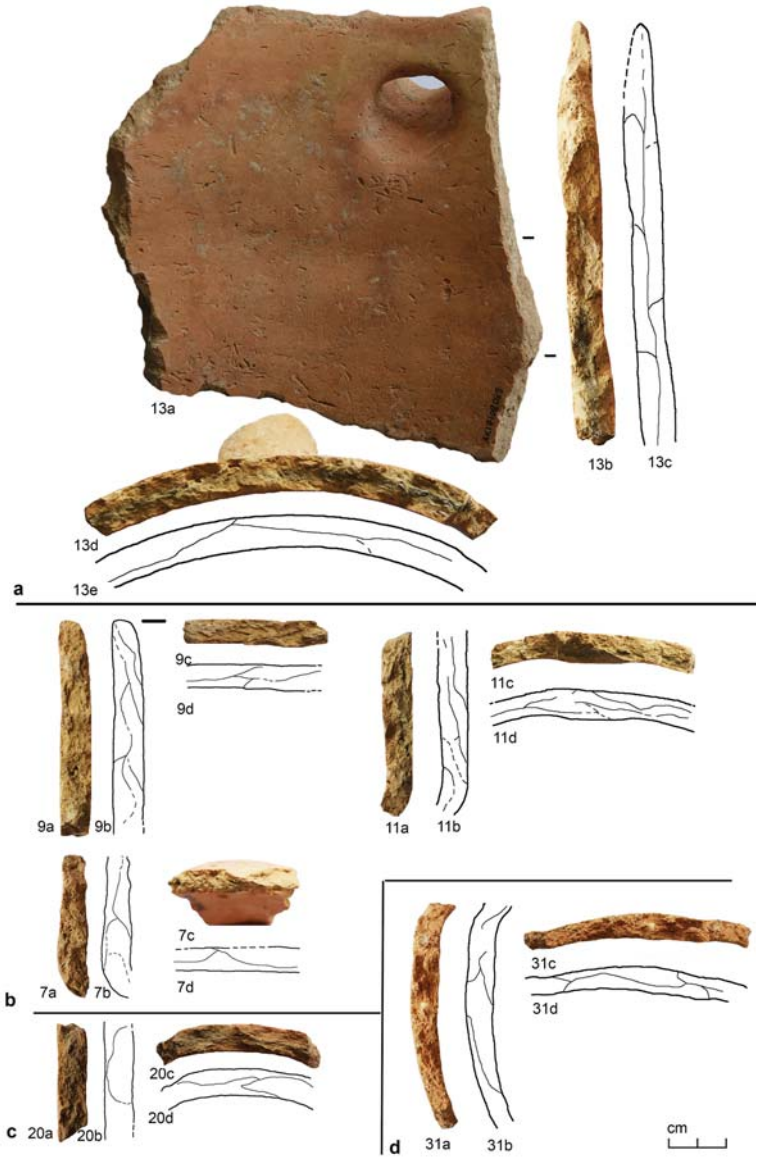

Fig. 5. Ali Kosh. Forming techniques methods: two-layer slabs. **a**,**b** ***Ja'far Paint;*** **c** ***Ja'far Plain;*** **d** ***Khazineh Red (photos and drawings here and further made by N. Petrova).***

Fragments of Ja'far Plain are usually covered with the same slightly ferruginous clay (Fig. 9a), but sometimes with highly ferruginous clay, as evidenced by characteristic cracks on the surface (Fig. 9b,c). This last case is interesting: when smoothing over a well-dried surface and then firing it in an oxidized atmosphere, the effect of a 'reddish colour' appeared. In one case the vessel was polished with a hard tool. As the result, both surfaces of the vessel acquired a bright red colour (Fig. 9.c.26a-d).

In case of Khazineh Red (Fig. 10), two sub-types of surface treatment can be distinguished. First, the surface was covered with an additional clay coating from the same clay on both surfaces of the vessel. This is usually accompanied with chips of the upper layer (Fig. 10.a.27b,29) and characteristic cracks (Fig. 10.a.30). In two cases, burnishing with a hard tool is recorded on a not completely dried surface (the so-called 'leather-hard' condition, when barely visible grooves left by the smoothing tool remain on the surface) (Fig. 10.a.29, 30). In general, this tradition of surface treatment is also characteristic of the Ja'far Plain and Ja'far Painted types. Regarding Khazineh Red specifically, however, the outer surface of fragments is completely red or sometimes plum coloured (Fig. 10. a.30). Second, the vessel has a layer of red slip (clay mixed with some red pigment) on both surfaces. The slip is indicated both by cracks on the outer surface (Fig. 10.b.31b) and by a layer, 0.1mm thick (Fig. 10.b. 31c), that is easily distinguishable under a microscope in the cross-section. Interestingly, in one case while the outer surface of the fragment was only covered with red slip, the inner red-slipped surface was overlaid with plum colouring (Fig. 10.b.31a,d,c), but the outer surface only had a layer of coating with the same clay (Fig. 10.b.31d,e).

In the case of the samples from Mahtaj, an additional coating with the same clay is distinguishable on the outer and inner surfaces of the vessels. Cracks are also visible on both sides.

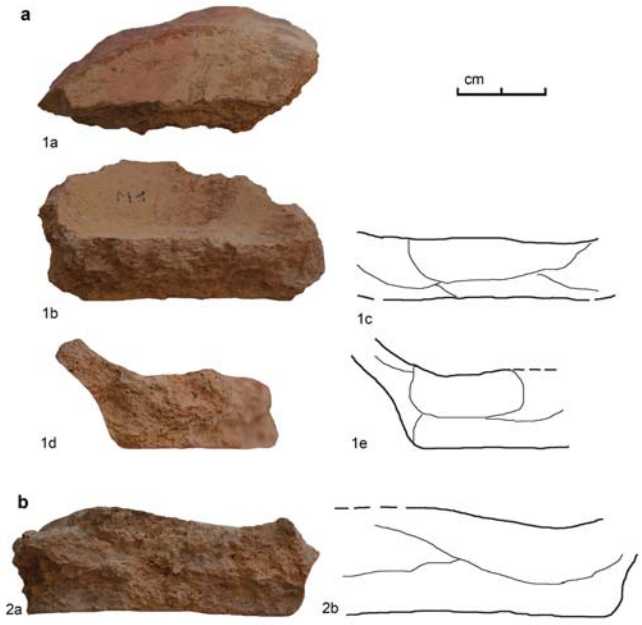

Fig. 6. Mahtaj.* a,b *two-layer slabs in the bases of different vessels.

At Guran, the Standard Painted ceramics, including Charmo (Fig. 11.a.1) and Guran styles (Fig. 11.a.2), Sarab Geometric (Fig. 11.b) and buff wares (Fig. 11.c) were slipped with a clay similar to their paste before firing, as evidenced by characteristic cracks on the surface (Fig. 11. b.3c,19c) and delamination of the coating layer, under which the surface is visible with a high density of organic inclusions (Fig. 11.c.22). The buff ware was also burnished in all cases. The ceramics types of the Charmo style, Guran style and Sarab Geometric were decorated with geometric designs painted in red ochre. Here, Red-slipped ware can also be divided into two sub-types.

In most of the available samples, both outer and inner surfaces (or sometimes just the outer) of the Red-slipped ware (Fig. 12), based on the colour uncharacteristic of natural clay, are covered with a mixture of clay and red pigment before firing (Fig. 12.a). In addition, a variation of brown slip is found (Fig. 12.a.14). The thickness of the slip layer varies (for a comparison see Fig. 12.a.5d – 0.15mm, and Fig. 12.c.17c – 0.05mm) and in all cases it is applied to the unfired surface, as evidenced by characteristic cracks (Fig. 12.a.6c) and by surface losses – *i.e.* rounded chips inside these cracks (Fig. 12.a.5a,b,c,6a, 8b). The slipped surface is usually slightly or highly burnished. From time to time, one can find prints of textile indicating its application either in smoothing or slipping with a textile (Fig. 12.a.11c).

In three cases the surface of vessels was covered with the same clay and then fully overlaid by colouring (Fig. 12.b,c,d). Two samples represent a reddish-brown colouring just on the outer surface (Fig. 12.b.15a,16a). In another case, brown colouring was applied to the outer surface (Fig. 7.d.17a,c,d), while the inner surface contains red colouring (Fig. 12.d. 17b,e). In one interesting case, brown paint covered a layer of red slip applied to the outer surface of the vessel (Fig. 12.c.18a,c,d), but the inner

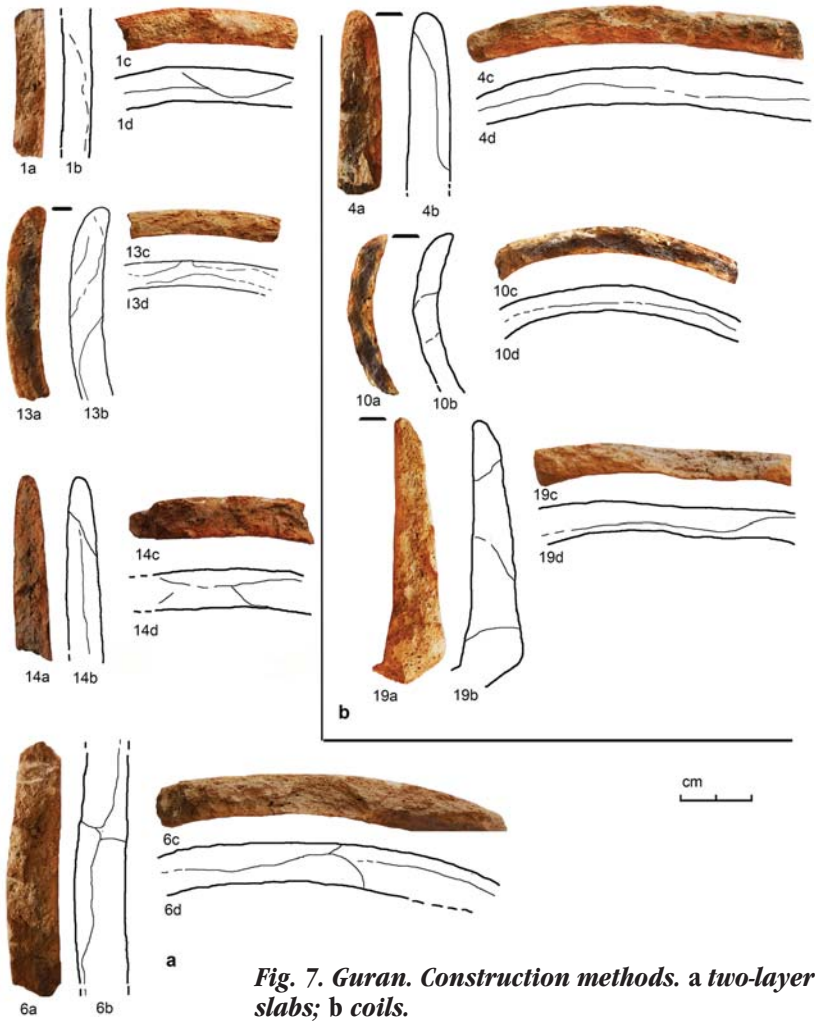

Fig. 7. Guran. Construction methods.* a *two-layer slabs;* b *coils.

surface was covered by red slip only. Different variants of brown colour can be reached by using iron oxide pigments with firing at higher temperatures (*Hole* et al. *1969.113*), for example magnetite, hematite and limonite in a different oxidative and reduction firing atmosphere (*Nieuwehuyse* et al. *200.158–160*).

Firing

All the Ali Kosh vessels were fired using an oxidizing atmosphere. Two fragments of Khazineh Red pottery are fully oxidized (Fig. 5.d). Others have a dark or light grey core. In half of the cases, the margin of the transitional layer between the outer orange layer and dark core is sharp (this mainly refers to the Ja'far Plain ceramics (Fig. 5.c.9a, 16c, 19b,20b), which indicates that the vessel did not cool down in the firing device and was abruptly removed after a short exposure to high temperatures. In other cases – mostly Ja'far Painted – the margin of the dark core is gradual and the oxidized layer is much thicker, which may indicate a longer stay in the firing device (Fig. 5.a,b). Judging from the thickness of the oxidized layers and the presence of calcined organic residues in some fragments, the ceramic vessels of Ali Kosh seem to have been fired at a temperature of about 650–700°C (*cf. Bobrinsky 1999.99; Rue 1981.118*). Our analysis showed that the bases recovered from Mahtaj are completely oxidized (see Fig. 6). All the Guran samples were also fired in an oxidizing environment at a temperature not lower than 700–750°C, and the lack of organic inclusions suggests their long exposure to the heat. Thin-walled fragments of Jarmo, Guran and Sarab Geometric styles are all oxidized (Fig. 7.a.1), while just half of other types had the same feature (Fig. 7.a.6,b19), and the rest have a light grey core with gradient margins, although complete oxidation is also recorded in different parts of the fragment (Fig. 6.a.13,14, b4,10). Of the analysed samples only one piece of Red-slipped ware contains a very thin oxidized layer, with a dark grey core and a sharp margin between oxidized and core layers of its cross-section.



Fig. 8. Ali Kosh. Ja'far Painted ceramic type – covering with the same clay + paint.

Discussion: development of Neolithic pottery technology in Zagros

The ceramic assemblages analysed for this research were sampled from Neolithic sites that are located in both the highlands and lowlands. At the same time, they, and specifically Ali Kosh and Guran, represent the most common Neolithic ceramic types in the region. This inspired us to deploy a deductive approach in order to reach some 'generalization', though local criteria should also be given attention. In the light of available evidence and based on the current research, however, we may discuss the development of early pottery technology of the Zagros region with regard to the analyses outlined above.

Addressing the emergence of pottery technology, it is necessary to draw on Vandiver's assumption highlighting its connection with building technologies (*Vandiver 1987*). In this regard, general clay architectural remains from the pre-pottery Neolithic, and specifically those from Ganj Dareh, indicated the presence of a large plant admixture added during the

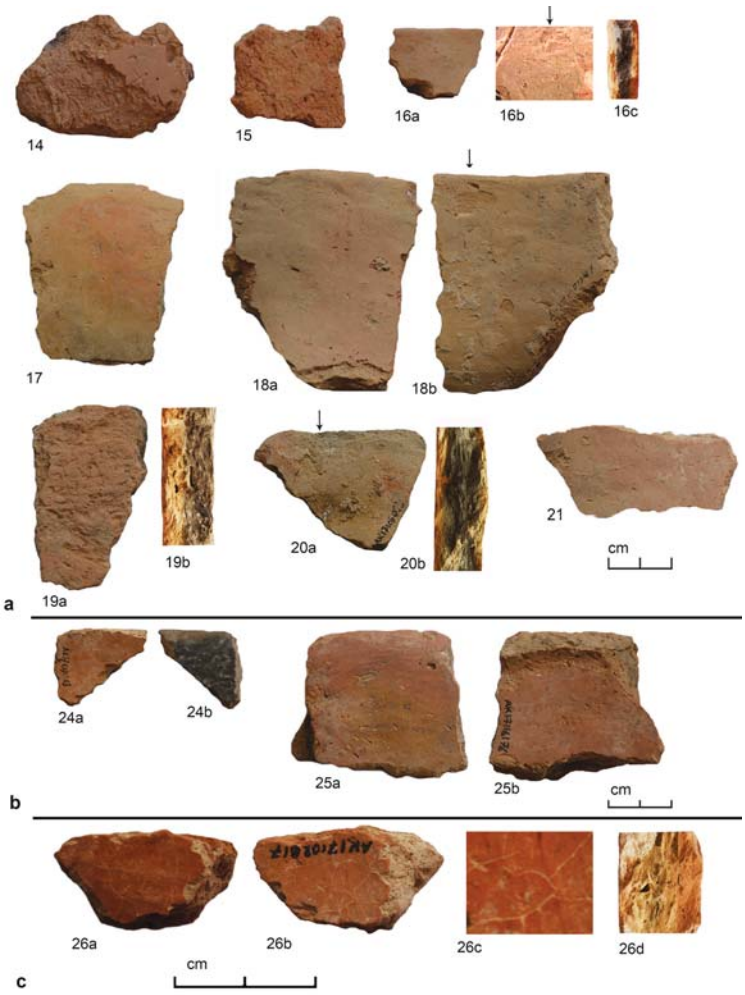

Fig. 9. Ali Kosh. Ja'far Plain ceramic type.* a *coated with the same slightly ferruginous clay;* b *coated with the same highly ferruginous clay + burnishing;* c *high burnishing over the highly ferruginous clay creates the effect of a 'red surface', in the cross-section a calcined highly ferruginous layer of clay can be seen (*26.d*).

construction of adobe buildings. At Ganj Dareh, the clay building construction elements are found in two types: chineh (strips) and mud bricks (*Smith 1990. 328–332*). It is noteworthy that such features were omnipresent at early Neolithic sites such as Ali Kosh, Sheikhi Abad, Mahtaj and Abdul Hosein. Along with the production of clay vessels, stone vessels, baskets and white ware, as well as clay objects, such pise walls reveal both long experimentation and knowledge before the appearance of true pottery. From an architectural perspective, pise building and plastering or coating walls either with clay or red ochre merits specific attention as a key precursor to pottery-making and decorating. The small and large clay containers from Ganj Dareh evidently support this idea. Here, large unbaked storage vessels were in some cases fixed to the floor or attached to the wall. These were large, round, up to one meter in height, storage vessels, and semicircular storage compartments that had one common wall with the dwelling (*Smith 1990. 332*). Vandiver (*1987.25*) noted that montmorillonite clays are mainly used in the settlements of the region. Our observations of earlier ceramics of Ali Kosh, Mahtaj and Guran demonstrated the careful and intentional selection of raw materials, and that the clay was used without large mineral impurities, including limestone seen in an insignificant concentration and small size. This shows differences compared to Ganj Dareh, where some vessels were made of clay with a large mineral admixture (*cf. Smith 1990.332*).

As for intentionally added impurities, the earliest clay vessels of Ganj Dareh are of two types: small samples without any visible, specially added temper, and oversized items (larger pottery, storage vessels, and basins) where plant impurities are recorded (*Vandiver 1987.17; 1985.194–195*). When it comes to the pottery paste, the putative organic temper is considered for the Neolithic assemblages though various terms like 'vegetal', 'straw' or 'chaff' are also applied. However, the presence of dung was already reported from some sites, such as Charmo, Gird Ali Agha and Tell el-Khan (*Adams 1983; Matson 1960. 68*), Shimshara (*Tauber 1970.143*) and Guran (*Mortensen 2014.50*; also see above). With regard to the samples from Ali Kosh and Mahtaj, the organic temper from the very beginning has a different and multicomponent composition: dung and crushed coarse plant inclusions, both separately and in combination. It can be assumed that the tradition of adding the dung of sheep and goats to the pottery paste spread during the 7th millennium BC. It is noteworthy that dung had also been used as fuel resource in the Zagros region during the pre-pottery Neolithic, as evidenced by micro-morphological analysis (*Matthews* et al. *2013; 2016; 2020; Fatui Dilanchi* et al. *2020*). We assume that dung along with crushed plant admixtures was used by local potters, though a full understanding of the organic material (threshing waste, chaff or some other type of crushed straw) requires further consideration. The technological characteristics of the later stage at Guran (from level O onwards) showed the

predominance of dung added to the pottery paste.

The Neolithic ceramics in the studied region were mostly produced using clay slabs (Fig. 13). Even their precursor, namely clay containers from Ganj Dareh, had a similar method of production (*Vandiver 1987.18*). Slab construction in the Zagros region has been reported from a number of sites, such as Sarab (*Vandiver 1987.18*), Chogha Sefid (in layers of later Neolithic – Sefid and Surkh phase) (*Hole, Tonokie 2021*), Sabz (*Hole* et al. *1969.111–112*), Chogha Mish (*Delougaz, Kantor 1984.228*), Hajji Firuz (*Vandiver 1987.18–19; Voigt 1983.149–152*) and in Northern Mesopotamia – Yarim Tepe I, Sotto, Umm Dabaghiya of Proto-Hassuna and Hassuna periods (both Archaic and Standard) (*Petrova 2019; 2021*). Based on our analysis, the ceramics were built up in two-layer slabs in Ali Kosh and Mahtaj. This method is also attributable to the later Guran ceramics from level O onwards, specifically in the cases of tadpole (Charmo and Guran styles) and Red-slipped wares.

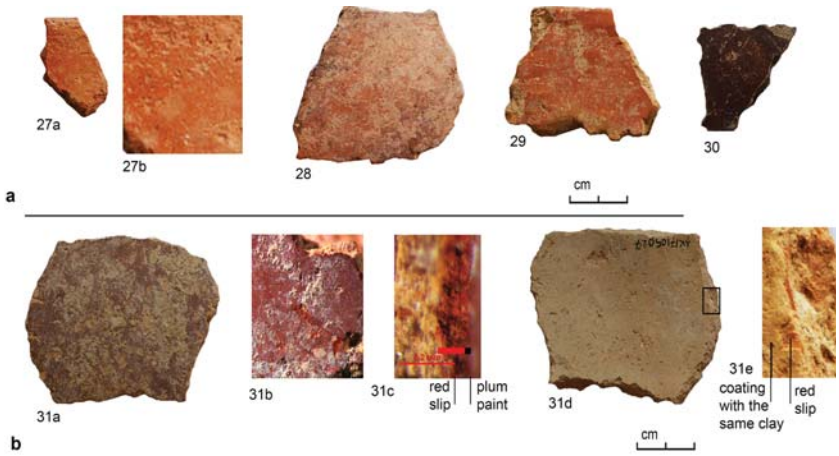

Fig. 10. Ali Kosh. Khazineh Red ceramic type.* a *coating with the same clay + full pigment colouring;* b *coating with red slip (clay mixed with red pigment). Outer surface – red slip + plum colouring (*31.a,b,c*). Inner surface – red slip + coating with the same clay (*31.d,e*).

In connection with the use of sequential slab construction, the question of using the mould to which these slabs were stuck arises. On the one hand, the connection with building technologies suggests free modelling, and that the first storage vessels were most likely built in this way. On the other hand, some of the vessels made of two-layer slab construction are small and thin-walled, which is difficult to do without using a mould and paddling. It is noteworthy that sticking clay slabs onto a base mould is still being used by some women who produce pottery vessels in Baneh, Iranian Kurdistan (*Sedighian, Mahjour 2010.83*). According to archaeological materials, the use of a mould was previously supposed for the vessels from Ganj Dareh (*Smith, Crepeau 1983. 56–58*). The prints of weaving, which possibly remained from a liner that covered the mould (to help separate the future vessel from mould), were found on the ceramics of the later site of Hajji Firuz, northwestern Iran, where they are seen inside the bases of the vessels and on the outer surface under a layer of coating (see *Voigt 1983.149, Pl. 25*). In addition, some samples from Chogha Mish showed the appli-

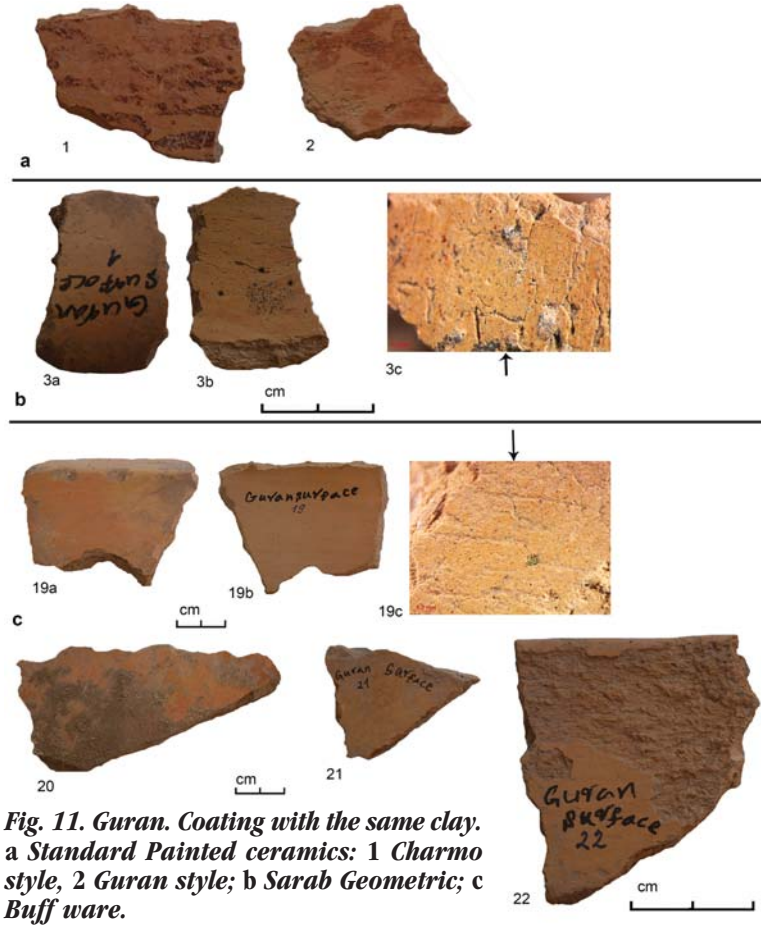

Fig. 11. Guran. Coating with the same clay.* a *Standard Painted ceramics:* 1 *Charmo style,* 2 *Guran style;* b *Sarab Geometric;* c *Buff ware.

cation of the same method on their inner sides (*Delougaz, Kantor 1996.228*). The use of a mould in making pottery vessels has not yet been reported from other Neolithic sites in Zagros. Hole *et al.* (*1969.111*) noted the absence of features of paddling in Ali Kosh, and although such features are also seen in our assemblage from the site, they are comparatively smaller in size. However, as indicated by some fragments from Hajji Firuz, a mould or link might have been applied during the Neolithic, though their prints were hidden by subsequent clay coating.

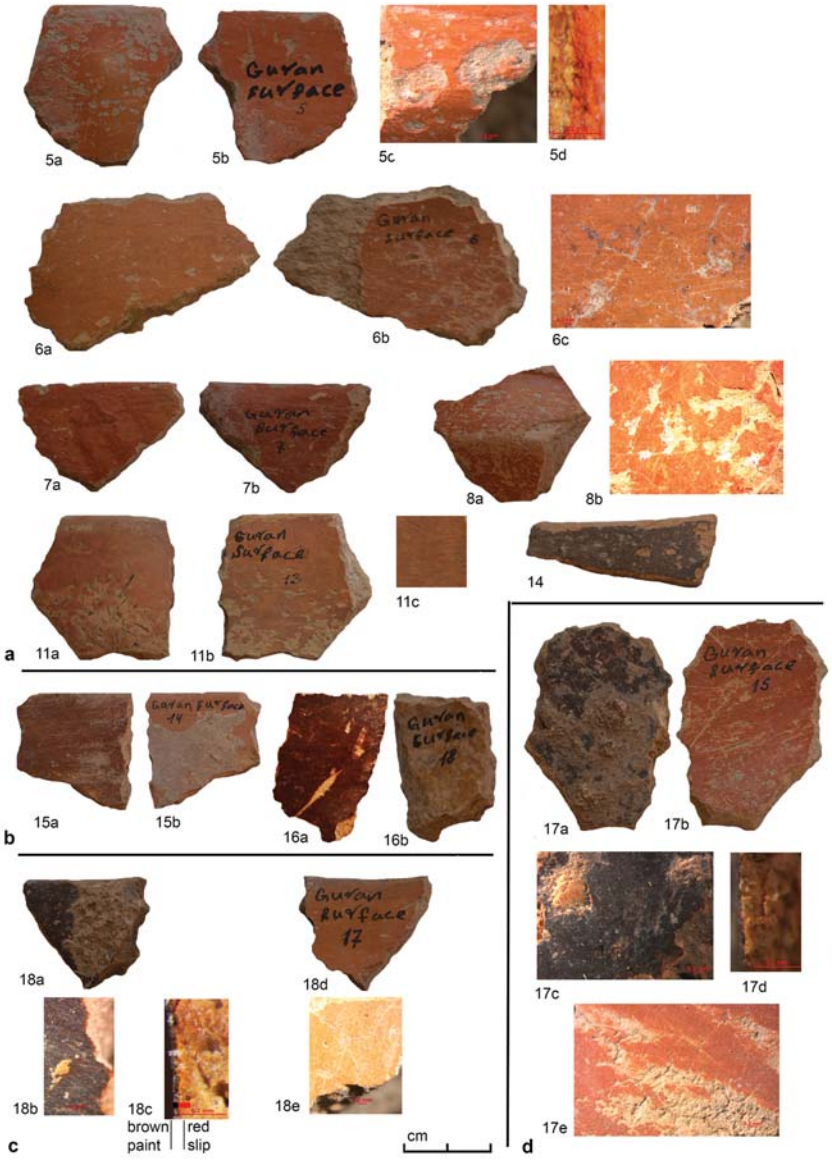

Fig. 12. Guran. Red-slipped ware.* a *both surfaces covered with red slip (clay mixed with red pigment);* b *outer surface coated with the same clay + red-brown paint, inner surface – coating with the same clay;* c *outer surface coated with red slip + brown paint (*18.a,c,d*), inner surface – red slip (*18.b,e*);* d *outer surface coated with the same clay + brown paint (*17.a,c,d*), inner surface – coating with the same clay + red paint (*17.b,e*).

At Guran, some samples of Buff and Red-slipped wares were produced using coil construction. However, it is difficult at present to conclude whether this method was used from the beginning of ceramic levels of the site, or it was a later tradition that had been brought from outside. This issue requires further data. The use of coils was previously recorded from the sites of Hajji Firuz and Ali Agha, both dated to the late 7th and early 6th millennia BC, in northern and northwestern/western Zagros, respectively (*Voigt 1983.149–152*) and in Northern Mesopotamia – Yarim Tepe I, Sotto, Umm Dabaghiya of Proto-Hassuna and Archaic Hassuna periods (*Petrova 2019; 2021*).

According to ethnographic data, different technological stages react differently to innovations (*Bobrinsky 1978; Schiffer, Skibo 1987; Stark 1999*). At all stages of pottery technology, it is very important to distinguish the construction methods deployed for making the vessels. This technological stage is least susceptible to outside influence, and may indicate not only cultural interactions but also the composition of the population and its changes, in contrast to the methods of making the pottery paste and surface treatment (*Bobrinsky 1978.244; Fowler 2017.14; Gosselain 1992.582; 2000.192*).

The surface of the ceramics from our three sites share a feature, the presence of an additional clay coating (covering by the same clay or a slip). This is also reminiscent of an earlier building construction technique when the walls of the houses were covered with additional clay coating in pre-pottery Neolithic settlements. Clay coatings are noted on the ceramics recovered from various sites such as Ali Kosh (*Hole* et al. *1969.110*), Guran (*Mortensen*

2014.50–66), Chogha Bonut (*Alizadeh 2003.46, 56*), Chogha Mish (*Delougaz, Kanto 1984.227*), Chogha Sefid (*Hole 1977*), and Sarab (*McDonald 1979*). In most cases, the coating is similar to the texture of the vessels.

Smoothing and burnishing of the surface is ubiquitous during the Neolithic period. We identified various methods of surface treatment in association with Ali Kosh and Guran: smoothing the surface having varying degrees of dryness with a hard tool (seen in all ceramic types of Ali Kosh) up to the appearance of the effect of slightly burnishing (in Ja'far Plain) and full burnishing (characteristic of Buff ware and Red-slipped ware at Guran). In addition, the surface was also smoothed with textile at Guran.

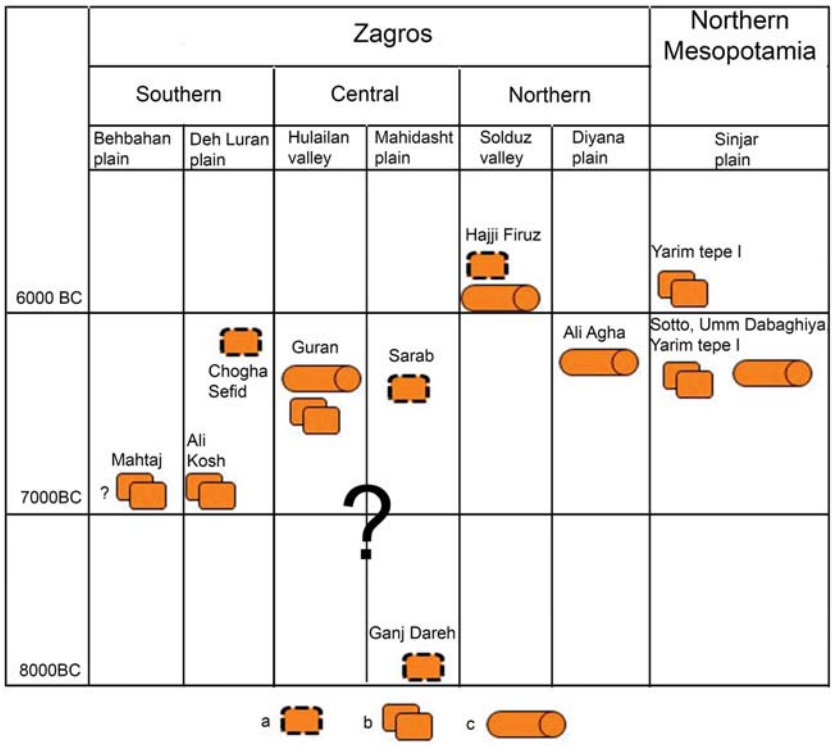

Fig. 13. Pottery construction methods seen in Neolithic Zagros:* a *slab construction (shape and number of layers unknown);* b *two-layers slab construction;* c *coil construction.

Stamped and carved ornaments, specifically punctate impressions like carved lines and crescent notches produced by a fingernail or the end part of a bone, are seen on the earliest ceramics of Guran and also those from the earlier site of Ganj Dareh (*Mortensen 2014.50; Smith 1974.207*). The nature of such early decorated samples is still ambiguous, as they are documented as vessels made of untempered clay and it is still arguable to what extent they can be taken as the incipient clay/pottery containers. However, this type of ornament was then replaced by the paint decoration in the region. Soon after, the surface decoration is associated exclusively with the use of pigments such as red ochre, which were either applied for making geometric designs or completely covered the surface. As mentioned above, at Ali Kosh and Guran such pigment was applied over a surface previously covered with a red slip. This suggests an attitude by the early potters to treat slip as a way of covering, but not decorating, the surface. Our analysis showed various methods of achieving the 'red surface' of Khazineh Red and Red-slipped ware at both sites. This can be divided and diachronically traced. Firstly, a full coverage of the surface with only a colouring pigment such as ochre on a covering of the same clay was common. Secondly, it seems that during the process of treatment a red-slipped surface appeared when the covering with the same clay was mixed with red pigment. This method came about over time, as seen from uppermost levels at Ali Kosh, where fully coverage of the outer surface with of plum-coloured paint is synchronously seen.

All the fragments we studied were fired using an oxidative firing. The vessels from Ali Kosh show the existence of various heat treatments: short or long exposure in the heating zone, depending on the type of ceramics. In this regard, the Ja'far Plain samples were usually fired for a relatively short time, while the Ja'far Painted and Khazineh red ones underwent longer exposure. However, we have some fragments from Ali Kosh of different ceramic types that are fully calcined. At Guran an increase in firing duration for all types is seen over time: in half of the cases the items they are fully calcined; in some other cases (Red-slipped ware and Buff ware) the vessels were fired with long exposure to the heat zone. In general, this may indicate possible improvements in the process of ceramic firing.

According to some researchers, dung was an outstanding fuel resource in western Asia from the early Neolithic onwards (see *Hesse 1984; Matthews*

et al. *2020; Miller 1984; Miller, Marston 2012.97; Spengler 2019*). However, in ethnographic research it is cattle dung that has been mostly given attention (*Mahjour* et al. *2014.25; Matson 1974.345; Petrova 2011.135; Salimi 2014.589*), while the earliest evidence for cattle domestication is attributed to the early 6th millennium BC in Zagros (see *Arbuckle* et al. *2016*). Thus, the use of animal dung at the earlier settlements such as Ali Kosh and Guran would have been restricted to that of goats and sheep. According to Wendy Matthews (*2016.116–117*) the type of fuel used varied depending on local conditions, and dung was widely used as a fuel. In this regard, woods (and specifically oak trees) were more often burned in the highlands (in particular the landscape surrounding Ganj Dareh), while in the foothill-steppe region and on the plains, in particular the Deh Luran Plain where the settlement of Ali Kosh is located, grasses and reeds were used for this purpose (*Helbaek 1969.387; Miller 1996.521–525*). However, the presence of dung in the pottery assemblage from Ali Kosh suggests the multi-purpose usage of dung. As mentioned before, micromorphological analysis has also shown presence of animal dung, most likely goat, at the pre-pottery sites of Sheikhi Abad (*Matthews* et al. *2013*) and Mahtaj (*Fotuhi Dilanchi* et al. *2020*) prior to its use in association with early pottery production, whether as temper or fuel. Our knowledge about firing devices still remains at the level of assumption: firing was carried out either in bonfires, or in hearths coated with clay and built up with mud bricks, or in ovens (*Schmandt-Besserat 1974.15; Hole* et al. *1969.40, 42*). However, excavations at Yarim Tepe I (level 10) have shown the remains of a two-stage pottery kiln dated to the Archaic Hassuna period in Northern Mesopotamia) (*Munchaev, Merpert 1981.75*). The presence of such a developed device at the end of the 7th millennium BC allows us to assume the existence of simpler devices at an earlier time, coinciding with the emergence of pottery in the Iranian Zagros foothills.

Concluding remarks

The technological analysis conducted on the ceramic assemblages from the three Neolithic sites shed new light on the nature of early developments of pottery production along the Iranian Zagros. To conclude the current research, we may highlight both similarities and differences in terms of construction methods, paste, raw materials, firing and surface treatments that were applied by the early potters across highlands and lowlands. Of the samples from Ali Kosh, the Ja'far Plain type is somewhat different from the other two types with regard to the technology. The walls are thicker and firing time was shorter. Sometimes it contained an abundant admixture of coarse plant residues in the pottery paste, occasionally combined with dung. It was previously believed that Ja'far Plain was identical to Ja'far Painted unless the latter was decorated (*cf. Hole* et al. *1969.117*). However, our analysis indicated that the Ja'far Painted type shared some similarities with Khazineh Red, as they both show the predominant use of dung as a temper and a longer firing. The Khazineh Red type represents three variants: the earlier indicated by the samples bearing a red paint fully overlaid with clay slip, and the later represented by red-slipped vessels showing a mixture of clay slip and reddish pigments. However, the third group includes some different cases showing red slip on the outer surface overlaid with full colouring, and on the inner surface with a layer of the same clay covering. We assume that the technology of the Ali Kosh ceramics had definitely passed some stages of development when it emerged at the site (*cf. Hole* et al. *1969. 352*). However, its predecessor still remains a controversial issue. The clay was specially selected without any large natural mineral inclusions. The pottery paste also has a different and multicomponent composition: crushed plants (possibly, threshing waste – chaff) and the dung of sheep and goats. In the construction stage, two-layer elongated slabs were built up along a circular horizontal path. During surface treatment, there is always a clay coating on the vessels. Various smoothing techniques were applied at the site using a hard tool, with varying degrees of dryness on the surface to be slightly or fully burnished. With regard to firing, there are various approaches: short or long exposure in the high temperature zone, depending on the type of vessel being made.

The main technological characteristics of a few pottery fragments from Mahtaj are close to those of Ali Kosh in the way that a combination of dung and coarser plant impurities are seen in the paste. Moreover, the sequential two-layer slab construction of vessels and coating the surfaces with wash are also notable.

Although various ceramic types are present at Guran, they share some technological characteristics: selection of clay without any large amount of natural mineral inclusions, intentional adding of dung into the pottery paste, two-layer slab construction, an intentional covering layer on the vessel (wash or

slip) and the presence of significant amount of completely calcined sherds during firing. In addition to the ubiquitous method of slab construction, clay coils were attested for some Red-slipped and Buff ware fragments. However, the emergence of the coil construction method at Guran is as yet unknown either as a locally developed or an imported tradition. To better understand this a study of stratified early materials from the site seems important.

As in case of Ali Kosh, at Guran three variants of 'red surface' can also be determined in Red-slipped ware: first, a fully red painted surface overlaid with a layer of clay similar to the paste; second, red slipped (clay mixed with pigment) surface, which is present in the majority of cases. The third case is represented by two very interesting ceramic fragments recovered from Ali Kosh and Guran. The pigment was applied over a surface previously coated with a red slip. The presence of similar items in both settlements could synchronize the upper layer(s) of the Ali Kosh settlement and the corresponding layer(s) at Guran, if the ceramics came from stratified excavations. However, the existence of this unusual treatment at both sites may indicate cultural interactions between highlands and lowlands. Such close interactions are mirrored in a majority of comparable archaeological finds, from lithic types to architectural layouts and to pottery style sand construction methods, as well as in the spread of obsidian across Zagros. This may undermine the idea that in the Neolithic period contacts between the foothills of the Zagros (Ali Kosh) and its central regions (Ganj Dareh, Guran) were unlikely, because they were separated by the 'formidable' Kabir Kuh – the longest of the Zagros Mountain ranges (*Hole 2018.178*). Although such natural barriers could have affected the path and rate of interactions, the role played by the transhumant people who were tracking a vertical movement and river valleys, such as Seimarreh, should not be overlooked.

In case of Ali Kosh, the emergence of pottery seems to have happened abruptly at the site, an issue suggesting that some earlier steps may have been taken somewhere else. In this regard, Abbas Alizadeh (*2003*) assumed that the so-called phase of 'Susiana Formation' at Chogha Bonut was a precursor of the Mohammad Ja'far phase at Ali Kosh. However, this hypothesis is still open, as both sites experienced different pottery styles. Therefore, one may see the pottery Neolithic (*c.* 7000–6000 BC) as a millennium which saw a combination of local creativity and inter-connectedness with surrounding areas.

With regard to the initial construction methods, we suppose both free construction of vessels and making them on a mould. The former is seemingly connected with building technologies, while the latter suggests another experience, possibly influenced by coating pits with clay. However, the early ceramics were commonly produced using a slab construction method, though clay coils were sometimes also applied. The origin of the coil construction method in the Zagros region is not yet known. Nevertheless, one may see it as one of the variants in the development of building techniques or elongated slabs. This idea, of course, requires further investigation.

In this study we have brought to light some general information about the technology of the earliest ceramics along the Iranian Zagros. However, placing such analyses within a larger region will allow us to better understand the Early Neolithic pottery technology in the Eastern Fertile Crescent.

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Appendix

Tab. 1. Technological characteristics of Tapeh Ali Kosh ceramics.

Vessel No.	Type	Context	No.	Part of vessel	D of rim (cm)	Thickness (mm)	Clay ferru-gination	Added inclusions %		Constructi-on method	Surface treatment		Painting		Firing
								Dung	Large plant		Outer	Inner	Outer	Inner	Oxidized
Ja'far Painted (covering with the same clay + paint ornament)															
1		118	180	spout		8-9	high		20		the same clay+ bone/pebble	the same clay +fingers	red ornament		partial, sharp boarders
2	Ja'far Painted	118	181	wall		7	high	30			the same clay+ bone/pebble	the same clay +bone/pebble	red ornament		partial, gradual boarders
3	Ja'far Painted	116	175	wall		10	high	20	10	slabs	the same clay+ bone/pebble	the same clay +bone/pebble	red ornament		partial, gradual boarders
4	Ja'far Painted	115	161	rim		7	medium	10		slabs	the same clay+ bone/pebble	the same clay +bone/pebble	red ornament		partial, gradual boarders
5	Ja'far Painted	115	162	rim	23	7-11	medium	20	10	slabs	the same clay+ bone/pebble	the same clay +bone/pebble	red ornament		partial, gradual boarders
6	Ja'far Painted	115	164	rim		10	medium	10			the same clay+ bone/pebble	the same clay	red ornament		partial, gradual boarders
7	Ja'far Painted	113	138	wall		8-12	high	20	10	slabs	the same clay	the same clay +bone/pebble	red ornament		full
8	Ja'far Painted	112	135	rim		8-10	medium	10		slabs	the same clay+ bone/pebble+ slightly burnishing	the same clay +bone/pebble	red ornament		partial, gradual boarders
9	Ja'far Painted	112	116	wall		10	medium	20	10	slabs	the same clay+ bone/pebble	the same clay +bone/pebble	red ornament		partial, gradual boarders
12	Ja'far Painted	106	049	wall		10	medium	20	10		the same clay	the same clay	red ornament		full
10	Ja'far Painted	111	111	rim	17	7-9	medium	10		slabs	the same clay	the same clay	red ornament		partial, gradual boarders
13	Ja'far Painted	102	024	wall		8-12	low	10	20		the same clay bone/pebble	the same clay	red ornament		full
11	Ja'far	108	083	rim	15	6-13	medium	30	5	slabs	the same clay	the same clay +bone/pebble	red ornament		partial, gradual boarders

Continuation

Ja'far Plain (covering with the same slightly ferruginous clay)															
15		127	198	wall		14	medium		50		the same clay	the same clay			partial, sharp boarders
16	Ja'far Plain	127	196	wall		>11	high	30	30		destroyed surface	destroyed surface			full
14	Ja'far Plain	127	202	rim	25	7	medium	30			the same clay+ bone/pebble + slightly burnishing	the same clay			partial, sharp boarders
18	Ja'far Plain	115	148	wall		11	medium	30	5	slabs	the same clay+ bone/pebble	the same clay +bone/pebble			partial, sharp boarders
17	Ja'far Plain	107	077	rim		10	medium	15	5	slabs	the same clay	the same clay +bone/pebble			full
19	Ja'far Plain	108	102	wall		11	medium		30	slabs	the same clay	destroyed surface			partial, sharp boarders
20	Ja'far Plain	105	028	wall		12	medium	15	5		the same clay	the same clay			partial, sharp boarders
21	Ja'far Plain	108	097	wall		10	medium		30	slabs	the same clay	the same clay			partial, sharp boarders
22	Ja'far Plain	124	190	wall		15	high		30	slabs	the same clay+ bone/pebble	the same clay			partial, sharp boarders
23	Ja'far Plain	117	178	wall		12	high	30			the same clay+ bone/pebble	the same clay			partial, sharp boarders
Ja'far Plain (covering with the same highly ferruginous clay + burnishing)															
24	Ja'far Plain	107	083	wall		12	high	15			the same clay	the same clay +bone/pebble +slightly burnishing			full
25		108	017	wall		13	high	20	10		the same clay+ bone/pebble+ burnishing	the same clay +bone/pebble burnishing			partial, gradual boarders
26	Ja'far Plain	116	176	wall		10-14	high	30	5	slabs	the same clay+ bone/pebble	the same clay +bone/pebble			partial, sharp boarders
Khazineh Red (covered with the same clay + full pigment coloring)															
27	Khazineh Red	116	177	rim		7	medium	30		slabs	the same clay+ bone/pebble	the same clay +bone/pebble	red full coloring		partial, gradual boarders
28	Khazineh Red	116	168	wall		10	medium	10	20	slabs	the same clay	the same clay	red full coloring		partial, gradual boarders
29	Khazineh Red	105	043	rim		10	medium	10		slabs	the same clay+ bone/pebble+ slightly burnishing	the same clay +bone/pebble	red full coloring	red partial coloring	partial, gradual boarders

Continuation

30	Khazineh Red	102	014	wall		8	medium	10			the same clay+ bone/pebble	the same clay	full plum		partial, gradual boarders
Khazineh Red (covered with red slip (pigment + clay))															
31	Khazineh Red	105	027	wall		8-12	medium	30	5	slabs	red slip	red slip+ the same clay		plum full cover	full

Tab. 2. Technological characteristics of Tapeh Mahtaj ceramics.

No.	Part of vessel	Thickness (mm)	Clay ferrugination	Added inclusions %		Contruction method	Outer and inner surface treatment	Firing
				Dung	Large plant			Oxidized
1	base/wall	19/9	medium	20	30	slabs	soft	full
2	base/wall	20	medium	20	30	slabs	soft	full

Tab. 3. Technological characteristics of Tapeh Guran ceramics.

Number	Type	Part of vessel	D of rim (cm)	Thickness (mm)	Clay ferru-gination	Added inclusions %		Constructi-on method	Surface treatment		Painting		Firing
						Dung	Large plant		Outer	Inner	Outer	Inner	
1	Jarmo style	wall		7	medium	30		slabs	the same clay+ slightly burnishing	the same clay	red ornament		full
2	Guran style	wall		5	low	50			the same clay+ textile?	the same clay	red ornament		full
3	Sarab Geometric	rim	20	7	low	20		slabs	the same clay	the same clay		red ornament	full
Red-slipped ware (both surfaces covered with slip)													
4	Red-slipped ware	rim	41	10	medium	20	20	coils	red slip+ burnishing	red slip			partial, gradual boarders
5	Red-slipped ware	rim	28	8	medium	50			red slip+ burnishing	red slip+ burnishing			full
6	Red-slipped ware	wall		10	medium	50		slabs	red slip+ burnishing	red slip+ burnishing			full

Continuation

7	Red-slipped ware	rim	24	9	medium	50			red slip+fingers +burnishing	red slip			full
8	Red-slipped ware	rim+wall		8-11	medium	20-30	5	slabs	red slip+ burnishing	red slip			full
9	Red-slipped ware	rim	27	8	medium	20-30		slabs	red slip+textile +burnishing	red slip			partial, gradual boarders
10	Red-slipped ware	rim	14	5	medium	15		coils	red slip+textile +slightly burnishing	the same clay			partial, gradual boarders
11	Red-slipped ware	rim		6	medium	20-30		slabs	red slip+ burnishing	red slip			partial, gradual boarders
12	Red-slipped ware	rim		8	medium	20-30		slabs	red slip	the same clay +burnishing			partial, sharp boarders
13	Red-slipped ware	rim	10	7	medium	15	5	slabs	red slip+textile	red slip			partial, gradual boarders
14	Red-slipped ware	wall		7	medium	30	5		brown slip	the same clay +fingers			full
Red-slipped ware (different variants)													
15	Red-slipped ware	rim		6	medium	10-15	5	slabs	the same clay+ slightly burnishing	the same clay	red-brown full coloring		partial, gradual boarders
16	Red-slipped ware	wall		7	low	50	5	slabs	the same clay	the same clay	brown full coloring	red full coloring	partial, gradual boarders
17	Red-slipped ware	rim		7	low	10-15			red slip+ slightly burnishing	red slip	brown full coloring		partial, gradual boarders
18	Red-slipped ware	wall		8	medium	30			the same clay+ burnishing	the same clay	red-brown full coloring		full
19	Buff ware	wall		5-9	low	30	5	coils	the same clay+ burnishing	the same clay			full
20	Buff ware	wall		13-15	low	30	5	coils	the same clay+ burnishing	the same clay +burnishing			partial, gradual boarders
21	Buff ware	wall		12	low	10-15			the same clay+ burnishing	the same clay			partial, gradual boarders
22	Buff ware	rim		7	low	30	5	coils	the same clay+ burnishing	the same clay			partial, gradual boarders

The end of the earliest ceramic traditions: Dnieper-Dvina region became part of the Circum-Baltic space at the turn of the 6th to 5th millennium BC

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ABSTRACT – *The Dnieper-Dvina area is one of the regions in Eastern Europe which was part of a wider network of the earliest ceramic traditions, spread in the first half to the middle of the 6th millennium BC. After the collapse of this network new ceramic complexes appeared here, called the Rudnya culture, and at the end of the 6th millennium BC this manifested in changes in the directions of cultural connections. This region became part of the cultural space of the Circum-Baltic area. Several complexes within the Rudnya culture originated in different groups of Narva pottery, and are dated to* c. *5400–4400 cal BC.*

KEY WORDS – *early pottery; hunter-gatherers; Narva culture; Circum-Baltic space; bone industry*

Konec najzgodnejših keramičnih tradicij: regija Dneper-Dvina postane na prehodu iz 6. v 5. tisočletje pr. n. št. del cirkumbaltskega prostora

IZVLEČEK – *Področje Dneper-Dvina je ena od vzhodnoevropskih regij, umeščena v široko mrežo najzgodnejših keramičnih tradicij, ki so se razširile v prvi polovici 6. tisočletja pr. n. št. Po razpadu te mreže so se pojavili novi keramični kompleksi, imenovani kultura Rudnya, ki ob koncu 6. tisočletja pr. n. št. kažejo spremembe v povezavah kultur. Regija je tako postala del kulturnega prostora cirkum-Baltika. Več kompleksov znotraj kulture Rudnya namreč izvira iz različnih skupin kulture Narva keramike, datirane ok. 5400–4400 pr. n. št.*

KLJUČNE BESEDE – *zgodnja keramika; lovci in nabiralci; kultura Narva; področje cirkum-Baltik; predmeti iz kosti*

Introduction

The hunter-fisher-gatherer economic and cultural system, formed as a result of the adaptation of the Final Palaeolithic population to natural changes, appeared to be very flexible and existed until at least the Middle Neolithic in Eastern Europe (*Zhilin 2004*). The rich and varied ecological niches of the East European Plain allowed ancient communities to maintain a hunter-gatherer way of life for a long period of time (*Dolukhanov 1997; 2008; Zvelebil 2008*). The instability of ecological niches due to climatic and/or anthropogenic factors and the variability of biodiversity may have forced societies to change their adaptation mechanisms – through the development of new habitats, the adoption of innovation, the formation of new social and economic systems and networks (*Burger, Fristoe 2018*). The emergence and spread of ancient pottery in Eastern Europe at the end of the 7th to the first half of the 6th millennium BC can be seen as part of these processes (*Mazurkevich, Dolbunova 2015; Andreev, Vybornov 2020*). The *chaînes opératoires* of pottery manufacture are suggested to be embedded in social trajectories and social identity (*Gosselain 2002; Livingstone-Smith 2001; Pétrequin, Pétre-*

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quin 2006; Gallay 1991), constituting ceramic traditions unique to each group which all makes it a powerful proxy for social reconstructions. By the middle of the 6th millennium BC ceramic traditions spread over most of the territory of Eastern Europe, following mainly the south-north direction, along river systems. Regional ceramic traditions were formed on their basis, preserved their initial technological, morphological and decorative features, and continued to be part of these earliest ceramic traditions (*Mazurkevich, Dolbunova 2015*). Later, by the end of the 6th millennium BC, this early ceramic network, partly overlapping the pre-existing Mesolithic network (*Dolbunova, Mazurkevich, submitted; Timofeev 1998a*) collapsed. Ceramic styles changed greatly, new regional traditions appeared, as well as new directions of contacts, and a new supra-cultural network was formed. This complete change in all the constituents of *chaînes opératoires* may be regarded as the end of the earliest ceramic traditions on the territory of Eastern Europe which occurred at the end of the 6th millennium BC. They were replaced by communities with completely different ceramic complexes (*e.g.,* Lyalovo culture in the Upper Volga (*Lozovskaya* et al. *2016*), Eneolithic cultures in the Don (*Skorobogatov* et al. *2015*) and Lower Volga region (*Vybornov* et al. *2016*)). In turn, the first pottery spread in the Circum-Baltic space only from 5200–5000 cal BC (*Loze 1988; Hartz, Lübke 2006; Raemaekers 2011; Povlsen 2013; Piezonka 2015; Kriiska* et al. *2017*) (Fig. 1).

The Dnieper-Dvina area (Fig. 2) is one of the regions in Eastern Europe where the oldest ceramic traditions penetrated in the first half to the middle of the

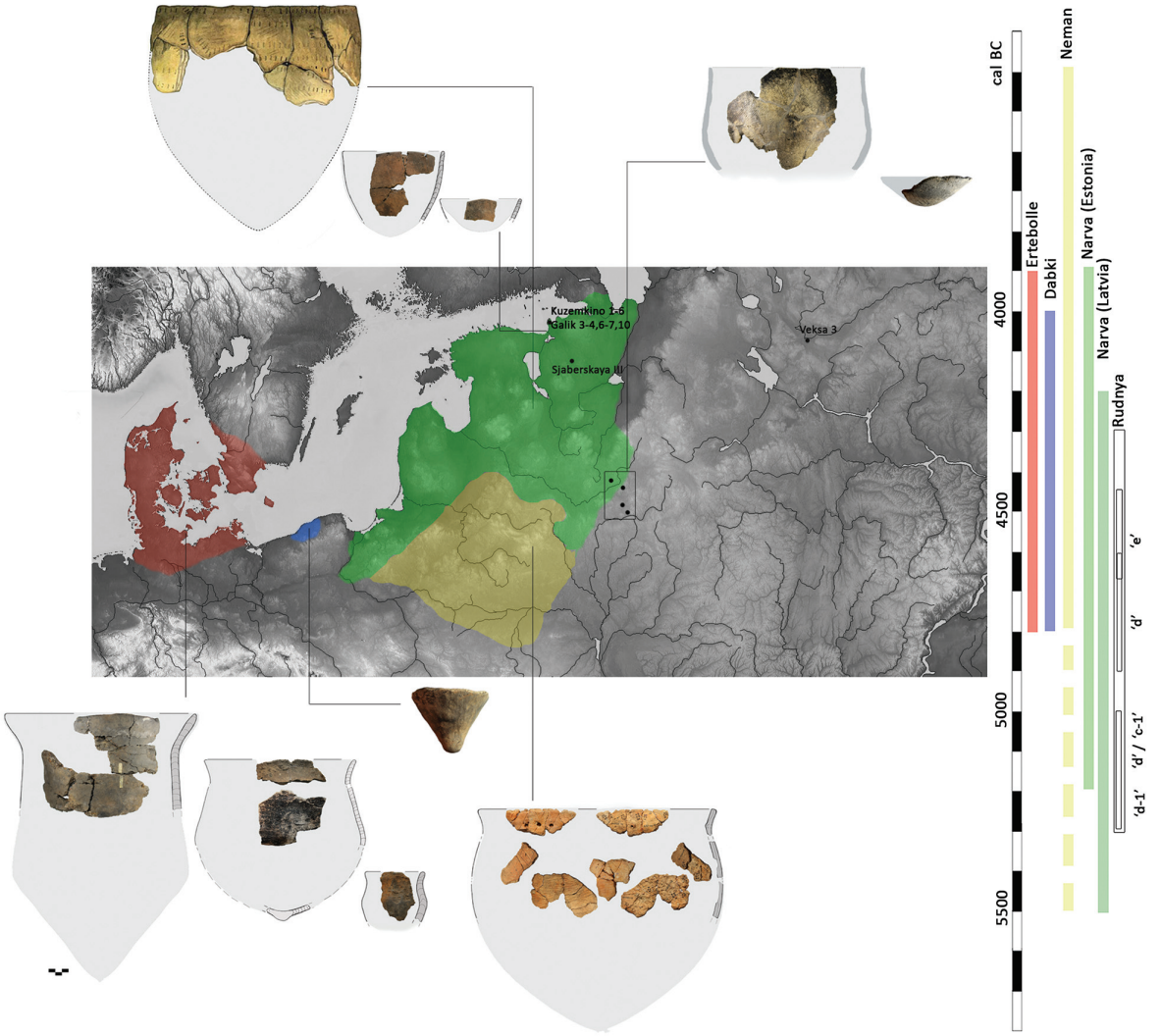


Fig. 1. Earliest ceramic complexes in the Circum-Baltic space (Ertebølle, Narva, Neman culture, Dąbki site), sites with Narva culture materials in the eastern part and Dnieper-Dvina basin (based on the data from* Courel *et al.* 2020; Kotula *et al.* 2015; Hartz, Lübke 2006; Povlsen 2013; Tkachou 2018; Wawrusiewicz *et al.* 2017*).

6th millennium BC (*Mazurkevich, Dolbunova 2015*). Later, after their disappearance, it became part of the Circum-Baltic cultural space manifested through ceramic complexes which have direct analogies in Narva culture. In this study we examine to what extent this tradition is similar to the preceding initial ceramic complexes, or if it should be regarded as an independent phenomenon; how this area was embedded into the Circum-Baltic space at the end of the 6th to 5th millennium BC; and why there was no long evolutionary development of the earliest ceramic traditions that originated on the territory of forest-steppe and steppe zone of Eastern Europe.

Dnieper-Dvina region. Paleoenvironmental setting

The Western Dvina Lakeland (western part of the East European Plain) is close to the European watershed of three catchments: the Baltic Sea, Black Sea and Caspian Sea. The main traits of the geology and terrain relief of this area were formed during the Valdai (Weichselian) Glaciation and later transformed in the Holocene. This region is characterized by developed lacustrine landscapes widely chosen for inhabitation by ancient hunter-gatherers. The environmental conditions of these basins seem to have

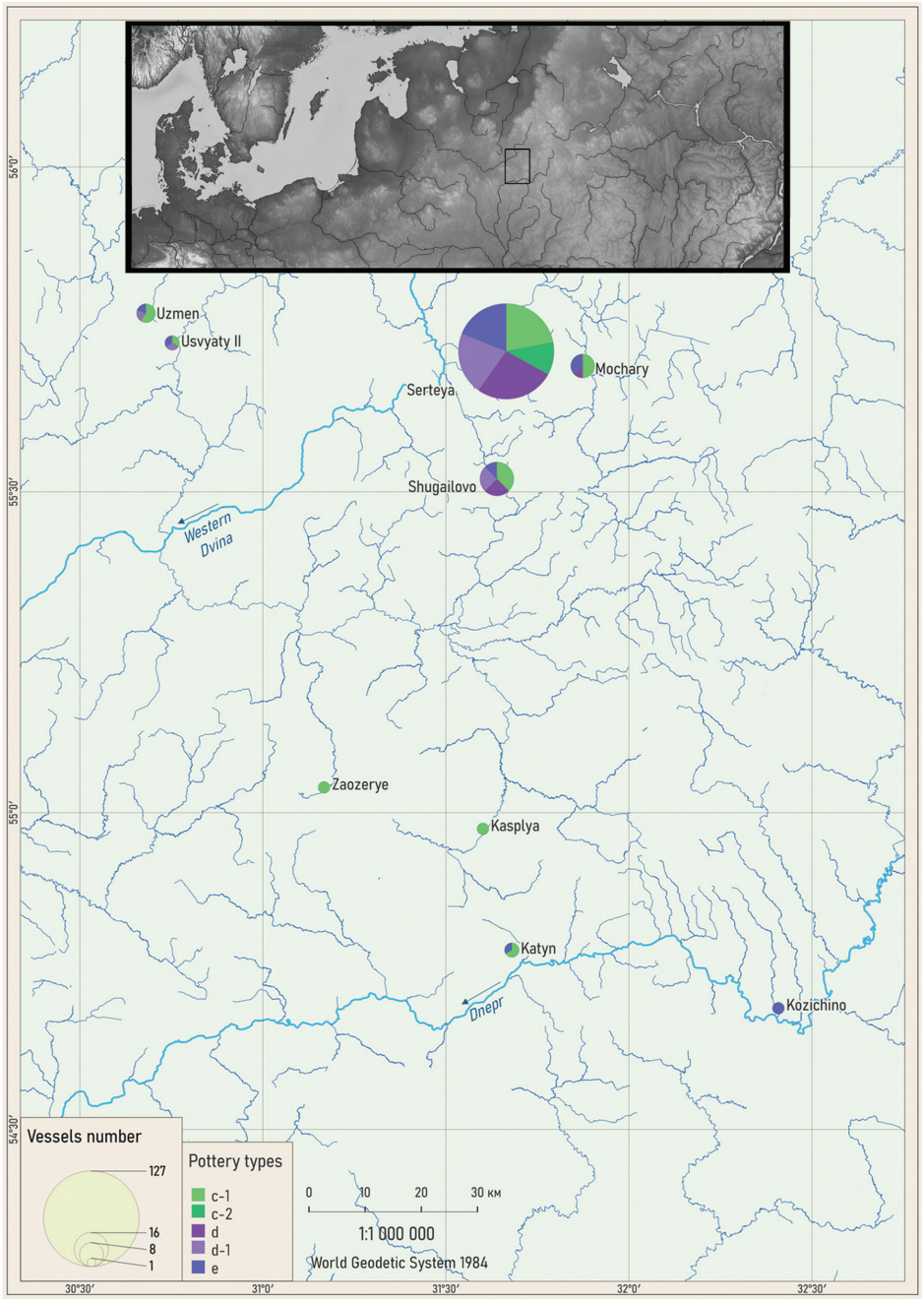


Fig. 2. Rudnya culture sites distribution in Dnieper-Dvina basin.

been very attractive for hunter-gatherer communities – due to a high level of landscape geo- and biodiversity, with small lakes, rivers and fertile hydrogenic and semihydrogenic soils.

Microregional studies were concentrated within the Serteyka River basin (Serteya microregion), left tributary of the Western Dvina (Daugava) River (Fig. 3). The river was presumably draining subsequent palaeolake water bodies during the Holocene. A few palaeolake basins were documented within the lower section of the present-day valley. These basins are 100–600 metres wide, 100–2000 metres long and are connected by narrow erosive segments of the river valley. They are filled with organic deposits of lacustrine and swamp origin up to 8 metres thick covered with sandy-silty overbank alluvia (*Kulkova* et al. *2001; Kittel* et al. *2018*). There are several of

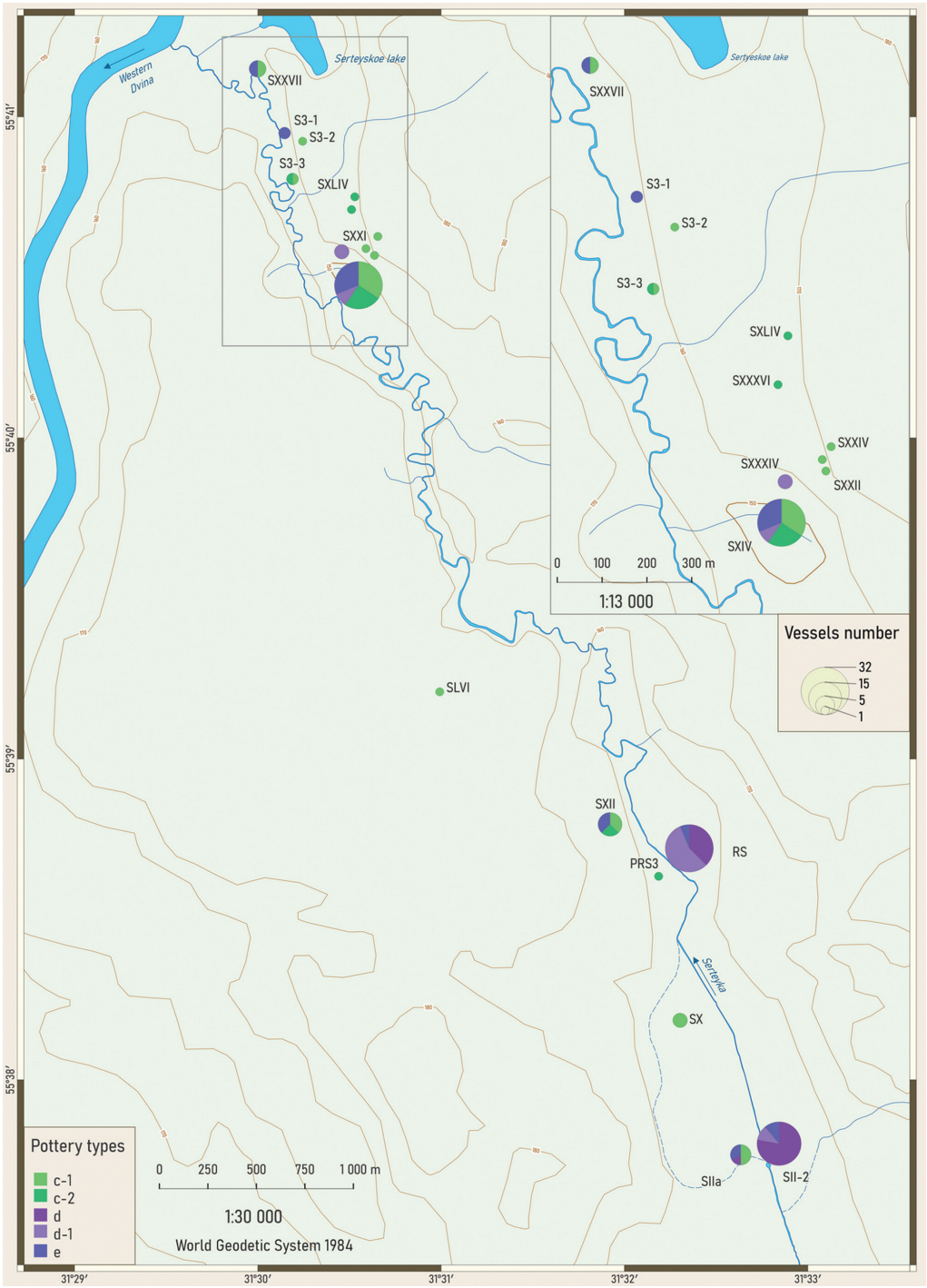


Fig. 3. Rudnya culture sites distribution in Serteysky microregion of Dnieper-Dvina basin (ceramics of phases 'c-1', 'd', 'd-1', 'e').

them noted – the Great Serteya Palaeolake Basin (GSPB), Nivniky Basin, and Rudnya Basin, on the shores of which sites of the Rudnya culture were found.

Seasonal and centennial climatic fluctuations might have influenced ancient communities. Detailed multi-proxy palaeoecological analyses in the Serteya micro-region indicate weak cooling oscillations at the 7.0–6.8, 6.2, 5.9 and 4.2 ka cal BP and an increase of continentality during these periods, manifested in a lower winter temperature and lower annual precipitation (*Kittel* et al. *2020; Mroczkowska* et al. *2020*).

Rudnya archaeological culture

Ceramic complex

The Rudnya archaeological culture was distinguished based on materials of the stratified Rudnya Serteyskaya site, excavated in the Serteya microregion (Fig. 3) in 1983–1987 (*Dolukhanov* et al. *1989; Mazurkevich, Miklyaev 1998*). Several ceramic phases were distinguished named 'c-1', 'c-2', 'd', 'd-1', and 'e'.

Ceramic phase 'c-1' (Fig. 4. 1, 6, 7). The vessels were made from fat paste tempered with organics and shells, judging by the traces of burned-out residue. The vessels were made of short coils/slabs, elongated during vessel construction, 1.7–3.5cm in height with a very sharp horizontal and vertical cut. A separate group is represented by vessels made from coils 1–1.5cm in height, with N-juncture (phase 'c-2'). The technique of beating is testified by flattened roundish areas on the surface of fragments. Traces of scratches on both surfaces were recorded, left after the application of a thin liquid clay layer. They were polished afterwards, which can be seen on a number of fragments with a well-preserved surface, which might have been common for all the vessels of this phase. The shapes of the vessels are mostly closed with a pointed or rounded rim. Ceramics was not decorated.

Ceramic phase 'd' (Fig. 5; 6.1–4, 6, 9). Pottery was made from paste tempered by a large amount of shell and organics. The vessels were manufactured from stretched coils/slabs with an S-juncture. The extreme fragmentation of the vessels complicates accurate determination the size and type of coils/slabs and the presence of the beating technique. The vessels are 0.4–0.7cm thick. On both sides there are traces left by a comb tool. The external side of some of the vessels was polished. The vessels were poorly fired, only thermally dried at low temperatures (*Mazurkevich, Miklyaev 1998*). The rims are flattened, and the vessels are slightly profiled. One conical bottom with an added clay lump at the extremity and a roundish bottom were found. The vessels were decorated with small pits, notches, small triangular marks and impressions of a thin, curved comb stamp, which differed from the decoration of the vessels of the previous Serteya culture. They were decorated by one or several horizontal rows or a combination of horizontal and vertical ones. Only two vessels were decorated by a combination of pits and notches, pits and impressions of a comb stamp. Only the upper part of the vessels was decorated, the rest was often covered by scratches, which were deliberately left and not smoothed over.

Ceramic phase 'd-1'. Vessels were made from paste tempered by shell and organics (Fig. 7; 6.5, 7, 8, 10). The vessels were made from stretched coils with an N-juncture. On both sides there are traces left by a comb tool. The surface was polished afterwards in major cases. The beating technique was widespread. On the surface of the vessels there was a cracking mesh due to drying clay, which was subjected only to temperature drying. The rims are bevelled inwards, flattened, straight or inclined inwards. The bottoms are rounded. The vessels are 0.7–0.9cm thick. The pots were not decorated or decorated with a single line of holes under the rim or a net made from scratches. One of the vessels is decorated with triangular marks, arranged in horizontal lines. This group also includes a series of small bowls with a C-shaped profile and pointed rim.

Ceramic phase 'e'. Vessels were made from fat paste tempered with organics, judging by the burnt-out remains, from short coils/slabs in the S-technique (Fig. 4.2–5, 8–11). In a few cases, the use of U-juncture was noted which was applied for vessels construction from the slabs. The surface of the vessels was smoothed, occasionally there are traces of scraping, smoothed afterwards in a number of cases. The rims of the vessels are flattened and straight. The pottery is decorated with small pinholes, a grid of dashed lines and small oval imprints.

A comparison of the ceramic manufacturing technology of the Rudnya culture and preceding Serteya culture using correspondence analysis of features, which constitute the *chaîne opératoire* (Fig. 8.1; see description of features – Fig. 8), indicates two completely different technological groups. Major differences are also observed in decoration and morphology (see the description of the Serteya culture in

Mazurkevich and Dolbunova (*2015*)), which may indicate a complete change in the ceramic traditions and, probably, local population that existed in the Dnieper-Dvina Basin in the first half to the middle of the 6th millennium BC and later – at the end of the 6th to the first half of 5th millennium BC.

A comparison with the Narva complexes shows particular similarities both in the technological sphere (see the correspondence analysis of technological features in Fig. 8.2) and decorative, morphological one. Ceramics of 'd-1' appear to be close to some types of ceramics of the Zvidze site and sites in Estonia (Kääpa complex) (*Kriiska 1996; Kriiska* et al. *2017*) and in Belarus (*Charniauski 2017*). Pottery of phase 'd' seems to be closer to the ceramics found at sites of Lubana Lake, and specifically the Zvidze and Osa sites (*Loze 1988; Zagorskis 1973*). Pottery of phases 'c-1' and 'c-2' is similar to that found at the coastal river estuaries and coastal lagoon group of sites in Estonia (*Kriiska 1996; Kriiska* et al. *2017*).

Flint and bone industry, the remains of constructions

A few flint and bone items were found nearby the pottery of the phases 'd' and 'd-1' at the Rudnya Ser-



Fig. 4. Pottery fragments of phase 'c-1' (1 Serteya XII; 6, 7 Uzmen); 'e' (2–5, 8–11 Uzmen).

teyskaya site (*Mazurkevich, Miklyaev 1998*), and single items were found at Serteya II (II-2) and Serteya X (Figs. 9, 10). At the Rudnya Serteyskaya site, the flint industry includes a rhomboid-shaped arrowhead with bifacial retouch, end scraper, roundish scrapers with a rounded blade, oval axes with an asymmetrical lenticular cross-section and polished areas on the blade. Two single-platform edge-faceted cores and two double-platform nuclei were also found.

Bone tools include knives, which are characterized by a lateral cutting edge (Fig. 10.1, 6). They were produced by scraping from various anatomical supports, always from elk. It should be noted that the knives known for the Middle-Late Neolithic Usvyaty and Zhizhitsa cultures were made exclusively from elk ulna. Early Neolithic bone knives are known in the Baltic area (*Vankina 1999*), and also in Belarusian sites (*Charniauski 2007*).

A few ornaments are also recorded. The Serteya X site provided a pendant made from an incisor with a grooved suspension (Fig. 10.4). Two other boar incisors with grooved suspension were found at the Serteya II-2 site. Several elk tooth grooved at their proximal part were also found in Early Neolithic layer at the Zamostje 2 site (*Lozovskaya 2018*). Teeth pendants remained fairly common throughout the Neolithic period, but their attachment system changed, and perforation began to be used in the Middle Neolithic.

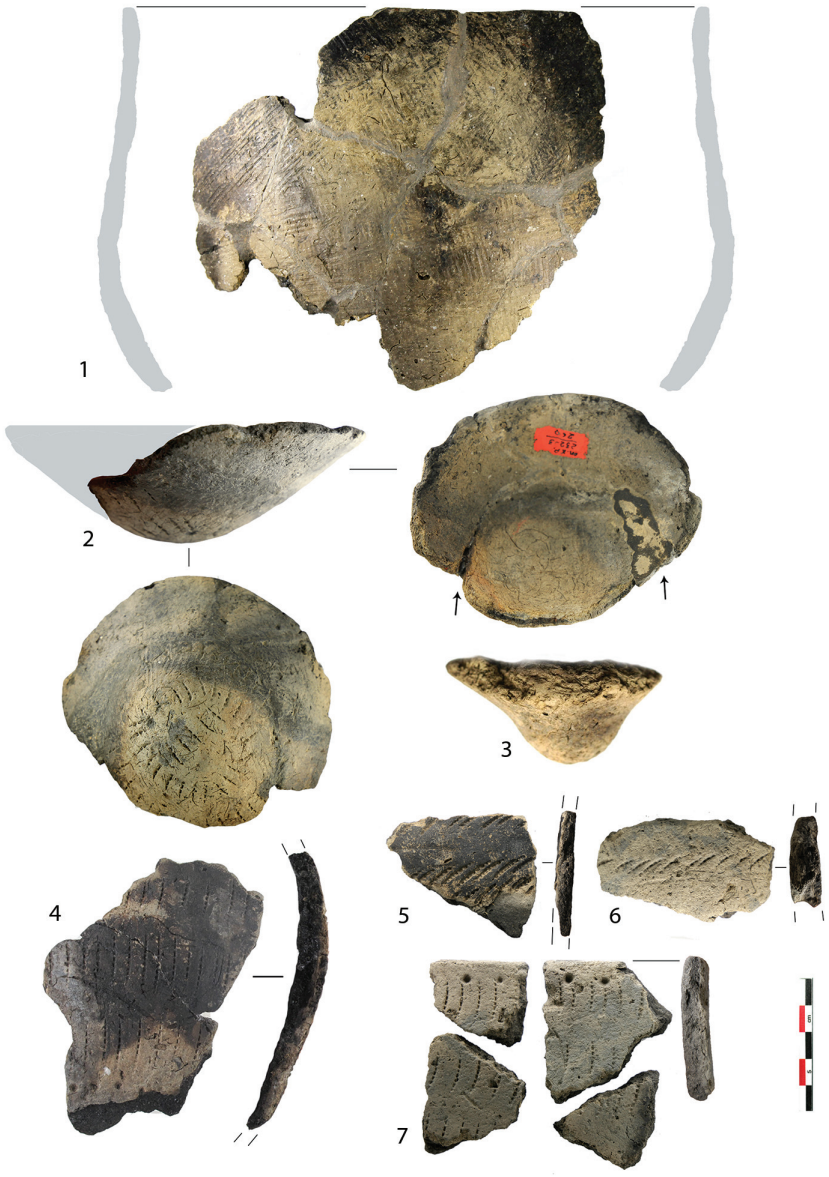


Fig. 5. Pottery fragments of phase 'd' (1–3 Rudnya Serteyskaya, 4–7 Serteya II).

Most of the Early Neolithic bone projectile points are characterized by bulging and often biconical heads, mostly with a tapered tip (Fig. 9.2, 4, 5), one of them was decorated with short incisions (Fig. 9.4). Their shaft, quite short, is often pointed and could be flattened or rounded in cross-section. This type is also quite common in Upper Volga (*Lozovsky, Lozovskaya 2010; Lozovskaya 2019; Zhilin* et al. *2002*), and in the Narva culture (*Vankina 1999; Loze 1988*). A particular type of a biconical flattened arrowhead with symmetrical wings and a short, pointed shaft was found at Rudnya Serteyskaya (Fig. 9.3) and the Serteya II-2 site (Fig. 9.1). These projectile points found in the Dnieper-Dvina Basin constitute discriminating elements of the Early Neolithic which will no longer exist in the following periods. Rudnya Serteyskaya had a rather particular bone projectile point with a very long shaft and a head decorated with short transverse incisions (Fig. 9.8). A wooden projectile point imitating bone items was found at the Rudnya Serteyskaya site (Fig. 10.2).

Two harpoons (one is fragmented) were found (Fig. 10.6, 7). The whole piece consists of a three-barbed harpoon with shouldered proximal part. It might have been made from a bone blank extracted from an elk metapodium. Most of the harpoons from the Upper Volga culture feature a tight succession of barbs and a pointed proximal part (*Lozovskaya, Lozovsky 2013*), which does not correlate with Early Neolithic pieces from the Dniper-Dvina basin. Neither of the analogies can be traced within the Baltic complex (*Vankina 1999*). In these two regions, shouldered proximal parts of the harpoons seem to arrive later (Middle or Late Neolithic).

The remains of stake structures of rectangular or circular shape with ground hearths were recorded at the Serteya X and XIV sites (*Mazurkevich* et al. *2003*). The remains of a fishing trap at the Serteya XIV and Rudnya Serteyskaya sites and strongly eroded wooden objects (on Serteya II-2 site) can also be attributed to different stages of the Rudnya culture (Tab. 1).



Fig. 6. Pottery fragments of phase 'd' (1–4, 6, 9), and 'd-1' (5, 7, 8, 10) on Rudnya Serteyskaya site with indication of coils/slabs juncture (2, 7, 10).

Rudnya culture chronology

The archaeological layers with materials of the Rudnya culture lie above the layers or are separated spatially from the materials of the Serteya culture, which made it possible to create the sequence of these cultures (*Mazurkevich* et al. *2017*), supplemented by typological analysis. Ceramics of phases 'c-1'/'c-2', and 'd-1' are among the earliest within the sequence of Rudnya culture, following by materials of ceramics of the phase 'd' and later phase 'e'. The absolute chronology is based on a series of radiocarbon dating by associated terrestrial material (wood and charcoal), deposited together with finds of ceramics of the Rudnya culture at the Rudnya Serteyskaya, Serteya II and Serteya XIV sites (Tab. 1). The difficulty of using direct dating of ancient hunter-gatherer ceramics is connected with the reservoir effect arising at dating of food crust formed after processing of mainly aquatic products in vessels (*Courel* et al. *2021.SI*).

The Rudnya Serteyskaya site is located on a terrace that was buried under wetland deposits, on a small promontory that juts into the Rudnya lake basin. The uncovered area of the site was 146m^2 (*Mazurkevich, Miklyaev 1998*). Archaeological layer A, with finds of Early Neolithic ceramics of the Serteya culture dated to the 6th millennium BC, was deposited in a layer of fine sand at the base of bluish gyttja. The overlying layer B, where fragments of Rudnya culture pottery were found (phases 'd' and 'd-1'),

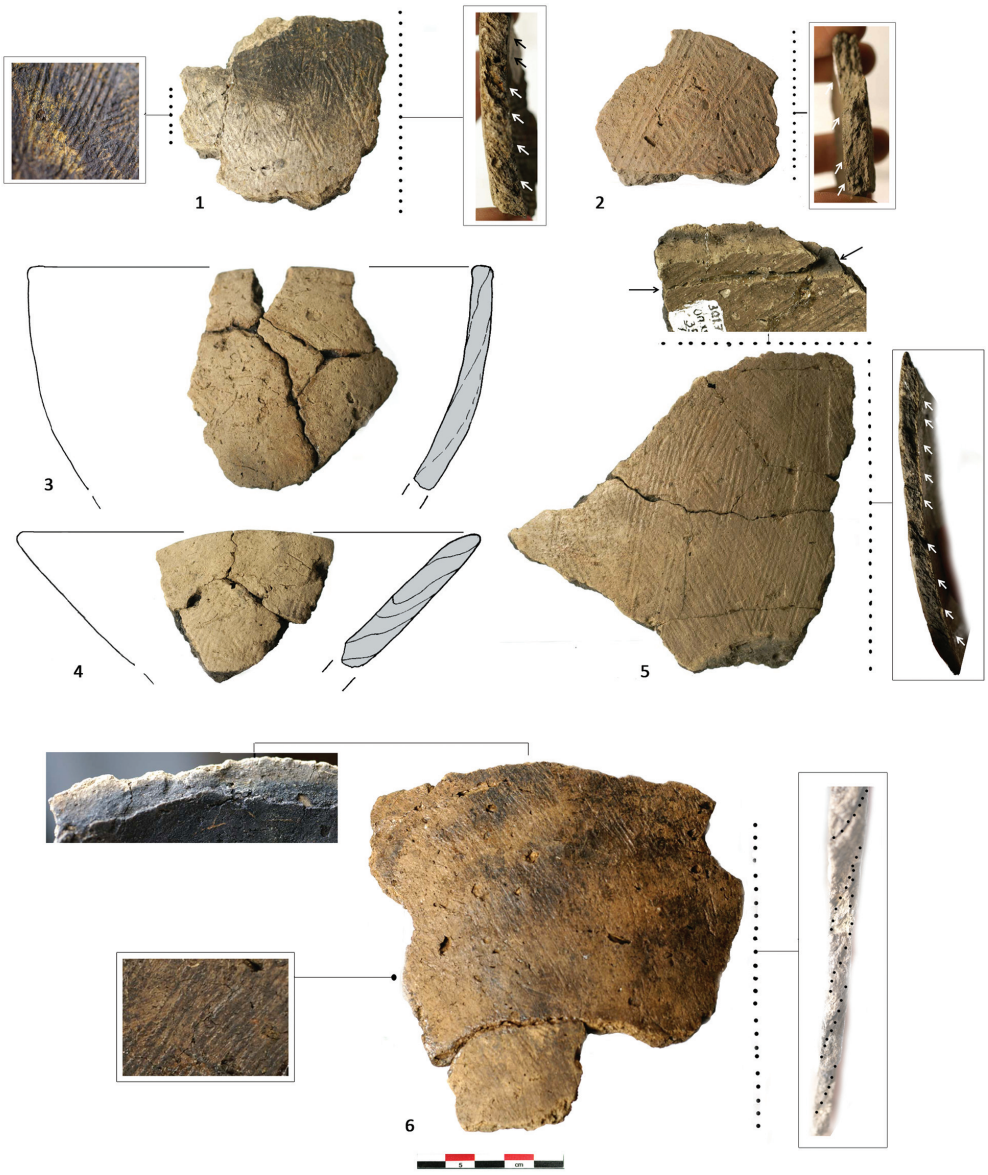
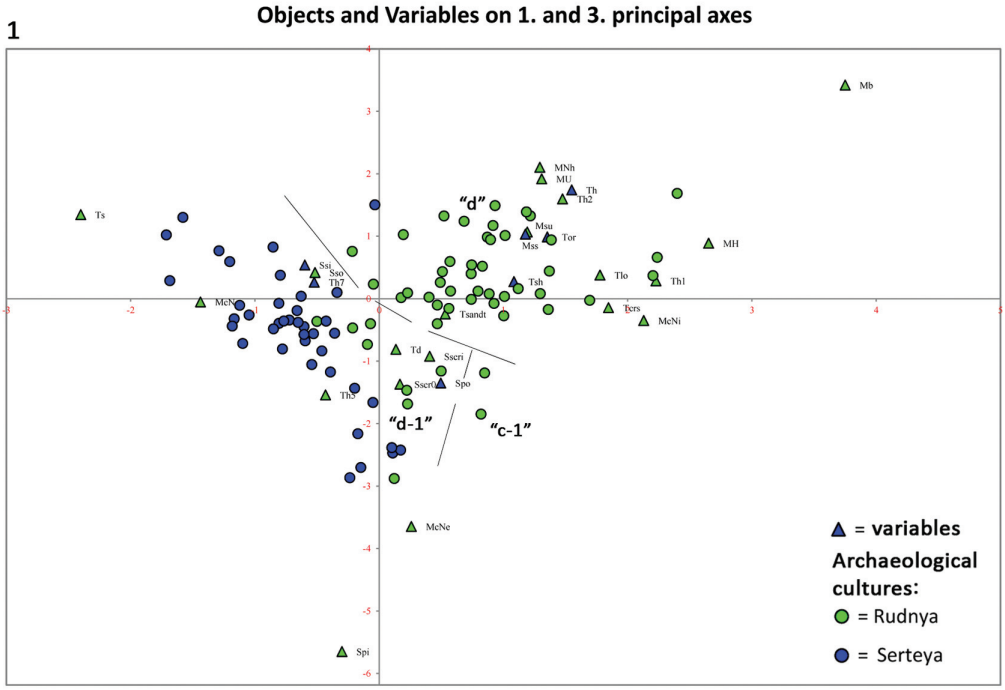
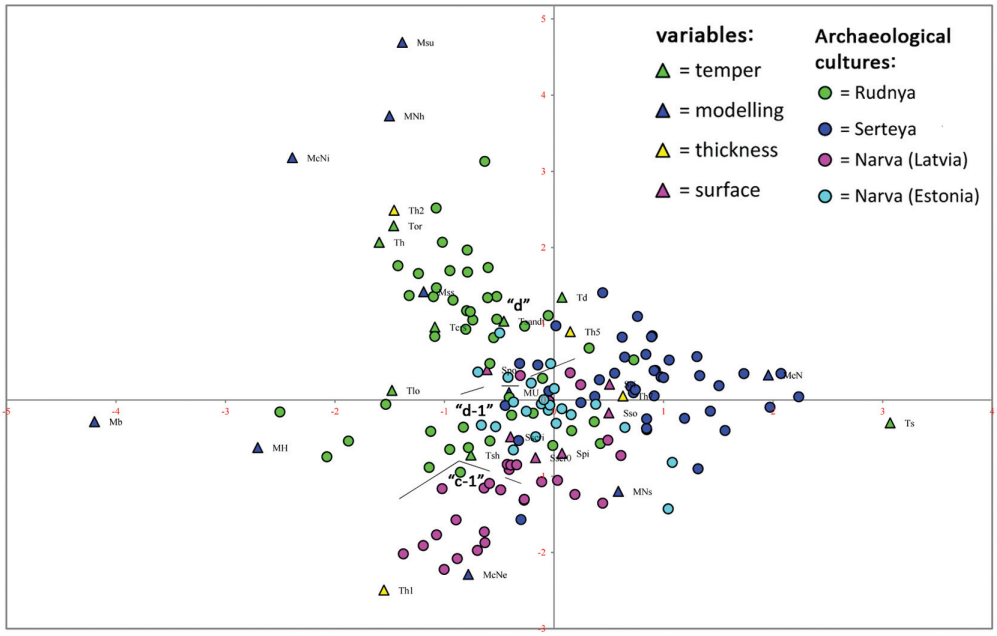


Fig. 7. Pottery fragments of phase 'd-1' (1, 3, 4–6 Serteya XIV; 2 Usviaty II) with indication of traces left during surface treatment (1, 6) and coils juncture (1, 2, 5, 6).

1



2



Temper	Td	dense paste (not tempered)
	Tsh	shell
	Ts	medium/coarse-grain sand
	Tsandt	thin sand
	Th	hematite
	Tcrs	crushed stones
	Tm	mica
	Tlo	elongated particles (organic temper)
	Tor	roundish particles (organics temper)
Modelling	McN	N-technique (coils 1-1.5 cm long)
	McNe	N elongated (up to 3 cm)
	McNi	N inverse
	Mss	slabs (S technique)
	MNs	slabs (N juncture, 2 parallel slabs)
	MNh	slabs combined - two layers

Modelling	MsU	slabs (U-juncture)
	MU	U-technique
	MH	H-technique
	Mb	beating
Thickness	Th5	0.4-0.6
	Th7	0.7-0.8
	Th1	0.9-1.2
	Th2	1.3-1.8
Surface treatment	Ssi	smoothed in
	Sso	smoothed out
	Sscri	scratches inside
	Sscr0	scratches outside
	Spo	polished outside
	Spi	polished inside

Fig. 8. Correspondence analysis of Rudnya and Serteya culture pottery (1); Rudnya, Serteya and Narva culture pottery (Zvidze and Narva Joaorg sites) (2).

was deposited in a layer of sandy gyttja with charcoal inclusions, located between bluish and brownish gyttja. Vessel fragments of phases 'd' and 'd-1' were recorded in different parts of the site. The radiocarbon dates obtained probably reflect several stages of site occupation. Fragments of worked wood, deposited in close proximity to the ceramics of the Rudnya culture, are dated to 5210– 4952 cal BC (first group) (*Mazurkevich, Miklyaev 1998*). The charcoal from the base of the oval ground structure of Serteya XIV site can also be dated to this time (5332–4944 cal BC).

Wood fragments overlying the layer B are dated to *c.* 4932–4608 cal BC – the time when gyttja accumulated over the Rudnya culture remains during the transgression phase. The second group of dates made on wooden items (including the remains of a fishing trap) (*c.* 4727–4497 cal BC) possibly correlates with the appearance of sites on mineral shores with materials of the 'e' phase.

Ceramic fragments of the Rudnya culture on the Serteya II site were found in its western part (II-2 area), which is a multilayer complex with several succeeding phases of occupation (*Mazurkevich* et al. *2020; Kittel* et al. *2018*). A very dynamic local hydrological system and palaeolake shore conditions had a considerable influence on the formation of archaeological layers and distribution of finds. The oldest ceramics attributed to the Serteya culture were found in the lowermost sandy layer, attesting to a coastal activity zone during the Early Neolithic. Rudnya culture fragments were found in a dark brownish-grey sandy layer with organic remains and in brown gyttja (see *Kittel* et al. *2020*). The fragments were eroded which could indicate the redeposition of the archaeological layer and organic matter in the lake shore zone. They could have been washed away from higher parts of the site. The bone arrowheads attributed to the Rudnya culture deposited in the dark brownish-grey sand and black gyttja layers may be evidence of hunting. Two heavily eroded wooden items (one of them probably a paddle) are dated to *c.* 5208–4849 cal BC. A wooden stake – evidence of coastal activities – was dated to 5373–5213 cal BC.

The results from the macrobotanical study show a gradual shallowing of the lake level after 6900 cal BC. During this time, the palaeolake already seems to be rich in faunal and floral aquatic resources, and thus attractive for exploitation. In the further course of time, a transgression phase occurred between *c.* 5550 and 3600 cal BC (*Wieckowska-Lüth* et al. *2021*). Natural accumulation of minerogenic and or-



Fig. 9. Early Neolithic bone industry: **1–2** ***Serteya II;*** **3, 7–9, 10** ***Rudnya Serteyskaya;*** **4, 5, 6** ***Serteya X.***

ganic material in the transition zone between the lake and land, fluctuations in lake water level (inflow of minerogenic material, wave erosion), and periodic drying was recorded for this time period (*Kittel* et al. *2020*).

Distribution of Rudnya culture sites in the Dnieper-Dvina Basin

Upper Western Dvina basin. The vessels of phase 'd-1' are known on the Rudnya Serteyskaya, Serteya II-2, X, XIV, XXXIV sites (Fig. 3) located at low hypsometric levels, and archaeological layers are buried under wetland deposits.

Vessels of the Rudnya culture are found much less frequently at the sites located on drylands. These are mostly vessels of the 'c-1', 'c-2' and 'e' phases. There are a few fragments of 'd-1' and 'd' phases, found in the sandy deposits at the Uzmen and Usvyaty II sites, Shugailovo, and Mochary sites. Vessels of phase 'e' are found within sandy sediments at the

Date (BP)	Date (cal BC)	Index	Material	Site	Context	Attribution (culture)
5770±60	4730-4488	Le-2570	wood	Rudnya Serteyskaya	peaty gyttja with wooden remains and algae, wood from fishing construction	Rudnya culture
5780±40	4723-4535	Le-7182	charcoal	Serteya XIV	sq. A/14, yellow sand	–//–
5780±50	4727-4497	Le-2577	wood	Rudnya Serteyskaya	peaty gyttja with wooden remains and algae, wood from fishing construction	Rudnya culture
5850±150	5057-4362	SPb-1197	food crust	Serteya XXXIV	ceramic belly fragment undecorated (No. 1726-1728)	Rudnya culture
5890±60	4935-4605	Le-2586	wood	Rudnya Serteyskaya	wood from the horizon above layer B	Rudnya culture
5900±40	4850-4686	Le-7173	charcoal	Serteya XIV	sq. 6/3, dwelling, base layer	–//–
6090±40	5081-4896	Poz-146276	wood	Sertyeya II-2	treated and eroded wood (w405), lying in horizontal position, on whitish sand	Rudnya culture
6090±40	5081-4896	Poz-146882	wood	Sertyeya II-2	treated and eroded wood (paddle?) (9814)	Rudnya culture
5940±130	5137-4537	Le-2566	wood	Rudnya Serteyskaya	sandy gyttja with charcoals, layer B, sq. D/1	Rudnya culture
5940±130	5137-4537	Le-4101	wood	Rudnya Serteyskaya	sandy gyttja with charcoals, layer B, sq. B/9	Rudnya culture
6050±40	5053-4837	Le-9764	wood	Serteya XXXIV	sq. D/2, low part of ferruginized sand	Rudnya culture
6130±30	5210-4988	Le-9763	wood	Serteya XXXIV	sq. D/2, No. 2254, low part of ferruginized sand	Rudnya culture
6130±40	5210-4952	Le-2579	wood	Rudnya Serteyskaya	sandy gyttja with charcoals, layer B, sq. B/4	Rudnya culture
6130±50	5215-4935	Le-7175	charcoal	Serteya XIV	yellow sand with charcoal, sq. b/13	–//–
6180±40	5218-5003	Le-2569	wood	Rudnya Serteyskaya	sandy gyttja with charcoals, layer B, sq. D/1	Rudnya culture
6320±40	5373-5213	Poz-146296	wood	Sertyeya II (part 2)	sharpened stake (W454) in vertical position	Rudnya culture
6210±80	5332-4944	Le-7176	charcoal	Serteya XIV	dwelling's floor, yellow sand	–//–
6230±40	5306-5054	Le-2568	wood	Rudnya Serteyskaya	sandy gyttja with charcoals, layer B, sq. D/1	Rudnya culture
6240±60	5326-5028	Le-3054	wood	Rudnya Serteyskaya	sandy gyttja with charcoals, layer B, sq. B/3	Rudnya culture
6388±38	5417-5306	Le-7174	charcoal	Serteya XIV	sq. b/13, fish-trap	–//–
6640±110	5738-5372	SPb-750	burnt bones	Serteya XXII	located nearby early neolithic vessels (phase 'b-1'/'b-5')	Serteya culture
6792±120	5913-5482	SPb-748	burnt bones	Serteya XXVII	sq. M-L/4, located nearby early neolithic vessel (phase 'b-5')	Serteya culture
7300±120	6419-5983	SPb-749	burnt bones	Serteya XXIV	sq. B/1, located nearby early neolithic vessel (phase 'b-4')	Serteya culture
7350±180	6571-5885	Le-5260	wood	Serteya X	bluish sandy gyttja layer with shells, cultural remains of early neolithic Serteya culture	Serteya culture

Tab. 1. Radiocarbon dates of materials attributed to Serteya and Rudnya culture.

Uzmen, Usvyaty II, Serteya IIα sites, Shugailovo, and Mochary sites. The pottery of phase 'c-1' was found on sites situated on mineral terraces of palaeolakes in the southern (Serteya X, Serteya XII) and northern lake basin (Serteya XIV, XXVII), on shores of palaeolakes in the northern basin of the Serteya microregion (Serteya XXI, XXII, XXIV, 3–3, and 3–2). The pottery of phase 'c-2' was found on sites situated in mineral terraces of palaeolakes (field above Rudnya Serteyskaya No. 3 (PRS3), Serteya XIV) and also on the shore of palaeolake in the northern lake basin (Serteya 3–3, XXXVI, XXXVII, XLIV).

Upper Dnieper Basin. Pottery of phase 'c-1' was found at the Katyn 9 site, and of phase 'e' at the Katyn 17 and Kozichino sites. These are the most south-eastern sites of the Rudnya culture.

Vessels of the Rudnya culture were found on the sites located in the immediate vicinity of the paleolacustrine shoreline, which were most likely seasonal one (testified by avifauna at the Rudnya Serteyskaya site (*Sablin* et al. *2011*)). The supposed settlement system differs from the previous time, when various types of sites were recorded: summer and winter camps, long-term and specialized hunting or fishing sites (*Mazurkevich, Dolbunova 2009*). Vessels of the Rudnya culture are accompanied by finds of single bone arrowheads, the remains of fishing traps, strongly eroded wood items with traces of processing (one of which may be a paddle), and wooden stakes, testifying to household activity on the ancient shoreline (Serteya II and XIV sites).

Discussion

The cultural space, formed in the late 6th to 5th millennium BC in the Circum-Baltic region, includes the Ertebølle culture and the Dąbki site in the west, Narva and Neman cultures in the east, and Sperrings and Sär 1 in the north (*Gurina 1967; Rimantiene 1992; Timofeev 1998a; Loze 1988; Kriiska 1996; Kriiska* et al. *2017; Charniauski 1979; 2017; Piličiauskas 2002; German 2018; Torvinen 2000; Kotula* et al. *2015*). A number of regional and regional-chronological groups have also been distinguished within these (*Kriiska 1996; Kriiska* et al. *2017; Vankina* et al. *1973; Rimantiene 1973; Miksaite 2005; Piezonka 2015; Tkachou 2018; Wawruciewicz 2013*).

The hunter-gatherer-fisherman cultures of the Western and Eastern Baltic existed at the same time as agricultural communities to the south. Thus, the origin of pottery in the Ertebølle culture has been suggested to be a local innovation, the influence of hunter-gatherer communities from the East (*Gronen-*



Fig. 10. Early Neolithic bone industry (1, 3–7), and wooden arrowhead (2). Serteya X site.

born 2011), or of Neolithic farming groups (*Povlsen 2013*). The emergence of pottery among hunter-gatherer tribes of the Swifterbant culture *c.* 5200/5000 cal BC was explained by the influence of neighbouring agricultural groups (*Raemaekers 2011*). The influence of local farming communities on the formation of hunter-gatherer pottery complexes in the 5th and 4th millennia BC was also noted for Central Europe (*Nowak 2017; Guminski 2020*). The origin of the Narva culture early ceramic complex is still under discussion. The asynchrony of the processes of ceramics acquisition in different regions by hunter-gatherer communities is evidenced by the differences in time of the pottery's appearance and significant variations in the ceramic technology. The differences in the *chaînes opératoires* of ceramic manufacture testify to major differences between various cultural traditions of hunter-gatherer communities of the Circum-Baltic world (*Dumpe* et al. *2011; Glykou 2010*).

The widespread S-profiling of the vessels in early complexes forced researchers to look for the eastern origin of these in the Elshanskaya culture, where S-profile vessels are known (*Timofeev 1998; Gronenborn 2011; Andreev, Vybornov 2021*). However, the differences in technology, chronology and morphology (*Courel* et al. *2021.Fig. S2*) indicate the more different nature of these complexes.

Studies into ceramics contents and their use (through traces of use) point to different functional patterns of vessel use among foraging communities (*Courel* et al. *2020; 2021; Papakosta* et al. *2019; Pääkkönen* et al. *2016*). A predominance of vessels used for aquatic products was found typical for Narva (including vessels from the sites located in the Serteya microregion (*Courel* et al. *2020*)). Vessels of the Rudnya culture were found on sites with rather specific contexts – oriented towards the use of water resources – with finds of fishing traps and paddles located in the shoreline zone, associated with fishing grounds or household activity in the shoreline area.

Specific technological, morphological and ornamental features of ceramic phases ('c-1', 'c-2', 'd', 'd-1' and 'e') and the particularities of their deposition within archaeological layers allow us to identify several groups within Rudnya culture. These may reflect penetration of various traditions from different territories, which are also testified by comparison with different Narva complexes. The flint complex of the Rudnya culture does not have any similarities with the preceding stone industry, bone and antler items find analogies both in the Late Mesolithic and Early Neolithic materials of Eastern European forest zone sites, and in the Lubana basin (*Loze 1988; Vankina 1999*).

The chronological timeframes of the Rudnya culture correlate with chronological periods identified for the Zvidze site, where the early Narva pottery was found in several archaeological layers, dated to *c.* 5409–4944 cal BC, 5211–4835 cal BC and 4850–4582 cal BC; the lower border of Narva culture here was attributed to 4446–4157 cal BC (*Loze 1988.73–74*). The appearance of this ceramic complex around 5500–5300 cal BC is confirmed by stratigraphic observations, dating of accompanying materials (wood) (*Loze 1988*) and direct dating of charcoal found in the vessel fragments (*Courel* et al. *2020*). A comparison of the radiocarbon chronology of the Lubana sites with those of the Rudnya culture shows that the latter appeared later in the east in the upper reaches of the Western Dvina River.

The similarity of the technological, ornamental, morphological and functional characteristics of the vessels of the Rudnya culture with the groups of the Narva culture makes it possible to consider the transfer of ceramics as one package resulting in the Rudnya culture formation: along with *chaînes opératoires*, ornamental and morphological traditions, the functional pattern was transferred. All of these may testify to the migration of people from different regions of the Eastern Baltic to the south-east.

There are single and rare evidences of Narva culture materials on other sites in northwestern Russia, but all these complexes are extremely sparse and could instead indicate single penetrations of individual groups to the east: Veksa 3 (*Nedomolkina* et al. *2015; Piezonka 2015*), Kuzemkino 1–6, Galik 3–4, 6–7, 10 (*Holkina 2019*), Sjaberskaya III (*Timofeev 1993*), and in the Upper Dnieper basin (Fig. 1, 2).

Conclusion

The emergence of pottery in hunter-gatherer-fisher communities in continental Europe may have followed different spatial and cultural trajectories, responding to different economic or cultural challenges. The emergence of pottery was accompanied by extensive development of the Eastern European territories, overlapping only in part with the preceding Mesolithic network. Destruction of this initial network is manifested through the disintegration of the oldest ceramic traditions that originated in the steppe and

forest-steppe zones. The role of pottery might have been different – as an important adaptive mechanism and innovation in some regions, and perhaps a non-utilitarian element in others (*Courel* et al. *2020*). Societies that practiced pottery manufacture might have existed independently among Mesolithic societies on the territory of Eastern Europe, occupying free ecological niches, for a rather short period of time, and thus did not make any significant contributions to later ceramic traditions. The change of ceramic types, groups and cultures did not lead to the formation of hybrid ceramic types. The tradition of pottery making seems to be not of a widely used practice, which is evidenced in the small number of the earliest vessels found on a number of sites (*Mazurkevich, Dolbunova 2015*). The emergence of pottery outside the East European Plain in hunter-gatherer communities at a later time in Central Europe may refer to a completely different process – the borrowing of pottery-making skills from agricultural groups (*Nowak 2017; Guminski 2020*).

Ceramic complexes of the Rudnya culture are not the most ancient or first in the territory of the Dnieper-Dvina Basin, unlike in the Eastern Baltic. This cultural group follows the earlier ceramic traditions (*Mazurkevich, Dolbunova 2015*), which originated in the Upper and Middle Don, Desna River, Bug-Dniester Basin. The closest analogies to the Rudnya culture ceramic complex can be found in the lower course of the Western Dvina River in the Lubana Basin. Thus, the Rudnya culture can represent an independent phenomenon within a larger cultural entity of the Narva culture. The bone industry of the Dnieper-Dvina region shows some items existed throughout the Neolithic (*e.g.,* knives made from elk long bones) and other particular for only the Early Neolithic – pendants with a grooved suspension and specific types of bone arrowheads. The latter fits into the evolutionary scheme of arrowhead development from the Mesolithic to Early Neolithic following the common trajectory of the size getting smaller. The shortening of bone projectile points could reflect the appearance of a new hunting strategy as the role of bows increased, and may indicate the increasing importance of fur hunting. Analogies in both the Upper Volga area and the Baltic may reflect this common trend.

Different areas of origin evidenced for the Serteya and Rudnya cultures testify to changes in the directions of cultural interactions at the end of the 6th millennium BC from south-north to west-east. This could be a marker of the destruction of the established network that existed before, during the late 7th and 6th millennia BC. Such a significant change in material culture was due not only to the cultural impulse, but possibly the penetration of a new population from the western territories, which likely established a new system of cultural and social relations.

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A Middle Neolithic pottery workshop at Magoula Imvrou Pigadi, at the crossroads of eastern-western Thessaly and Phtiotida

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ABSTRACT – *This paper presents the first known and systematically excavated Middle Neolithic pottery workshop in southwestern Thessaly at Imvrou Pigadi. The excavations and* in situ *finds, along with the pronounced kiln structures, their typological classification and pyrotechnological operation, suggests considerable expertise in pottery manufacture. The pottery itself, together with the chipped stone industry and other small finds, as well as the fauna and archaeobotanical assemblages are presented. The results of the ^{14}C dating programme point to use of the workshop at the beginning of the 6th millennium. All this evidence suggests an active settlement where pottery production was carried out, which was then circulated within the wider region.*

KEY WORDS – *Neolithic; Thessaly; workshops; pyrotechnology; specialised production; kilns; pottery; exchange networks*

Srednjeneolitska lončarska delavnica v magoula Imvrou Pigadi na stičišču vzhodne in zahodne Tesalije in Ftiotide

IZVLEČEK – *V članku predstavljamo prvo znano in sistematično izkopano lončarsko delavnico iz srednjega neolitika v jugozahodni Tesaliji pri Imvrou Pigadi. Izkopavanja in najdbe* in situ *skupaj z deli lončarske peči, njihovo tipološko razvrstitvijo in pirotehnološkim delovanjem, kažejo na precejšnje poznavanje lončarskih tehnik. Predstavljamo lončenino, odbitkovna kamena orodja, druge drobne najdbe ter živalske in arheobotanične zbire. ^{14}C datiranje kaže na delovanje delavnice na začetku 6. tisočletja pr. n. št. Vse to priča o aktivni naselbini, v kateri se je izdelovala lončenina, ki se je nato širila v regiji.*

KLJUČNE BESEDE – *neolitik; Tesalija; delavnice; pirotehnologija; specializirana proizvodnja; peči; lončarstvo; izmenjevalna omrežja*

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Introduction

Until recently, western Thessaly was widely believed to have been less intensively occupied than the eastern part of the Thessalian plain during the Neolithic. This perception was due to limited research and the large-scale land-reform project carried out in the lowlands of Karditsa during the 1960s, leading to more intensive farming and irrigation which flattened the plain and buried several tells (magoula). In fact, the area has many Neolithic sites, which form the predominant settlement type. In no way could we have imagined then that Imvrou Pigadi would produce the first complex of pottery kilns ever found in either Thessaly, or Greece as a whole, dated to as early as the Middle Neolithic. As indicated by the geophysical survey, during which rectangular anomalies representing prehistoric buildings were identified, the tell itself is very extensive, with the rest of the deposits probably belonging to a typical settlement (*Tsokas* et al. *2009*). If the excavations had only been carried out within the more central part of the tell, it is almost certain that the pottery workshops would not have been discovered.

The workshop complex at Imvrou Pigadi was first referred to during *2o AETHSE* (*Kyparissi-Apostolika 2006*) and then later in *Documenta Praehistorica* as indications of the presence of relevant activity in the area (*Kyparissi-Apostolika 2012*). This exceptional discovery was actually presented in a preliminary report, about which we were initially rather sceptical as there were no similar examples to compare it with. In the present paper some points which were less clearly described in the previous publications are now clarified. Additional research at the site has revealed an extensive pottery workshop spread over two different but adjacent levels, with a height difference between the two of approximately 2m, covering around 50m^2, as far as we currently know. A total of 23 structures have been identified, although more are believed to be located under the adjacent unexcavated deposits. Our investigations included excavation, geophysical survey and several different analytical approaches to the datasets. In this paper we present some of the results of the excavations and the study of the material recovered, while focusing in parallel on the cultural context of the settlement and its special role in the area.

The site and the excavations

Based on a surface survey, Imvrou Pigadi was first referred to as a prehistoric site by Sofia Dimaki (*1994*). Located at an elevation of 165masl on the southwestern edge of the Thessalian Plain (Fig. 1), the site is administratively located in Phthiotida, Neo Monastiri, in the municipality of Domokos. It lies at the crossroads between eastern and western Thessaly and Phthiotida, and is also very close to the

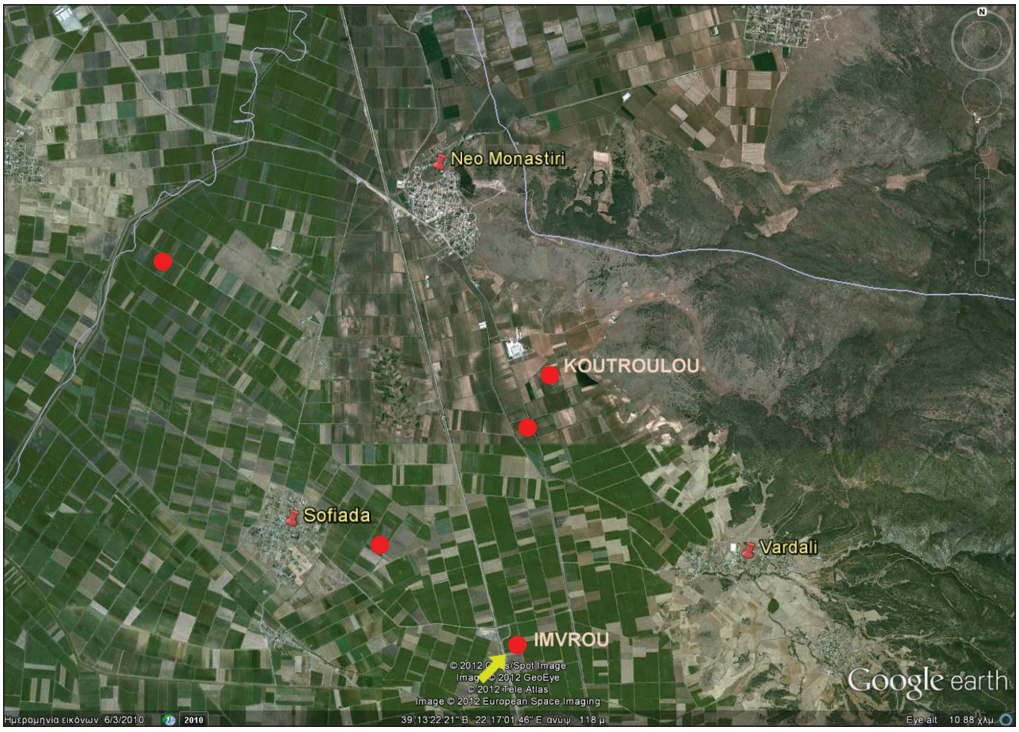

Fig. 1. Site location map with Imvrou Pigadi marked by an arrow and other Neolithic sites by red dots.

railway linking Athens and Thessaloniki, just over a kilometre north of the Domokos station.

Other Neolithic tells are visible in the area, amongst which Koutroulou stands out (*Kyparissi-Apostolika 2003; Hamilakis, Kyparissi 2012; Hamilakis* et al. *2017*), while many other Neolithic settlements are located in the adjacent western part of the Thessalian Plain in Karditsa (*Kyparissi-Apostolika 2019; Orengo* et al. *2015; Krachtopoulou* et al. *2020*). Imvrou Pigadi is one of the most outstanding tells in the area because of its significant extent and height, at over 4m above the road. Based on the geophysical survey, the site extends to at least 14 000 square metres (*Tsokas* et al. *2009*), although since part of its western side was cut during construction of the local road and railway, it may well have been even larger, 22 326 square metres according to Dimaki (*1990*). The tell is located in a private field where cotton has been regularly cultivated.

The excavations were begun on the western upper edge of the site in 2002, and were concluded in 2019.[1] They consisted of four trenches (1, 2, 3 and a/2016), with pottery kilns in all except for trench 3 (Fig. 2). Trench 1 was 5m by 5m square and began with a deposit ranging from 1.03m to 1.5m in thickness (phase A). This produced evidence for possible domestic activities, as defined by the pottery (see below, in the section on the pottery evidence), along with some figurines and obsidian and flint tools. At this depth, a yellowish-red clay surface was identified, beginning in the northeastern corner of the trench and sloping down towards the south. It

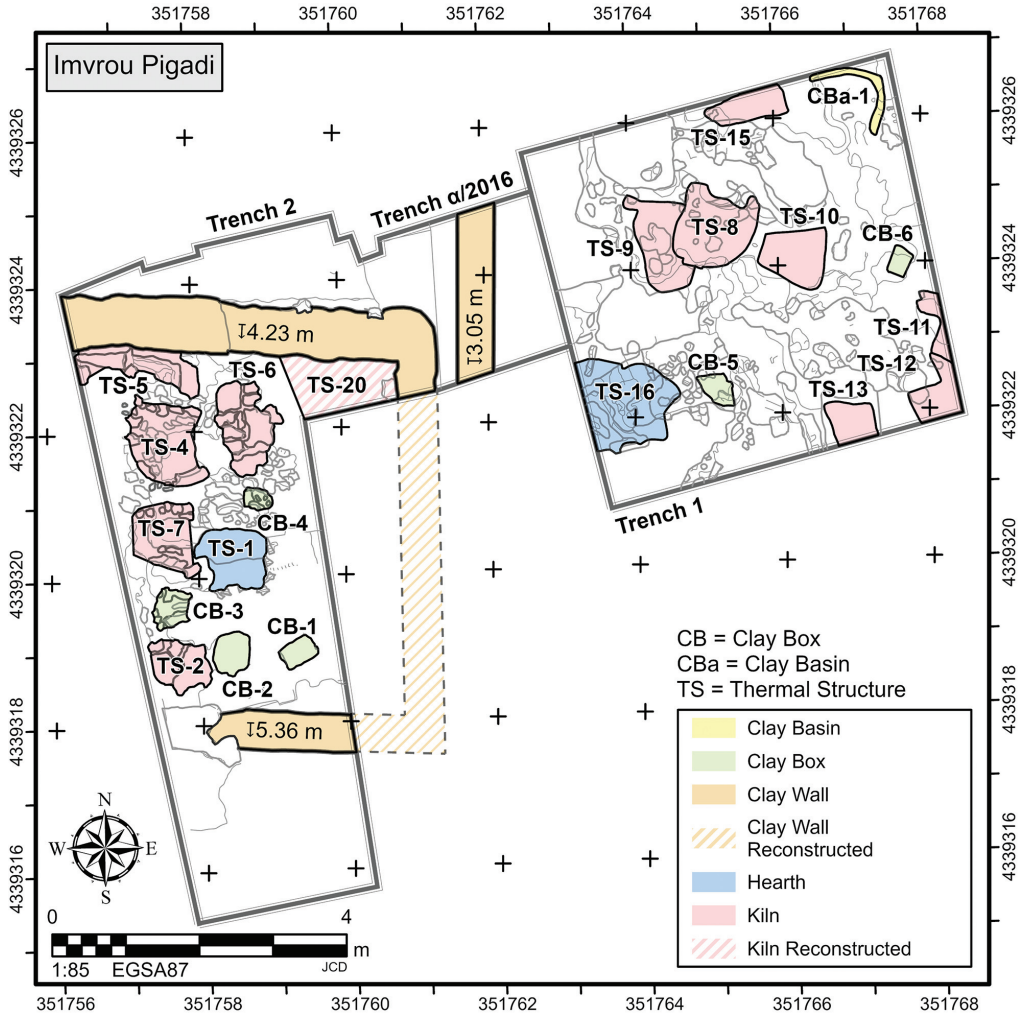

Fig. 2. Trenches 1, 2 and a/2016 showing the location of all structures (drawn by Chryssoula Founda of the Ephorate of Antiquities of Phtiotida, with digital processing by Jamie Donati).

1 The excavator is thankful to the archaeologists Nana Almatzi, Eleni Froussou, Sophia Ntafou, Stavroula Gaga, Evita Kalogiropoulou and Niki Saridaki, who as trench supervisors worked very carefully, recording invaluable information that helped in documenting the special character of the site.

formed all of the eastern side and most probably continues beyond the edges of the trench towards the east and north. In the rest of the trench, parts of this original hardened clay surface were also found. Beneath it, damaged clay structures were uncovered (phase B1) (*Kyparissi-Apostolika 2006.Fig. 2*), at depths ranging from 1.5m to 2.58m. Amongst these, significant quantities of sling bullets were found, as well as brick fragments with surfaces and corners attributed to the structures. Nine structures in total were identified in this trench (Nos. 8–16), along with two clay boxes and one clay basin, while more structures were seen along the sides of the trench in unexcavated deposits (see the detailed description below, in the section on clay-based structures).



Fig. 3. Painted fruit stand found between structures 8 and 10, possibly a foundation offering.

The pottery recovered was mainly monochrome, although examples typical of Middle Neolithic decorated wares were also present (see below, in the section on the pottery evidence). Between two structures (Nos. 8 and 10) a painted fruit stand was recovered, possibly a foundation offering (Fig. 3). The excavations in trench 1 were halted at a depth of 2.5m in order to clarify the nature of the structures.

Trench 2 measured 7.8m by 2.6m and was opened to the west of trench 1, by the edge of the local road. It was around 2m below the excavated level of trench 1 and also below the local road, about 4.27m from the top of the tell, extending into the eastern draining ditch of the road. The structures in trench 2 were identified as kilns and located within an area of approximately 15 square metres. These were bounded to the north, east and south by solid argillaceous walls, with the eastern leg only revealed in 2018, so not referred to in the earlier publications (see Fig. 2). The walls were light yellowish brown to brownish yellow (Munsell 10YR 6/4 – 5/4 and 6/6 respectively) in colour, with the largest and strongest along with northern side, with a visible length of 4.3m. At its eastern end the wall turned south, forming the eastern branch. This continued for 1.37m before disappearing under a thick section of unexcavated deposits for 4.5m, before meeting the southern branch, so an estimated total length of 5.87m. The south wall measured around 2m in length, with its eastern end abutting the eastern wall, the latter estimated to be around 0.9m long, but also covered by the unexcavated deposits. The western branch of the wall was completely buried beneath the local road and therefore unexcavated. For the moment the full lengths of the walls remain unknown, as well as where the western wall is located within the probable rectangular shaped enclosure. For this reason, the total extent of the kiln structures will undoubtedly be larger than that observed during the excavations. The width of the walls differed considerably, with the northern branch measuring from 0.5m to 0.68m at its western and eastern ends res-



Fig. 4. The northern clay wall of the kiln complex, based on an arrangement of stones which may represent an original building phase.

pectively. The western part of the northern wall must have been constructed in two phases, one on top of the other, where it reached a thickness of 0.4m, while its eastern part measured only around half that thickness. In this latter area, the stones seen beneath the argillaceous wall (Fig. 4) at a depth of 4.71m may represent an earlier phase, or they may have been placed in order to provide a foundation.



Fig. 5. The borders of a ditch compacted by ash and tiny pieces of pottery, located to the south of the southern clay wall of the kiln complex. Towards the left can be seen the inclined layers of dumped ash.

The width of the eastern wall where it was visible was 0.6m, while the southern wall was 0.5m to 0.6m wide. The northern wall is at the elevated level of 4.23m compared to the southern (5.36m), with a difference of about 1.18m. Between 0.2m and 0.26m outside of the southern wall was another feature of intense bright red colour (Fig. 5). Apart from some random pieces of pottery and a few bones, it was covered only by ashy deposits.

It was subsequently determined that this red feature was actually the edge of a ditch, consisting of tiny pieces of pottery and hardened by ash, rather than another similar complex of kilns extending to the south of those seen in trench 2, as originally suggested (*Kyparissi-Apostolika 2012.435*). Instead, it consisted of ash thrown from the kiln complex to the north, as can be seen in the sloping ashy deposits in the profile. The ditch was excavated to a depth of 5.83m, producing nothing apart from ash and charcoal, and it probably continues further towards the south beyond the edge of trench 2.

Enclosed within the argillaceous walls were eight structures (Phase B2) (Nos. 1–7 and 20) and four clay boxes (see below, in the section on clay-based structures), while more structures were also visible within the east and the west profiles of the trench, extending into unexcavated deposits. The structures were covered by soil of about 0.5m thick, with colours ranging from red to dark red, while in areas with combustion residues, it was reddish black. The red material in this deposit was friable and dry, and included pieces of broken clay with reed imprints and other flat surfaces, giving the impression of destruction by fire. At a depth of between 5.12m and 5.20m the top surfaces of several structures were uncovered. The first strong indication of such a kiln structure was found within the corner between the northern and eastern walls, just a few centimetres below the upper surface of the wall. We excavated kiln No. 20 (Fig. 6) and found two vertically plastered clay walls of relatively low height forming a corner, together with a flat clay surface at the base, as previously described (*Kyparissi-Apostolika 2012.434, Figs. 2a,b*).

At the time, all of this newly discovered burnt material was attributed to the interior of a house, rather than a kiln. This conclusion was based on the limit-



Fig. 6. The first of red stained patches located in 2003, described as a thermal structure (TS 20).

ed amount of evidence we had at the time, as the excavations had only just begun and had not yet been extend into trench 2. This structure continued to the south beyond the edge of the trench, where it is still visible today in the profile of the unexcavated deposits. Pottery from amongst the structures was very dense and almost all was monochrome, with some from complete small and large vessels (*Kyparissi-Apostolika 2012.Figs. 4, 5*). Several rectangular clay containers measuring 22cm by 23cm by 26cm high were also found, probably used as storage boxes (*Kyparissi-Apostolika 2012.Fig. 3b*). Close to the northwestern corner of the enclosed complex and close to structure No 5 at a depth 4.92m, a four legged kiln figurine with two openings was found, with one of the legs missing (Fig. 7).



Fig. 7. Model clay kiln that probably reflects those in workshop. It was found amongst the structures in the burnt deposits, along with other pottery.

Also recovered from within the kilns were some deer antlers and a few pieces of bone, possibly used as fuel. Some obsidian and flint tools were found, along with a few additional figurines. An exceptional example was structure No 2 where deer antlers of various sizes were found, not by chance but purposefully and carefully placed (Fig. 8). At the bottom of the structure a fire had been set, with traces of burning on some of the antlers.

The burnt layer of intense red colour found outside of the northeastern corner of the walled enclosure, along with the slightly darker ones from within, both point to temperatures ranging between 600 and 700°C (*Roussos, Kyparrisi 2019*). This range is similar to those that have been proposed for the kiln structures within the enclosure (*Kalogiropoulou* et al. *in press*), further suggesting that the burnt layers may be discarded burnt sediments from the kilns mixed with ashes.

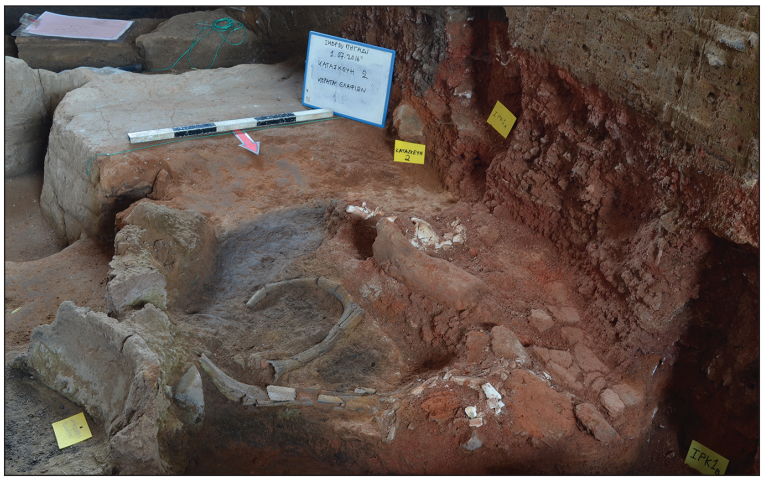

Fig. 8. Thermal structure 2, where deer antlers were deposited, possibly as an offering or future fuel.

In order to investigate the relationship between the two pottery workshop areas in trenches 1 and 2, which differed in height by around 2m, trench a/2016 was excavated in the gap between, corresponding almost exactly with an earlier stratigraphic clearance area of 2.2m by 2.1m square (*Kyparissi-Apostolika 2012.433; 2006.Fig. 8*). The thickness of the deposits was 2.75m at the eastern edge of trench 1 at a depth of 2.58m, where the excavation was halted, while to the west the new trench abutted the argillaceous wall of trench 2 at a depth of 4.22m. The linking trench was begun in 2016 and completed in 2018. Pottery finds included mainly monochrome sherds, along with a few flint and obsidian tools, as well as some figurines and bones. Another argillaceous wall was found at a depth of 3.05m, crossing trench a/2016 from north to south. Although not as robust as those seen in trench 2, it ranged from 0.64m to 0.79m in width (see Fig. 2). Another clay kiln structure, or possibly the remains of a failed one, was found at the eastern end of the trench, along with another which disappeared into the profile of the northeastern corner. The argillaceous walls and these two structures were at an intermediate elevation compared to the workshop areas in trenches 1 and 2, hereafter referred to as phases B1 and B2, respectively. So the intermediate workshop area was 0.5m below B1 and 1.2m above B2, representing either an additional phase, or possibly the initial working surface of B1.

Trench 3 was opened in 2007, almost 20m to the northeast of trench 1.

Measuring 5m by 5m square, its purpose was to check for possible similarities or differences in the use of space, as the geophysical survey had highlighted the presence of several rectangular anomalies in this area (*Tsokas* et al. *2009.1261–1267*). At a depth of approximately 1m, a ditch of 0.5m to 0.7m wide was found crossing the trench from north-east to south-west. Filled with loose soil, the ditch is recent as modern material was recovered, and according to local knowledge the area was in use during World War 2. Due to the presence of amorphous compact layers attributed to the effects of water in the southern part of the trench, the excavations were continued only in the north, where they were halted at a depth of 1.9m. The most distinctive elements of this deposit were the abundance of charcoal, the presence of mostly monochrome pottery, along with decorated wares typical of the Middle and early Late Neolithic (see the section on the pottery evidence). Figurines and ornaments, as well as several obsidian and flint tools, were also recovered. The excavations in trench 3 have been temporarily halted, with no structures like those seen in the other three trenches found so far. Although located close to the pottery workshops, this area appears to have had a more domestic function, possibly supplementary to or supporting the activities carried out in the workshops.

Chronology

During fourteen years of excavations from 2003 until 2017, numerous pieces of charcoal were collected. A total of eight samples were selected for radiocarbon dating, three by the radiocarbon unit of the Laboratory of Archaeometry of the Institute of Nanoscience and Nanotechnology of the National Centre for Scientific Research in Athens (Demokritos), using the gas counting technique (*Facorellis* et al. *1997*). The other five were dated by AMS at the Accelerator Mass Spectrometry Laboratory of the University of Arizona in Tucson (*Donahue* et al. *1990a; 1990b*). The conventional ^{14}C ages were calibrated using the latest version of the IntCal20 calibration curve (*Reimer* et al. *2020*) and OxCal v4.4.4 software (*Bronk Ramsey 2009*). The results are presented in Table 1, along with the probability distribution plots of the calibrated ages (Fig. 9).

The calendar ages of the samples from trench 1 (DEM-1435 and AA112953) ranged from 5888–5726 to 5985–5836 BC (within 2σ). They were derived from almost the same area from square A1 in the southeastern corner of trench 1, although with a difference in depth of approximately 0.4m. Trench 2 produced three dates within 2σ (DEM-1434, AA-112955 and DEM-1402). The first was from a charcoal sample within the southern leg of the argillaceous wall, with a calendar age of 5968–5747 BC. The second was derived from the area south of the clay structures, close to clay box 2 and at almost the same depth as the first sample, producing a calendar age of 5987–5786 BC. The third sample was derived from a deeper level (6.2–6.32m) just outside of the northern leg of the argillaceous wall, producing a calendar age of 5618–5474 BC. This probably

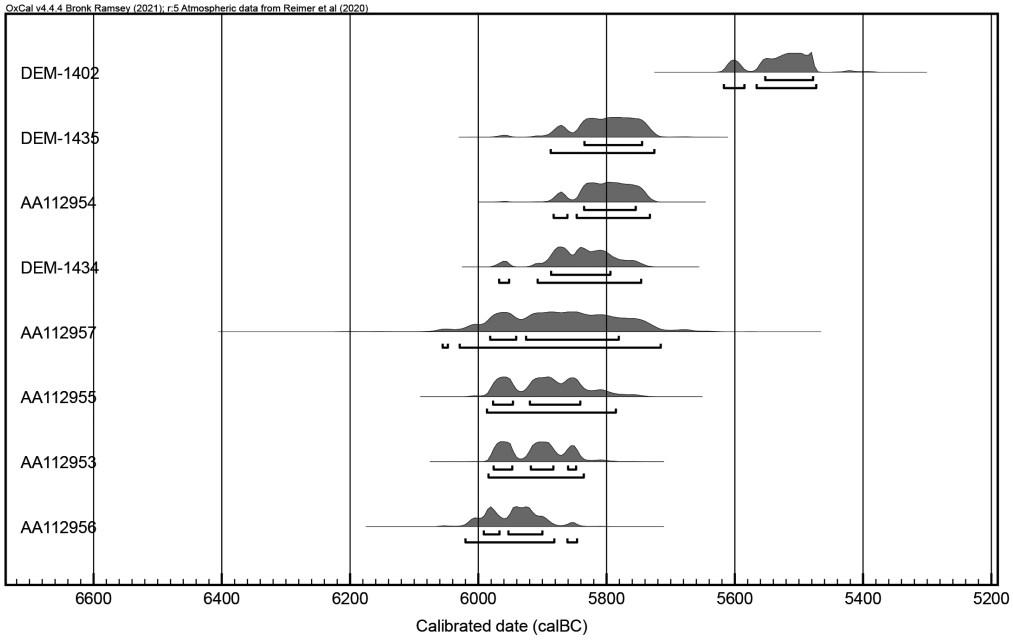

Fig. 9. Probability distribution plots for the calibrated dates from Imvrou Pigadi, sorted by increasing age.

Laboratory code	Sample ID and location	Collection date	Sample type	$\delta^{13}C$ (‰)	^{14}C age (yr B.P.)	Calendar age (yr B.C.)
DE-1402	Samples 34, 35, 36, Trench 2 at the side of the road, depth 6.20–6.32	15.10.2003	Charcoal	–25	6567±40	5553–5479 (1σ) 5618–5474 (2σ)
DE-1435	Sample 1, Trench 1, Π11, A1, Depth 1.66	29.9.2003	Charcoal	–25	6923±36	5835–5745 (1σ) 5888–5726 (2σ)
AA112954	Trench 3, Square B4, Pass 7, East: 1.38, North: 3.35, depth 1.48	29.11.2011	Charcoal	–24,5	6928±24	5836–5755 (1σ) 5883–5733 (2σ)
DE-1434	Sample 24, Trench 2 at the side of the road, Depth 4.7	29.9.2003	Charcoal	–25	6962±25	5887–5795 (1σ) 5968–5747 (2σ)
AA112957	Sample 3, Trench a/2016, Pass 47, North: 0.92, East: 0.75, depth 4.27	14.9.2018	Charcoal	–25,9	6993±90	5982–5782 (1σ) 6056–5716 (2σ)
AA112955	Trench 2 (β/2016), East of clay box 2	8.6.2016	Charcoal	–25,5	7008±40	5978–5842 (1σ) 5987–5786 (2σ)
AA112953	Trench 1, Square A1, South: 0.8, West: 0.3, depth 2.02	5.12.2012	Charcoal	–24,5	7016±25	5977–5848 (1σ) 5985–5836 (2σ)
AA112956	Sample 3, Trench a/2016, Pass 36, depth 3.4	11.10.2017	Charcoal	–25,3	7069±35	5992–5901 (1σ) 6021–5847 (2σ)

Tab. 1. Radiocarbon dates from Imvrou Pigadi Neolithic tell, sorted by increasing age.

suggests a different activity which occurred around 250 years later than those activities seen within the enclosing walls.

Two other charcoal samples (AA112956 and AA-112957) with a depth difference of 0.87m from trench a/2016 produced overlapping calendar ages within 2σ, of 6021–5847 BC (depth 3.4m), and within 2σ, of 6056–5716 BC (depth 4.27m). They were consistent with the two samples from trench 2 (DEM 1434 and AA112955), suggesting overlapping use of the areas uncovered in trenches 1, 2 and a/2016.

A final sample from trench 3 (AA112954) produced a calendar age within 2σ, of 5883–5733 BC, which coincides with the dates from the workshops, again suggesting contemporary use, although without the kiln structures. This area may have played a supportive role for the workshops and/or domestic activities.

Coring

Coring was carried out during 2012 in order to trace the outer edge of the tell, to explore the underlying stratigraphy, to measure the depth of the original paleosoil of the valley, and if possible, to trace any deeper deposits that might be linked with the pyrotechnical processes. Four cores were drilled down on a north south axis through trench 2, the first 18m to the north and a further two 10m and 16m to the south. The fourth was drilled at the deepest point in the northeastern corner of trench 2.

All of the cores within the walls and those to the south reached the paleosoil at depths of between 7.76m and 8.54m from the top of the tell. The northernmost core reached a maximum depth of 7.35m without hitting the paleosoil. Anthropogenic material including charcoal, ash and pottery fragments were observed in all cores from top to bottom, indicating continuous use of the tell throughout the Middle Neolithic and possibly extending the chronology of the site even further back in time. Deposits that could be linked with pyrotechnical activities were located in the two outer cores only, north and south of the excavated area, at depths similar to those seen in the excavated kiln area, while the internal core did not reveal any deeper deposits. This suggests that similar workshop areas may exist towards the north and south, but the kiln area in trench 2 is probably the earliest workshop phase uncovered so far. The natural fine-grained deposits found mixed with fine anthropogenic material at around 5.5m and 6.5m may suggest two small-scale flooding episodes.

The clay-based structures, their typology and pyrotechnological characteristics

A total of 23 clay structures were recorded, predominantly in the walled areas on the western edge of the settlement, with most attributed to the Middle Neolithic cultural horizon identified in that area. They were grouped into two general categories, the first including structures dedicated to the use of fire, like kilns and hearths made of clay. The second category included large containers like clay boxes and basins (Tab. 2).

ID*	Trench	Type	Shape	Size (m) **	Location of the entrance ***	Construction elements
TS 1	Trench 2	Hearth	Rectangular	1 x 0.75 x 0.12	East	Single heating surface
TS 2	Trench 2	Kiln	Horseshoe	0.85 x 0.76		5 heating surfaces
TS 4	Trench 2	Kiln	Horseshoe	1.26 x 0.98 x 0.42	West	2 heating surfaces, 3 wall plasters, outer plastic leaf-like decoration
TS 5	Trench 2	Kiln	Horseshoe	1.3 x 0.76 x 0.55		2 wall plasters, Apron
TS 6	Trench 2	Kiln	Horseshoe	1.05 x0.9 x 0.12	East	2 heating surfaces
TS 7	Trench 2	Kiln	Horseshoe	0.78 x 0.82 x 0.47	West, partly excavated	Wall plasters, Apron
TS 8	Trench 1	Kiln	Horseshoe	1.08 x 0.85 x 0.38	Northeast	4 heating surfaces, plastered outer dome surfaces, Apron
TS 9	Trench 1	Kiln	Horseshoe	1.33 x 0.9 x 0.10	North	3 heating floors
TS 10	Trench 1	Kiln	Horseshoe	0.85 x 0.74 x 0.27	Northeast	4 heating surfaces, 2 wall plasters
TS 11	Trench 1	Kiln	Horseshoe	0.54 x 0.5 x 0.10	West, partly excavated	3 heating surfaces, 5 wall plasters
TS 12	Trench 1	Kiln	Horseshoe	0.82 x 0.71 x 0.40	West, partly excavated	3 heating surfaces, Apron
TS 13	Trench 1	Kiln	Irregular	0.58 x 0.55 x 0.43	North, partly excavated	8 heating surfaces, 6 wall plasters
TS 14	Trench 1	Clay basin	Vertical walls	1 x 0.82 x 0.05	East	Low sidewalls
TS 15	Trench 1	Kiln	Irregular		Partly excavated	
TS 16	Trench 1	Hearth	Horseshoe	0.8 x 0.78 x 0.35 partly excavated	Northwest, partly excavated	Low side walls, Apron
TS 18	Trench 2	Hearth	Irregular	1.12 dia, height 0.09	Unexcavated	Single heating surface
TS 19	Trench 2	Kiln			Unexcavated	
CB 1	Trench 2	Clay box	Rectangular	0.47 x 0.36 x 0.22	North	
CB 2	Trench 2	Clay box	Rectangular	0.49 x 0.42 x 0.18	North	
CB 3	Trench 2	Clay box	Rectangular	0.51 x 0.4 x 0.20	West	
CB 4	Trench 2	Clay box	Square	0.32 x 0.32 x 0.13		
CB 5	Trench 1	Clay box	Rectangular	0.44 x 0.4 x 0.09	East	
CB 6	Trench 1	Clay box	Rectangular	0.29 x 0.2 x 0.25	Southwest	3 plastered wall surfaces

Tab. 2. The 23 clay-based structures identified at Neolithic Imvrou Pigadi (*TS=Thermal structure, CB= Clay box).

Kilns were the most numerous and impressive group, with 13 in total, while also present were three hearths, six clay boxes and a single clay basin. The preservation of the structures ranged from very good to heavily eroded, while the entire assemblage reflects a major investment of time and labour and a high degree of structural uniformity and sophistication. The kilns were studied both macroscopically and through several geoarchaeological approaches, in order to investigate their construction and use (*Germain-Vallée, Prévost-Dermarkar, Lespez 2011; Mentzer 2014; Mallol, Mentzer, Miller 2017; Roussos, Kyparissi-Apostolika 2019*).

The kilns consisted of above ground horseshoe-shaped structures with a solid vaulted compartment and front-loading entrance (*Prévost-Dermarkar 2002; Kalogiropoulou 2013*). On average, they were 1m in length by 0.9m in width, with a typical opening of 0.8m wide. They were made of local clay enriched with straw binding and the solid vaulted compartments were around 0.4m in height, with the dome built using the coiling technique or with a wooden mesh inner frame. The apron formed a prominent construction feature, preserved in four cases and consisting of a flat working bench beneath the entrance. One of the characteristic aspects of the kilns was that both the floors and walls of the domes were subject to multiple repairs. There were up to four phases of replastering of the smooth heating floors, with a consistent thickness of between 2cm to 3cm, set upon a substantially thicker initial foundation layer of up to 6cm thick. Micromorphological analysis revealed a striking absence of charcoal or any other combustion by-products between the individual plaster layers of the floor, suggesting that the structures were thoroughly cleaned before being repaired. The walls followed a similar pattern of re-

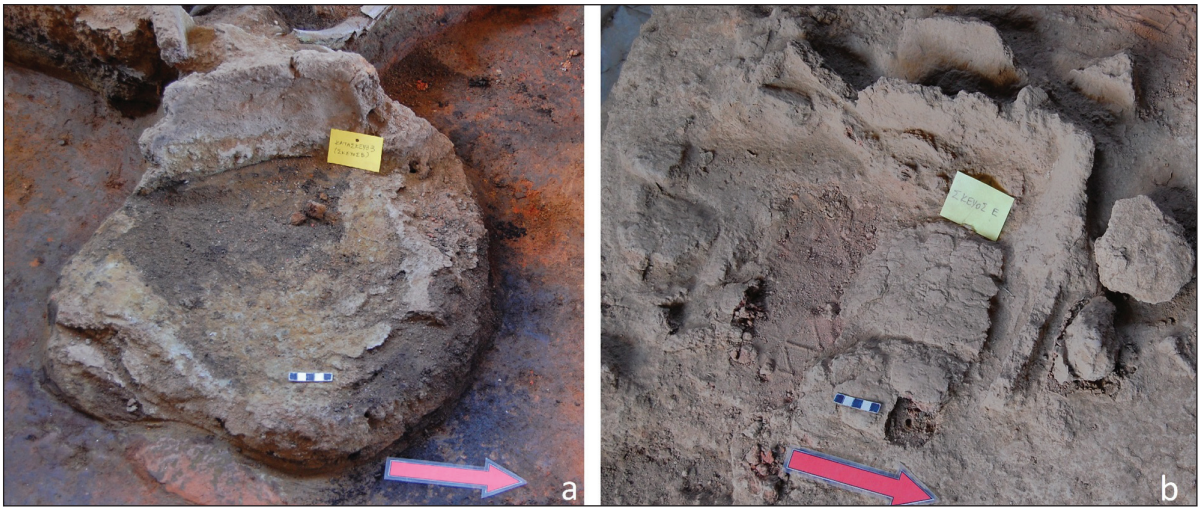

Fig. 10. Clay box 2 in trench 2 and clay box 5 in trench 1, two small rectangular features found in direct association with TS 2 and TS 16 respectively. From within clay box 5 were recovered several clay sling bullets.

pair in terms of frequency. Apart from TS4 that preserved a relief leaf-like decoration on its sidewall, the kilns were probably not ornamented. All the above observations point to careful and labour-intensive construction, maintenance and repair of the kilns, suggesting a significant element of expertise and standardisation. Another characteristic of the kilns is that they were all fired in oxidizing conditions, as indicated by their consistent bright red colour. That this uniformity in combustion is unrelated to the thickness of the walls and floors suggests high burning temperatures and probably repeated use of the structures. The analytical methods used indicated that the majority of the kilns were repeatedly heated to temperatures ranging between 700 and 1000°C (*Roussos, Kyparissi-Apostolika 2019; Conati Barbaro* et al. *2021*). These observations suggest a controlled burning environment and a sophisticated level of pyrotechnology for the Middle Neolithic. In the same way as the kilns, hearths were also above ground features with smooth heating surfaces. They were irregular or horseshoe-shaped, with an average diameter of around 1.1m. Five successive replastering phases of the heating surface was noted in hearth 16, which were also of a unique form, with low walls, an apron and an entrance opening.

Clay boxes were common at Imvrou Pigadi, directly linked with the kilns both spatially and functionally (Fig. 10). They were small rectangular structures with an average length of 0.45m and width of 0.4m, and low walls with an average height of 0.2m.

Their floors were laid directly on the ground surface and consisted of a single smooth clay layer that covered the lower surface of the structure. Their small size and the material found within them, including lithic artefacts, clay sling bullets, horns, pottery sherds and ash, suggest their use as storage or disposal features close to the kilns. Formed of two vertical low clay walls of 1m and 0.82m, a single clay basin (structure 14) was uncovered in the northeastern part of trench 1 (Fig. 11). It contained pure clay masses, along with two ground stones tools, and was roughly constructed with minimal investment of labour or building expertise.



Fig. 11. Clay basin (CBa-1 in Fig. 2) where clay masses were collected for later use.

The pottery evidence

Trenches 1 and 3, the domestic character of the assemblage

The ceramic material from trench 3 and the upper layers of trench 1 is dated to the Middle Neolithic, while some sherds from the upper layers and surfaces of the trenches are Late Neolithic. The pottery included large quantities of red monochrome wares, along with substantial amounts of various styles of painted wares (Fig. 13).

The most common shapes were open (40%), followed by closed vessels (30%), while a large proportion of sherds were without any diagnostic traits (30%). Most vessels were spherical, hemispherical and conical bowls, as well as basins and cups of small and medium size. The rims were usually straight, inwardly curving or S-profile. The necks of closed vessels were cylindrical or concave. Most bases were ring-shaped, often retaining traces of coil construction, with fewer flat and concave bases.

Monochrome vessels were predominant and in particular red slipped, followed by brown burnished or slipped, cloud burnished and then red burnished wares. The most common decorated ware was painted, followed by rare impresso and incised sherds. The well-known Thessalian red on white painted wares were also prevalent (*Wace, Thompson 1912; Theocharis 1973; Kotsakis 1983*). Decorated motifs were mostly linear, lines and zig-zags, along with solid triangles and zones, all indicative of an advanced phase of the Middle Neolithic (*Kotsakis 1983*). White on red and scraped wares were less common.

Vessels were mainly used for display and consumption, for transport of liquid or solid contents, and less frequently for storage. Preliminary assessment of the assemblage also noted the presence of cooking vessels. The sherds had traces of organic inclusions, while a considerable proportion had clouds (16%), although it was not always clear whether these derived from the initial firing of the vessels or whether they were the result of later use during cooking (Fig. 12).

The pottery from trench 3 and the upper layers of trench 1 highlighted



Fig. 12. Rim sherd of a cooking pot with traces of organic residues on the interior surface.

the domestic character of the assemblage, as it includes all of the types of vessels that a Neolithic household would require for consumption, display, storage, and cooking. The site is dated primarily to the Middle Neolithic, as characterised by the classic Thessalian red on white wares. The characteristic Late Neolithic sherds from the upper and surface layers of the trenches included black and grey burnished, polychrome painted (light red-orange and black paint on a white background), and incised wares (see also Fig. 13). These ceramic categories are dated to an early phase of the Late Neolithic, specifically Late Neolithic I, although their continuation into Late Neolithic II cannot be excluded.

Trenches 1 and 2, the pottery workshop

Small and medium-sized vessels continued to be the predominant categories in trenches 1 and 2. Vessel shapes included open (28%) and closed (21%) forms, with the most common types being bowls, cups, jars,

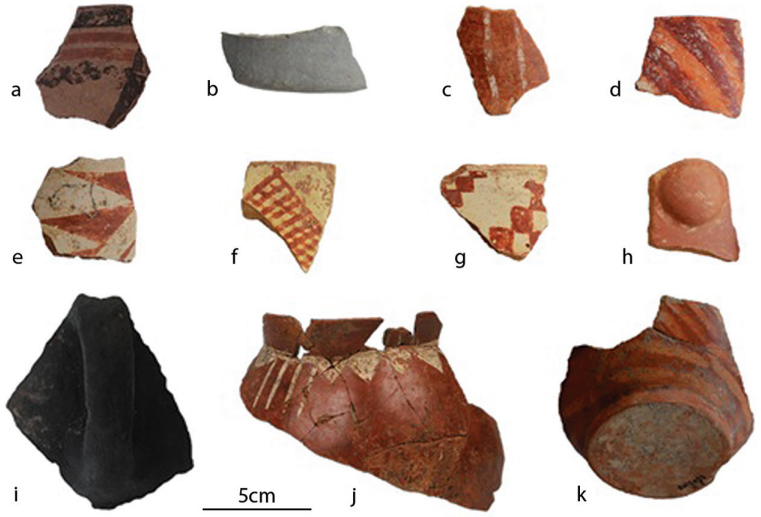

Fig. 13. Pottery decorative types from Imvrou Pigadi:* a *polychrome painted wares;* b *grey burnished wares;* c, j *white on red pattern painted;* d, k *scraped painted wares;* e, f, g *red on white pattern painted wares (triangles/flames, checkerboard and hatched motifs;* h *red-slipped with button plastic decoration;* i *black burnished wares.

and less frequently basins. The predominant decorative category was monochrome, red-slipped burnished, followed by brown burnished, brown slipped and red burnished wares, while the main manufacturing technique was coiling. The surfaces were highly burnished to a polished finish, while a few were smoothed, with shapes and surface treatment pointing to a high degree of standardisation and repetitive production.

The completed vessels recovered from around the pottery kilns in trench 2 were all monochrome red slipped bowls (Fig. 14). The vessels shared similar morphological characteristics with differences only in size. A significant proportion of the sherds were recorded as uncertain, and could represent unfinished vessels, such as three closed jars with unfinished smoothed exterior surfaces and visible tool traces. These jars preserve part of the manufacturing process, with unfinished surfaces prior to the application of the red slip.

The detailed macroscopic analysis of the pottery from trenches 1 and 2 indicated that over 70% of the assemblage consisted of monochrome red slipped wares of all shapes and sizes, allowing us to conclude that this was the predominant output, again pointing towards the presence of specialised pottery workshops at Imvrou Pigadi (Fig. 15).

Alongside the monochrome burnished wares, smaller quantities of decorated pottery were recovered from both trenches. These included painted wares, those with relief decoration, and rare impressed and incised motifs. The predominant painted style was the well-known Thessalian red on white (*Wace, Thompson 1912; Theocharis 1973; Kotsakis 1983*). Predominant decorative themes included linear lines, zigzags, combinations of bundles of rectilinear or wavy lines, along with solid inverted triangles and flames. Less common types included stepped Tzani, abacus and hatched motifs. Other rare painted types



Fig. 14. Red slipped bowls (open and closed) from the vicinity of the pottery kilns.

included white on a red background and scraped wares.

Buttons were a distinctive relief decoration, along with very rare grains. Vessels with the former were decorated around the main body of the vessel. The monochrome red burnished slipped open bowls with relief button decoration shared similar morphological characteristics (open hemispherical bowls) and were differentiated only in terms of their size, with heights of 13cm to 22cm. These vessels may also have been produced at Imvrou Pigadi (Fig. 16). The vessels recovered from trenches 1 and 2 were mainly for display and consumption, or the transport of liquid or solid contents. Conversely, storage and cooking vessels were rare.

The ceramic assemblage was characterised by a variety of painted decorative styles, with the dominant red on white wares and rare white on red. These painted vessels are common throughout Thessaly during the Middle Neolithic, pointing to their wide circulation (*Wace, Thompson 1912; Kotsakis 1983; Gallis 1996; Rondiri 2009; Hamilakis* et al. *2017*). This was also confirmed by two similar open bowls with red on white decoration, one from Imvrou Pigadi and the second from Astritsa in Karditsa (*Kyparissi-Apostolika 2006.Fig. 5; 2019.Fig. 9; Hatziaggelakis 2006.Fig. 4*). In addition, the small numbers

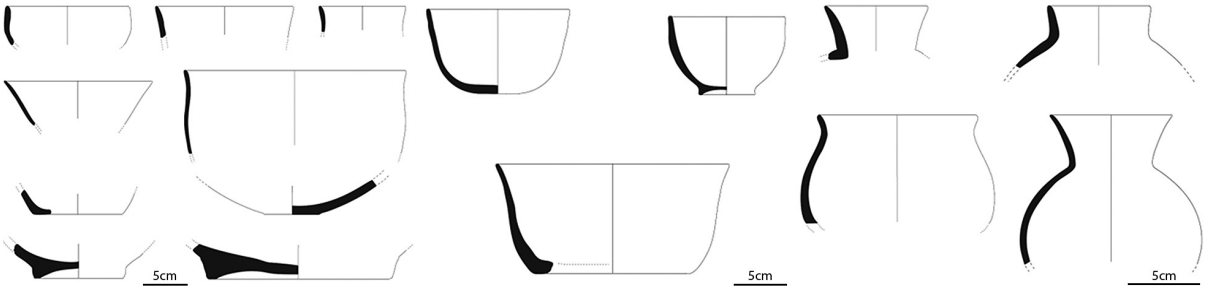

Fig. 15. Vessel types from Imvrou Pigadi (by Leonidas Zachariades and Efrosini Zachariadi, with digital processing by Eirini Tzemopoulou).

of scraped ware sherds may suggest links with the area of Rizava, where a regional production centre for such pottery is reported (*Krachtopoulou* et al. *2018; 2020*). The small number of buff burnished sherds found at the site may also suggest exchange with the Sesklo area (*Schneideretal 1994.64; Dimoula 2014*), with a programme of petrographic analysis currently being carried out on the material by Areti Pentedeka.



Fig. 16. Red slipped open bowls with relief button decoration around the body.

The chipped stone assemblage

The excavations at Imvrou Pigadi produced 653 chipped stone artifacts. Obsidian was the predominant raw material in use (n=411, 62.9%), followed by flint (n=234, 35.8%) and quartz (n=8, 1.2%). The obsidian was exclusively from Melos, while the silicious material was derived from a range of sources. The most abundant variety was the so-called chocolate radiolarite. This was imported from the Pindos mountains (*Kourtessi-Philippakis 2009*) and locally knapped, although the introduction of partially worked tools and blanks cannot be ruled out. The provenance of the so-called honey flint is less clear, but it was certainly being brought in from distant sources.[2] Tools made from this raw material were relatively rare, consisting only of retouched blades.

Evidence for onsite knapping was present for both obsidian and flint (Fig. 17). Obsidian knapping appears to have been less intense, with only five cores recovered, along with four crested blades and three core rejuvenation tablets. Even though six cortical flakes could indicate that obsidian nodules were occasionally reaching the site, it is more likely that they were derived from a core that retained some cortex after the initial preparation and forming of the crests. Four cores were used for the production of blades/bladelets, while the remaining one had flake scars only. The evidence suggests that obsidian knapping was mainly geared towards the production of blades/bladelets using the pressure technique. The evidence for the working of flint, in the form of 14 cores and 15 cortical flakes, suggests that although blades/bladelets were being produced, this material was more commonly used for the expedient production of flakes. This was also evident in the blade/bladelet versus flake ratio for each type of raw material. In the case of obsidian, blades/bladelets were overwhelmingly predominant (195 blades/bladelets versus 80 flakes), while in the case of flint the picture was different (19 blades/bladelets versus 64 flakes). Note that if the blanks used for formal tools were counted, the difference becomes somewhat less pronounced due to the tendency towards applying retouch on flint blades/bladelets. Preparation of core striking platform overhangs by trimming was occasionally evident on both flint and obsidian blades/bladelets.

Although flint knapping was to a large extent geared towards the production of flakes, it is noteworthy that obsidian rather than flint flakes were more frequently used for the manufacture of retouched tools. But flint and obsidian retouched blades/bladelets form the predominant formal tool category (n=50 and 37 respectively) (Tabs. 3–9). Retouched flakes and notches (Fig. 18), the latter always made on obsidian blanks, were less numerous, while side and end scrapers were rare. Other tool categories were represented by only a few examples, including truncated blades/bladelets, borers and burins. Although

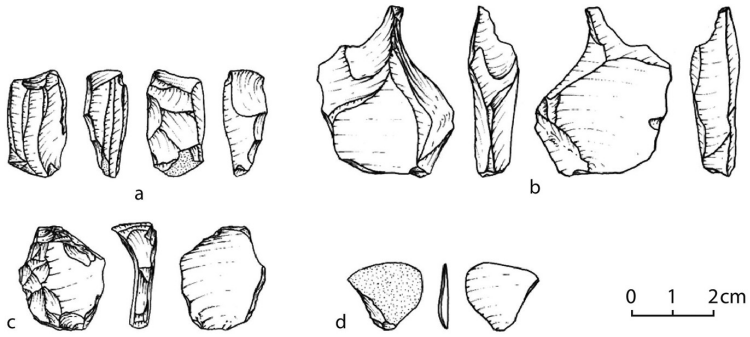

Fig. 17. Obsidian and flint cores, technical pieces and flakes:* a *obsidian core with flake decortication and laminar removals,* b *flint multidirectional flake core,* c *obsidian core rejuvenation tablet,* d *obsidian primary flake.

2 Raw materials referred to as honey flint could be distinct. For possible provenance see Catherine Perlès (*1990*), Georgia Kourtessi-Philippakis (*2009*) and Odysseas Kakavakis (*2014*).

Retouched tool types	Obsidian	Flint	Quartz	Total
Retouched blades/bladelets	35	56		91
Retouched flakes	16	10		26
Splintered pieces	9	4		13
Notches	14			14
Truncations	5	2		7
Arrowheads	1	3		4
Burins	3	1		4
End scrapers	1	2		3
Borers	1	1		2
Side scrapers		1		1
Backed blades		1		1
Technical piece, core rejuvenation tablet	1			1
Retouched indeterminate		4	1	5
Total	**86**	**85**	**1**	**172**

Tab. 3. Retouched tool categories.

Trenches 1 and 2 (Phases B1 and B2)	Obsidian	Flint	Quartz	Total
Blades/bladelets	54	2		56
Flakes	27	10		37
Cores	1	3		4
Technical pieces	1			1
Tools	18	16		34
Other (debris, indeterminate, natural pieces)	6	18		24
Total (%)	**107 (69)**	**49 (31)**		**156**

Tab. 4. Trenches 1 and 2 (phases B1 and B2) basic assemblage structure.

rare, projectile points (n=4) may be helpful in terms of chronological differences. A transverse arrowhead is probably Middle Neolithic in date, while the two tanged points probably date to after the Middle to Late Neolithic transition. Flint retouched blades were frequently used for cutting siliceous plants, as in 24 cases there was gloss along one or both edges. In addition to retouched tools, the assemblage also included splintered pieces and several unretouched pieces with macroscopic wear traces.

The chipped stone assemblage from Imvrou Pigadi is of additional interest due to the location of the site in the vicinity of the largely contemporary Koutroulou Magoula settlement. The latter has a raw material utilisation pattern that sets it apart from what is known from Thessalian sites further to the north, due to the high proportions of obsidian.[3] The evidence from Imvrou Pigadi is therefore useful in reconstructing these distinct regional patterns.[4] Imvrou Pigadi suggests that the high proportions of obsidian seen at Koutroulou Magoula are not unique, since at Imvrou Pigadi it was even more prevalent. It should also be noted that there is no stratigraphic evidence for a change in raw material utilisation over time at the site. This suggests the existence of a well-established regional trend in the far southwestern Thessalian Plain. The location of the site, close to routes leading from both the Spercheios Valley and the coastal area of Volos towards the western Thessalian Plain, was certainly conducive to the formation of this regional pattern. While obsidian was preferable for the production of blades/bladelets because of its flaking properties, sturdier flint blades were also locally made and probably, or certainly in the case of honey flint, imported through networks connecting the site with the rest of Thessaly and areas beyond.

Imvrou Pigadi appears to be in a transitional position due to its engagement within spatially overlapping networks. It was simultaneously part of the supply zone for the obsidian trade, but also had unhindered access to flint raw materials and finished tools, traded through networks prevalent in areas to the west and north. As a result of its connection within a variety of networks, the site appears to have been able to exercise a flexible strategy of raw ma-

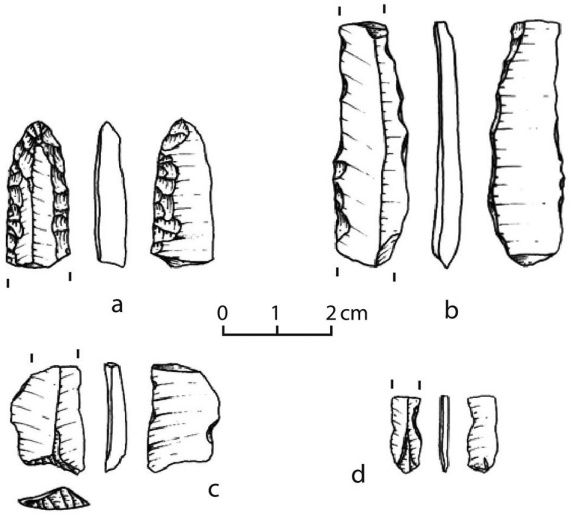

Fig. 18. Obsidian and flint retouched tools:* a, b *retouched flint blade,* c *truncated flint blade,* d *notched obsidian bladelet.

3 Yannis Hamilakis *et al.* (*2017.92*).

4 For an evaluation of lithic networks in mainland Greece during the Neolithic, see Katherine Perlès (*1990; 2009*). Regarding the area of Thessaly, see Evagelia Karimali (*2009*).

terial and tool procurement. Located on the edge of Thessaly, Imvrou Pigadi or other neighbouring sites may have served as important nodes in these flint and obsidian trading networks, which may have a bearing on the social perception and integration of lithic production and trade.

Other small finds

Small finds were not very common, reinforcing the interpretation of this part of the site as a workshop rather than a domestic area. Figurines were less abundant compared to other adjacent sites, just 65 from all years and all trenches. Amongst these were 20 small items with three- or four-sided bases, a type common at the neighbouring Koutroulou Magoula (*Kyparissi-Apostolika 2003.Fig. 4; Hamilakis* et al. *2017.Colour plates, Fig. 8*) and other sites in western Thessaly, such as Platia Magoula Zarkou (*Alram-Stern in press*) and Sykeon (*Alexiou 2015*). The remaining 45 figurines included several types, some of which are naturalistic and in other cases they had ornaments or paint on the body (Fig. 19) (*Kyparissi-Apostolika forthcoming*). Twelve figurine heads were also recovered, some of which were relatively large, up to 6cm (for example, ME 65/2009 and ME 9/2007), obviously from bigger figurines. Some larger examples of legs were also recovered (for example, ME 64/2017 and ME 35/2007). Most of the figurines were found in trench 3, followed by a/2016, with fewer in trenches 1 and 2.

Apart from the figurines, 20 ornaments were also found, mostly beads made of stone or bone, along with some from clay. Most were found in trench 3, with less in trenches 2 and a/2016. Another impressive category were the numerous sling bullets, with 73 in total, most of which were intact, as if just baked. They were found close to the kiln structures, also suggesting that they had been

Trenches 1 and 2 (phases A1 and A2)	Obsidian	Flint	Quartz	Total
Blades/bladelets	80	11		91
Flakes	33	36		69
Cores	1	4		5
Technical pieces	2			2
Tools	43	43		86
Other (debris, indeterminate, natural pieces)	25	22	3	50
Total (%)	**184 (60.7)**	**116 (38.3)**	**3 (1)**	**30**

Tab. 5. Trenches 1 and 2 (phases A1 and A2) basic assemblage structure.

Trench a/2016	Obsidian	Flint	Quartz	Total
Blades/bladelets	10	1		11
Flakes	8	4		12
Cores	2			2
Technical pieces	1			1
Tools	5			5
Other (debris, indeterminate, natural pieces)				
Total (%)	**26 (83.9)**	**5 (16.1)**		**31**

Tab. 6. Trench a/2016 basic assemblage structure.

Trench 3	Obsidian	Flint	Quartz	Total
Blades/bladelets	48	6		54
Flakes	11	14		25
Cores	1	7		8
Technical pieces	3			3
Tools	19	18	1	38
Other (debris, indeterminate, natural pieces)	9	16	4	29
Total (%)	**91 (58)**	**61 (38.8)**	**5 (3.2)**	**157**

Tab. 7. Trench 3 basic assemblage structure.

Surface finds	Obsidian	Flint	Quartz	Total
Blades/bladelets	2			2
Flakes	1			1
Cores				
Technical pieces				
Tools		3		3
Other (debris, indeterminate, natural pieces)				
Total (%)	**3 (50)**	**3 (50)**		**6**

Tab. 8. Surface finds basic assemblage structure.

Unretouched debitage, cores and technical pieces	Obsidian	Flint	Total
Blade/bladelet cores	4	4	8
Flake cores	1	8	9
Blade/flake cores		2	2
Crested blades	4		4
Core rejuvenation tablets	3		3
Cortical flakes	6	15	21
Blades/bladelets	195	19	214
Flakes	80	64	144
Total	**293**	**112**	**405**

Tab. 9. Unretouched debitage, cores and technical pieces from the complete assemblage.



Fig. 19. Large human figurine decorated with a bead-like ornament on the chest, along with a similar depiction on the back and wheat seed shaped beads decorating the shoulders.

fired therein. The majority (n=55) were found in phase B1 of trench 1 and then in trench a/2016, while only rarely in trenches 2 and 3. The clay objects also included a few spindle whorls and spinning and weaving implements, as well as a few cubes with incised dots (n=29). Ground stone tools and millstones were abundant, with at least 132 recovered. Additionally, there were 41 bone tools and worked horns in the assemblage of small finds. The bone tools came from all trenches and were directly associated with pottery production, including perforators, spatulae and needles, although the analysis of these objects is still in progress. They probably reflect the specific activities carried out in the workshops, but if or when excavations are carried out in areas of a more domestic character, this picture may change.

The archaeobotanical evidence

Archaeobotanical investigation was incorporated within the programme of research at Imvrou Pigadi from the very beginning of the excavations. Based on a systematic soil sampling strategy, the aim was to gather as much evidence as possible on the utilisation of plants and practices of cultivation, harvesting and consumption. The location of the site on the southwestern edge of the Thessalian plain, and its chronology within the Middle Neolithic, provide us with a unique opportunity to complement the fragmentary archaeobotanical evidence from this part of Greece and this phase of prehistory. The study of the plant remains is still in progress, and only generic and preliminary observations are presented.

Carbonisation was the only mode of preservation encountered in the assemblage. Cereals were represented by einkorn (*Triticum monococcum*) and emmer wheat (*Triticum dicoccum*), barley (*Hordeum vulgare*) and possibly oats (cf *Avena* sp.). Wheat was mainly present in the form of seeds, while the occurrence of glume bases, either separate or as whole spikelets, was more limited. The assemblage also contained smaller quantities of various pulses, including lentils (*Lensculinaris*), bitter vetch (*Vicia-ervilia*) and probably the common pea (cf *Pisum* sp.) and chickpea (cf *Cicer* sp.). Only the fig (*Ficus carica*) has been identified so far in the category of fruit and nuts.

A much wider range of wild plants were identified in the assemblage, including genera such as *Fumaria* sp., *Chenopodium* sp., *Galium/Asperula* sp., *Scirpus/Cyperus* sp., *Carex* sp., *Lolium* sp., *Bromus* sp., and several more as yet unidentified species of Leguminosae, Polygonaceae and Gramnineae (Tab. 10). All of these could have been present amongst the natural vegetation surrounding the site, or may have been included in the assemblage as weeds of cultivation or as evidence for a much broader variety of, as yet unknown uses within the context of daily life.

The unique character of Imvrou Pigadi as a site where specialised pottery production was being undertaken poses an interesting challenge for archaeobotany, in that it is associated with evidence for the use of plants in non-domestic contexts, in contrast to

	Latin name	Comon name
Cereals	*Triticum monococcum*	Einkorn
	Triticum dicoccum	Emer
	Hordeum vulgare	Barley
	cf *Avena* sp.	Oat
Pulses	*Vicia ervilia*	Bitter vetch
	Lens culinaris	Lentil
	cf *Pisum sativum*	Common pea
	cf *Cicer* sp.	Chickpea
Fruit and nuts	*Ficus carica*	Fig
Wild flora	Polygonaceae	Knotweed family
	Chenopodium sp.	Goosefoot
	Fumaria sp.	Fumitory/Fumewort
	Leguminosae	Legume family
	Galium/Asperula sp.	Bedstraw/Woodruff
	Lolium sp.	Ryegrass
	Bromus sp.	Brome grass
	Graminae	Grass family
	Scirpus/Cyperus sp.	Club-rush/Sedge
	Carex sp.	True sedge

Tab. 10. Preliminary list of plant species/genera/families identified at Imvrou Pigadi.

more mainstream archaeobotanical studies. The increased presence of seeds of the Gramineae family may relate to the preparation of the clay. Such seeds were probably attached to plant stems used as clay admixtures for crafting pottery or other clay objects. A comparative study of the plant imprints on the kilns and other structures may help to further clarify these questions.

The analysis of the archaeobotanical assemblage is ongoing and includes the identification of the plant species present in the assemblage, and an understanding of their taphonomic history and role in nutrition, as tools or as construction materials. Comparison of the range of plant remains within the four trenches may help to further clarify issues related to the use of space, as well as providing a more holistic view of the contribution of plants in the economic and socio-cultural life of the site. Comparison of the Imvrou Pigadi archaeobotanical evidence with that from the nearby contemporary settlement of Koutroulou Magoula will significantly broaden our current understanding of the vegetational environment, along with its role within the Neolithic of Thessaly and Phthiotida.

Taphonomy of the faunal remains

Trenches 1, 2 and 2016/a produced a total of 6284 faunal remains, including six human bones.[5] Although the four leporid, 15 avian and 109 cervid (red deer) bones may have derived from wild species that were hunted (one amphibian and eight tortoise bones, possibly from intrusive vertebrates were also recovered), the bulk of the assemblage from all three phases was dominated by domestic animals (Fig. 20). According to the NISP counts,[6] domestic species make up 98% of the assemblage, including sheep/goat, pig, cattle and dog, while a donkey first phalanx is a later intrusion.

The species composition points to an agrarian way of life during the Neolithic in western Thessaly, and a pastoral economy based on sheep and goat herding, which was common in the region. The 1338 animal bones recovered from trench 3 were assigned to the same species.

Sheep and goat bones accounted for 81% of the complete assemblage. Although cluster analysis based on the limited morphological features does not clearly separate sheep and goats,[7] it appears that sheep were more common, with twice as many fragments as those of goats.

Table 11 provides an overview of where the bones were found within the trenches, and how their distribution is related to other features of the manufacturing complex. Bones recovered from features such as kilns, hearths, clay boxes and pots, that were attributed to cultural phase B, accounted for 50.15% (n=3152) of the faunal assemblage examined so far. From the sediments covering the kiln features and the deposits underlying the fire installations and attributed to cultural phase C, a total of 2838 bones and 294 fragments were recovered. In neither of these assemblages were any of the bones articulated.

Evidence regarding the state of preservation (degree of fragmentation, erosion, gnawing, burning) has been taken into account at both the contextual and individual levels, and has been assessed for all domestic species and red deer. It should be noted that the stages of burning visible on bones were classified by colour. Three categories were established to assess the impact of fire and the damage caused.[8] These

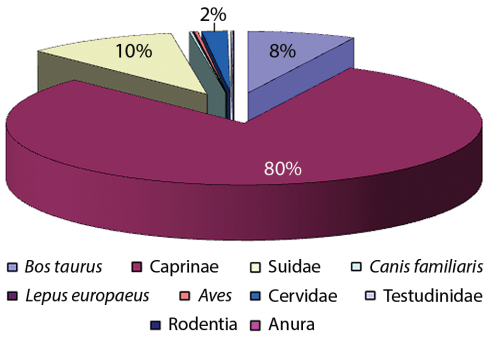

Fig. 20. Trenches 1, 2 and a/2016 ungulate and other minor species proportions based on NISP.

5 The recording per species, anatomical unit, fragment size, degree of preservation, age and sex (as well as the biometry in an electronic database) was carried out by Dimitris Filioglou and Kostas Nikolaou, supervised by Katerina Trantalidou and supported by the Institute for Aegean Prehistory.

6 Methods of quantification for the Imvrou Pigadi assemblage included Number of Identified Specimens (NISP), whole bone equivalents, Minimum Number of Individuals (MNI) and Minimum Number of Elements (MNE). But for the purpose of this paper, mainly to do with the taphonomy of the samples from the clay structures, only NISP is considered.

7 The distinction of sheep and goat was established based on the criteria of Joachim Boessneck (*1970*), Wietske Prumell and Hans-Jörg Frisch (*1986*), Melinda A. Zeder and Heather A. Lapham (*2010*) and Melinda A. Zeder and Suzanne E. Pilaar (*2010*).

8 The heating stages in bone have been described by Pat Shipman *et al.* (*1984*), Gilles Grévin *et al.* (*1990*), Paloma Vidal-Matutano *et al.* (*2019*), all with previous bibliography.

Taxonomic list: Phylum, Class or (Sub) Family		*Bos taurus*	*Ovis aries*	*Capra hircus*	Caprinae	Suidae	Sub-total domestic ungulates	Cervidae	Total ungulates	*Canis familiaris*	*Lepus europaeus*	*Aves*	Testudinidae	Rodentia	Anura	*Homo sapiens*	Total ungulates and others
Trench 2/ Kilns area	Deposits covering the structures	49	32	16	759	110	966	1	967	4	–	2	–	–	–	1	974
	Kilns area	57	43	14	595	106	815	59	874	–	1	2	–	–	–	2	879
	Ashy layers, Northern area	21	21	7	307	63	419	1	420	–	–	2	–	–	–	–	422
	Southern area	10	3	1	50	9	73	3	76	–	–	–	–	–	–	–	76
Total		**137**	**99**	**38**	**1711**	**288**	**2273**	**64**	**2337**	**4**	**1**	**6**	**–**	**–**	**–**	**3**	**2351**
Trench 1	Deposits covering the structures	108	62	17	1106	90	1383	5	1388	2	2	4	2	–	1	–	1399
	Structures	102	70	26	1388	128	1714	8	1722	6	1	5	5	2	–	3	1744
	Deposits under the structures	15	10	5	148	38	216	1	217	–	–	–	–	1	–	–	218
Total		**225**	**142**	**48**	**2642**	**256**	**3313**	**14**	**3327**	**8**	**3**	**9**	**7**	**3**	**1**	**3**	**3361**
Trench a/2016	Deposits covering the structures	55	21	13	290	83	462	2	464	–	1	–	1	–	–	–	465
	Bone accumulation I	43	1	2	11	11	68	–	–	–	–	–	–	–	–	–	68
	Bone accumulation II	2	–	–	6	2	10	–	–	–	–	–	–	–	–	–	10
	Pot 5, Eastern area	–	–	–	–	–	–	2	2	–	–	–	–	–	–	–	2
	S.W. edge of a Kiln	–	–	–	–	–	–	27	27	–	–	–	–	–	–	–	27
Total		**100**	**22**	**15**	**307**	**96**	**540**	**31**	**31**	**–**	**1**	**–**	**1**	**–**	**–**	**–**	**572**

Tab. 11. Spatial distribution of 6284 bone fragments recovered from the three trenches (By Filioglou and Nikolaou using NISP).

included moderate alteration (brown or intense orange), carbonisation at temperatures between 200 and 400°C (black) and calcination at temperatures greater than 600 degrees (grey or white). For example, red deer antlers tended to be highly altered in the area of the kilns and clay boxes, whereas light alteration was more common amongst suid bones than other species. The following are some general comments regarding the assemblage:

❶ The skeletal part representation within the bone assemblage was almost complete, even though phalanges were rare (Figs. 21 and 22). When the animals were slaughtered, the phalanges may have remained attached to the hide and discarded later during its processing;

❷ There is little evidence for any significant variation in the pattern of body part representation between phases for any of the domestic species;

❸ There is spatial variation in the preservation of the assemblages across the site, with bones in trenches 1 and 2 relatively more affected by fire than those in trench 3. In contrast, the bones in trench 3 were more coated by sediment than those found in the firing areas;

❹ Unburned bones were recovered from the layers above the clay structures, but also from the layers incorporating the structures;

❺ High degrees of fragmentation and pieces of less than 3cm were common. Approximately 15% of the Caprinae sub-family could not be identified to the level of major limb bone, humerus, radius, femur, tibia or metapodials;

❻ There was a wide range of variability in colour, related not only to burning time but also the histological structure of each bone;

❼ Hyperfragmentation (<1–2cm) and total thermoalteration, as seen in heavily burnt bones from altars and special deposit pits of Classical and Hellenistic antiquity (*Trantalidou 2013.Fig. 10; in press*), or where the bone itself was burnt (*Vidal-Maturano* et al. *2019.Fig. 11*), has not been full attested at Imvrou Pigadi;

❽ A working hypotheses is that much of the bone was used as fuel. Those fragments that do not exhibit visible traces of burning were either due to be used in the kilns or were in the sediments that intentionally covered the structures when they were no longer in use. More detailed spatial analysis using GIS is required;

❾ Bone burn time in those features was either limited or the level of technology in the Middle Neolithic did not permit them to reach much higher temperatures. Therefore, the destruction of all bones and the traces of combustion are not visible. Woody taxa should also be examined.

Discussion and conclusions

Excavations since the 1950s in western and eastern Thessaly, as well as elsewhere, never produced any evidence for the existence of early organised kiln workshops, with the firing of vessel in open fires widely accepted until recently (*Rondiri, Kalogianni 2018*). Several experimental programmes were initiated in order to investigate how pottery was fired (*Vitelli 1994; Rondiri, Kalogianni 2018*). Based on the observation of sherds, Karen D. Vitelli (*1997*) proposed several hypothetical designs for kilns that could have been used during the 6th millennium BC, which are quite close to those identified at Imvrou Pigadi. Her suggestion that such installations should probably be located far from the settlement is also reasonable. The excavations at Imvrou Pigadi and the structures themselves have convinced us regarding the function of the site as a kiln workshop. When some years later the site of Rizava was discovered a few kilometres to the west on the plain of Karditsa (*Krachtopoulou* et al. *2018*), as well as more recently the neighbouring site of Koutroulou (unpublished, *Kyparissi* et al. *2022 forthcoming*), our suggestion regarding the use of pottery kilns since the beginning of the Middle Neolithic in Thessaly was confirmed. The complex of ceramic kilns at Imvrou Pigadi appears to have been in operation almost from the beginning of the use of the western edge of the site, although the construction of the provincial road has obscured its original boundaries. When the kilns in trench 2 ceased operation (phase B2), the area appears to have been buried beneath a layer of burnt deposits, upon which, on the basis of the finds, activities continued although with a possible hiatus. The same appears to be the case in trench 1, where the deposits above the kiln structures were again covered with a layer of clay, before being reused for domestic activities rather than as a workshop. The workshop areas, albeit at different elevations, appear to have been used in parallel, as their dates are similar. Since they were not spatially overlapping, they could have been operated simultaneously, possibly for the firing of different objects or controlled by different groups of craftsmen.

Coring as well as the excavations in trenches 1 and 2 have shown that the workshop area would have extended even further towards the north and south of trench 2. This was also indicated by the geophysical survey, especially in the southwestern area of site and towards the west, now under the public road. Such an extensive workshop in operation at

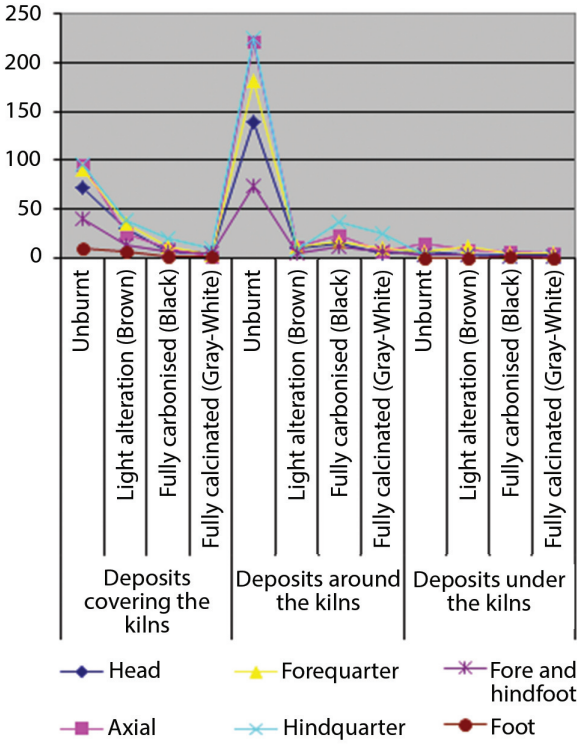

Fig. 21. Burnt and unburnt sheep and goat bone elements from trench 1.

one of the largest magoula sites in the region suggests that it probably catered for the pottery needs of other settlements as well. This is supported by the lack of other similar workshop complexes at sites nearby, although others would be expected at greater distances. It is also possible that different types of vessels were being fired in the various settlements, which were then redistributed amongst them. Such a scenario may be implied by the newly discovered complex at the site of Rizava, located around 30km to the west on the plain of Karditsa. But we also need to be mindful of the recent discovery of a smaller complex of kilns at nearby Koutroulou Magoula, just 3km away, which could potentially weaken the suggested model of longer distance exchange. The situation will hopefully become clearer when the excavations at Koutroulou are completed and we can compare the kiln complexes from the two sites, both chronologically and in terms of the finds. But it is also possible that due to its size and importance, Koutroulou may have been self-sufficient for at least some of its pottery needs with its own kilns.

The abundance of obsidian at Imvrou Pigadi is another striking aspect of the site, where the material accounted for 63% of all chipped stone recovered, contradicting the established model for western Thessaly, where chocolate flint from the Pindos is

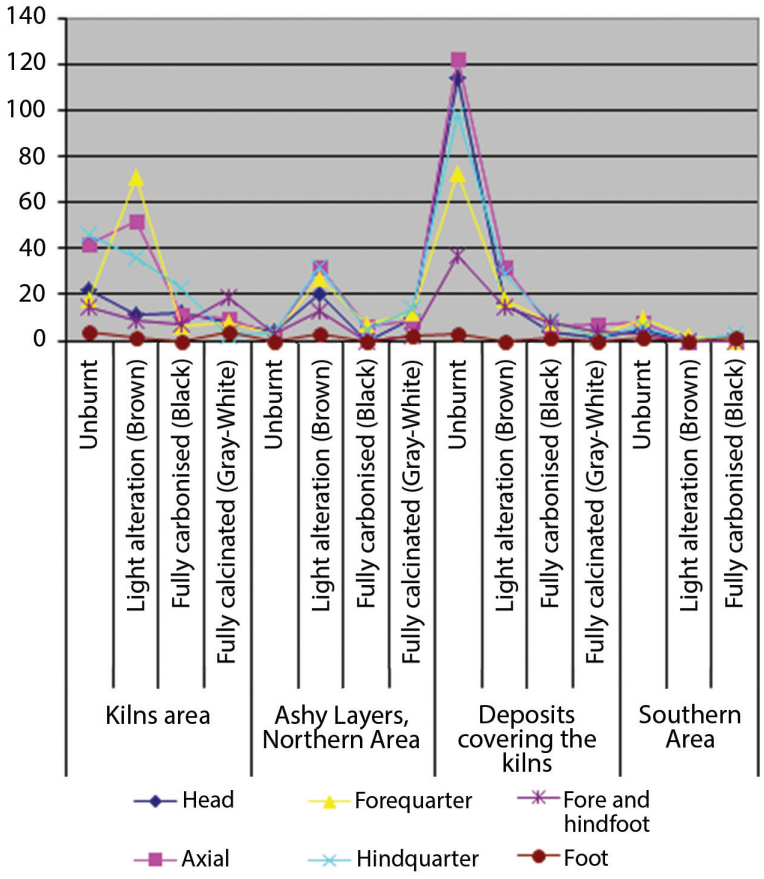

Fig. 22. Burnt and unburnt sheep and goat bone elements from trench 2.

predominant. However, given that similar proportions of obsidian have also been reported from nearby Koutroulou Magoula, it would appear that both sites were located along the route between eastern and western Thessaly on the one hand, but also towards Phthiotida to the south. On the other hand (*Perlès 2022 in press*), it would appear that the materials that arrived here, such as obsidian, were not widespread in western Thessaly. According to Karimali (*2022.195*), these two positions are characterised as atypical.

The pottery from Imvrou Pigadi presents the same decorative elements as the rest of Thessaly, indicating a wide network of communication and exchange. The presence of figurines, jewellery, stone grinding tools and millstones, as well as animal bones and fruit, is probably related to the wider use of the area around the magoula, which likely constituted a regular settlement, something that may be established in the future if the excavations are extended.

The faunal remains were dominated by sheep and goat bones, and reflect an agrarian way of life in Neolithic western Thessaly and a pastoral economy which is common in the geographical region. The picture in trench 3 was similar, while the bones in trenches 1 and 2 were relatively more affected by fire, probably related to differences in the use of space, leading to the working hypothesis that much of the bone recovered was used as fuel.

The presence of cereals and pulses in the archaeobotanical evidence points towards cultivation, while the broad range of wild plants may relate to the preparation of clay. The increased presence of seeds belonging to the Gramineae family were probably attached to plant stems used as clay admixtures for crafting pottery, other objects and the clay ovens themselves.

Because of its size, but mainly the systematic use of kilns, it would appear that the pottery workshops at Imvrou Pigadi operated as a production hub during the Middle Neolithic on the route between eastern and western Thessaly on the one hand, and Phtiotida via the Sperchios Valley and southern Greece on the other. It appears to have played a decisive role in the circulation of trade goods and the exchange of ceramic vessels and other aesthetic objects, which because of its position were promoted throughout western Thessaly, but also in the eastern part of the region and in settlements further south.

AUTHORS' CONTRIBUTON

Nina Kyparissi-Apostolika: Introduction, The site and the excavations, Chronology, Other small finds, Discussion and conclusions; Yorgos Facorellis, Chronology; Dimitris Roussos: Coring; Evita Kalogiropoulou and Dimitris Roussos: The clay-based structures, their typology and pyrotechnological characteristics; Niki Saridaki: The pottery evidence; Odysseas Metaxas: The chipped stone assemblage; Georgia Kotzamani: The archaeobotanical evidence; Katerina Trantalidou: Taphonomy of the faunal remains.

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Pottery firing in the Early Iron Age in western Slovenia

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ABSTRACT – *The article discusses the possible use of kilns for the firing of pottery in western Slovenia during the Early Iron Age. In the absence of archaeologically attested kilns, their use in this area is studied based on indirect factors,* i.e. *the analysis of the vessel firing technique, and with the help of experiments from the field of experimental archaeology. The article strives to determine the reasons for the poor state of preservation of the kilns in the area in question. Samples from archaeological experiments and archaeological pottery were subjected to AMS measurements, petrographic and mineralogical analyses (X-ray diffraction), which revealed the importance of considering the soaking time as a criterion for observing the firing processes and use of single-chamber kilns for the firing of pottery, even if they have not yet been discovered.*

KEY WORDS – *pottery; firing process; experimental archaeology; pottery kiln; ceramic technology; apparent magnetic susceptibility AMS; X-ray diffraction XRD; Early Iron Age; Kras; Slovenia*

Žganje lončenine v starejši železni dobi v zahodni Sloveniji

IZVLEČEK – *V članku obravnavamo potencialno rabo peči za žganje keramike v zahodni Sloveniji v starejši železni dobi. Ker arheološko še niso bile izkopane, je njihova uporaba predvidena na podlagi posrednih kazalnikov, kot so način žganja in poskusi s področja arheologije poskusov. Namen raziskave je prepoznati razloge za slabo ohranjenost peči na tem območju. Na vzorcih, ki smo jih pridobili iz arheoloških poskusov in na arheološki keramiki, smo merili navidezno magnetno susceptibilnost, izvedli petrografske in mineraloške (rentgenska difrakcija) analize. Rezultati teh analiz so pokazali na pomembnost upoštevanja časa žganja kot merila pri opazovanju žgalnega procesa in uporabi enoprostornih peči za žganje keramike, čeprav še niso bile odkrite.*

KLJUČNE BESEDE – *keramika; proces žganja; arheologija poskusov; peč za žganje keramike; tehnologija; navidezna magnetna susceptibilnost; rentgenska difrakcija XRD, starejša železna doba; Kras; Slovenija*

Introduction

How was pottery fired in the Early Iron Age in what is today western Slovenia? Can we assume the use of kilns despite their absence? On the territory of present-day Italy, two-part updraft kilns with a separate fireplace and firing chamber were known in this period, while on the territory of Slovenia they appear no sooner than in the Late Iron Age. We assume that the preservation of such structures in the discussed areas depends on various factors, so we will show the possible reasons for the poor preservation of these based on the results of experimental archaeology. Through macro- and microscopic analyses of

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the pottery and samples from archaeological experiments, we will try to reveal the features of the pottery associated with the firing process, which will indirectly help us identify structures for the firing of pottery.

Firing is one of the most important steps in pottery production, as it involves the transformation of clay into ceramics. Due to the complexity of the production process of pottery vessels, from the raw material to the final product, the concept of the ceramic *chaîne opératoire* has recently developed in ceramic analysis (*Lemonnier 1993; Roux 2016.104–107*). Based on such observations, we try to identify technological traditions and patterns of certain technical traits (*cf. Roux 2016.104, 112*). By including the ceramic *chaîne opératoire* approach, ceramic experimental archaeology has gained a more solid methodology (*Jeffra 2015. 141*), but only if when the principle of so-called controlled comparison is considered (*Roux 2016. 7*). Until the advent of experimental archaeology and scientific analyses, the process of pottery firing was actually the least known technological process in the ceramic *chaîne opératoire* (*Rado 1988.92*). We will attempt to answer the question of what type of structures were used for firing pottery in western Slovenia in the Early Iron Age by integrating data from the macroscopic and microscopic analyses of the pottery mass and firing technology. The data will be acquired from experimental archaeology, measurements of apparent magnetic susceptibility (AMS), and with the results of mineralogical analyses (X-ray diffraction).

The firing process

In the past, people had to rely on personal experience with firing, which in practice probably meant conducting numerous successful and unsuccessful experiments, as evidenced by the considerable overfired vessel waste at archaeological sites (*Cuomo di Caprio 1985.130*). Today, laboratory and archaeological experiments are carried out, adding significantly to the knowledge and, above all, to the understanding of technological processes, which are usually different under controlled laboratory conditions (*cf. Thér 2014.96*).

After clay transforms into ceramics during the firing process (*Cuomo di Caprio 1985.125*), a series of chemical and physical reactions occur affecting the hardness, permeability, porosity, and mineral composition of the final product. The products become impermeable, change colour, and lustre (*Heimann 1978–1979.79, 82*), and become hard and resistant to decay (*Rice 2005.55, 80*). The colour change is related to the presence or absence of iron minerals (chlorites, micas, Fe-oxides/hydroxides, sulphides) in the clay. In the are discussed in this study the clays are very rich in iron, which usually causes the vessels to turn red (oxidation atmosphere) or grey and black (reduction atmosphere) (*cf. Maritan 2018. 206*). The colour can also be affected by the presence of organic material, which converts to carbon and oxidizes into CO_2 in the presence of sufficient oxygen. This change occurs at a temperature of about 800°C and can be recognized by a change in colour (grey/dark grey when carbon is present and cream/reddish when carbon is oxidized) (*Gliozzo 2020.26*).

During firing, structural changes also occur in the minerals in the clay (*Cuomo di Caprio 1985.130; Levi 2010.112*). The thermal stability of the mineral phase and the changes induced by heat depend on numerous factors, such as grain size, the mineralogical and chemical composition of inclusions and temper, presence of aplastic inclusions, presence of organic material, position in the vessel, the position of the vessel in the kiln, the soaking time, and cooling (*Gliozzo 2020.5*).

What changes occur during the firing process and which of them are relevant for the pottery of the discussed area? Hydration begins at different temperatures, depending on the heating and the type of clay minerals (*e.g.*, illite 300–600°C), but the mixing of clays can lower it (*Rice 2005.87–88*). Carbon oxidation of carbon starts at 200°C and burns out completely between 600 and 750°C or at least just below 800°C (*Cuomo di Caprio 1985.131; Levi 2010. 121; Gliozzo 2020.26*). Experiments showed that the main loss of organic material (the use of barley straw) in daub and kilns occurs between 200 and 300°C, with the final loss at about 400°C (*Macphail, Goldberg 2018.235*). Between 675 and 870°C, calcite decomposes completely into calcium oxide, with cell volume decreasing and crystal size increasing (*Gliozzo 2020.6*). Above 800°C, complex aluminosilicates form and the phase of sintering begins (*Levi 2010.121*), which is lower for carbonate clay (around 800°C). Hence, we cannot develop a unified phase diagram for the firing process (*Gliozzo 2020.5*). The presence of calcium carbonate contributes to a lower sintering temperature because lime acts as a flux, causing vessels with admixed calcium carbonate to sinter faster (*Maggetti* et al. *1984; Shoval 2016.12*). In highly processed deposits, a fired mineral is present as rubefied mineral inclusions ranging in size

from silt to sand-size. The presence of these materials provides increased magnetic susceptibility, whereas iron-free minerals are not rubefied and therefore magnetic susceptibility is naturally high (*Macphail, Goldberg 2018.235*).

Iron oxides were frequently used for coatings, especially for the so-called *ceramica zonata*, which is typical for the Early Iron Age in a large area, ranging from northern Italy (Este, Padua) to Slovenia. Examples of so-called ceramic *situlae* from Slovenia are mostly considered imports (*cf. Grahek 2018. 315*). Red slips are also typical of other vessel types (*e.g.*, Dolenjska region in south-eastern Slovenia; *Dular 1982.90*). Iron oxide haematite (Fe_2O_3) provides a red or reddish colour, while magnetite (Fe_3O_4) provides grey, blue, green, and grey-brown colours, and in the reduction, black (*Heimann 1978–1979. 86; Rice 2005.334–336*).

The firing atmosphere controls the partial pressure of oxygen, which is higher in the oxidizing atmosphere. By leading the firing, we change the firing phases (*Heimann 1978–1979.86*). In an oxidizing atmosphere, complete firing occurs. We need dry firewood and an air supply to achieve the combustion of organic matter and the decomposition of sulfides if the latter is present. In a reduction atmosphere, incomplete firing happens. We close the air supply and pile organic material into the kiln (*e.g.*, horse hooves, straw, *etc.*), which may be slightly moist (*Cuomo di Caprio 1985.126, 131*).

In prehistory, different structures for firing pottery were known. The basic division is into firing in the open (bonfire) and firing in a kiln. In a bonfire, the maximum temperature is reached quickly (approx. 10–50 minutes, usually 20–30 minutes), while firing in a kiln takes longer (approx. 60 minutes to 11–12 hours). In a bonfire, the soaking time at maximum temperature is shorter (a few minutes) than in a kiln (up to 30 minutes). Oxidative and reductive atmospheres can be achieved in both, yet the latter is much more controlled in two-chamber kilns with a perforated floor, especially the exchange. Cooling takes less time in a bonfire (a few minutes to 1 hour), while it is slower in the kiln (1–4 days), and firing in a bonfire also takes less time than firing in the kiln (*Gliozzo 2020.2–3*).

Any natural clay type can be fired at low temperatures, *i.e.* below 800°C, but the lowest possible temperature for firing pottery is 500°C (*Rye 1981. 16, 96*). The data shows that prehistoric pottery was mostly fired between 550 and 650°C or at the most up to 750–850°C. Analyses from the field of experimental archaeology generally reveal that temperatures of 950°C and even 1100°C could be reached in the kilns known in the Neolithic (*Kovárník 1999. 315–317*). Nevertheless, it was found that the soaking time is of greater importance than the maximum firing temperature (*Gosselain 1992.244, Fig. 1*). Furthermore, it was also found that the temperature of the core of the vessel burned in a bonfire is not unified and that a temperature difference occurs between the outer surface and the fracture up to 220°C. The latter was also confirmed in the example of vessels fired in a kiln (*Maggetti* et al. *2011; Gliozzo 2020.4*). Consequently, it is necessary to examine the question of which part of the pottery production is associated with a particular firing structure (*Thér 2014.78*) or which forms or types of vessels were fired in which structure (*Gliozzo 2020. 27*). Based on 72 archaeological experiments, Richard Thér (*2014*) showed that there are no differences between firing structures at temperatures up to 1050°C when thermal profiles are observed and that the firing method is more important than the firing structure (*Thér 2014.79–80, 93*). Later, he tried to find out if it was possible to distinguish between products fired in a bonfire and those fired in a kiln by observing the thermal gradient of maximum temperature (XRD analyses) in the core of the vessel and in the outer and inner surfaces. He discovered that the difference between the maximum temperature between the outer surface and the core was 100–200°C when fired in a bonfire, and between 0 and 50°C when fired in a kiln (*Thér* et al. *2018.1144–1145, 1169*). This means that we have finally found a way to distinguish firing in bonfire from firing in a kiln.

Archaeological background

In general, only a few pottery firing structures from the Bronze and Iron Ages have been found in the area of present-day Slovenia. Until the end of the Early Iron Age, only single-chamber kilns are known (*e.g.*, Oloris near Dolnji Lakoš from the Late Bronze Age, Dobrava near Otočec (*Horvat Šavel 1988–1989. 130–131; Dular* et al. *2002.37, T. 24–25; Josipović* et al. *2015.16, Figs. 11–12*). While a two-chamber kiln with a perforated floor was found at the Late Iron Age site Hajdina at Ptuj (*Tomanič Jevremov, Guštin 1996.271, Fig. 4*). Generally, two-chamber kilns were used much earlier, as they appear individually in Italy no later than in the Middle Bronze Age (*Bronzo recente*), while their use increases in

the Early Iron Age[1] (*Levi 2010.117*). To date, no firing structures have been found in western Slovenia. All the consumptions in the literature are still based on indirect data, on the macroscopic analysis of the technology of pottery firing from three hillforts in the Kras, Tabor near Vrabče, Tomaj, and Štanjel (Fig. 1). In addition to stratigraphic data, also radiocarbon dates are also available (*Vinazza 2021.430–433, Fig. 5*). The Tabor site near Vrabče belongs to the transition from Late Bronze to Early Iron Age (Phase 1; 11.–10. cent. BC) and Early Iron Age (Phase 2; 8.–7. cent. BC). The Tomaj site belongs to the Early Iron Age (6.–5. cent. BC) and Štanjel belongs to the end of Early Iron Age (6th and 5th cent. BC). The macroscopic analysis indicated that at the end of the Late Bronze Age (Ha A2/B1) the majority of pottery was fired in a reduction atmosphere (*e.g.*, Tabor near Vrabče 38.2%). In the 8th and 7th cent. BC (Ha C0–C2) the ratio begins to change as less and less reductive firing take place, only 4.8% at Tabor near Vrabče and 25% at Tomaj. This trend continues until the end of the Early Iron Age, as shown by the analysis of pottery from Štanjel (7.1–23.9%). It should be emphasized that incomplete oxidation firing predominates throughout at all the sites, with the proportion of oxidation firing increasing only at the end of the Early Iron Age in the case of Štanjel (38.7%) (*ibid*. Tab. 3). Changes are also observed in the preparation of the pottery paste. The macroscopic analysis of pottery mass confirms the findings in the wider area of north-eastern Italy and western Slovenia, as a temper of calcite prevails at the end of the Early Iron Age, while pottery is more frequently fired in oxidation atmosphere (*Saracino 2014.104–122, 131–132; Grahek 2018.311; cf. Vinazza 2021.433, Fig. 1*).

Certain sites in Kras and in the Posočje region[2] revealed individual examples of the so-called red-black painted pottery (Este style, Ita. *ceramica zonata*). Case analyses from Posočje region, from Most na Soči, showed the presence of iron and manganese to achieve the red and black colour of coating on the pottery (*Grahek 2018.313–314*). This final colour effect is the result of the so-called *three-stage firing* (ORO), in which oxidation and reduction firing



Fig. 1. Sites mentioned in the text (© Google Earth Pro).

1 Ponte San Marco (*Poggiani Keller 1994.76*), Forcello di Bagnolo S. Vito (*Rapi* et al. *2019.107*), Montedoro di Scapezzano, Matelica (Macerata), Marche, Cesena, Foro Annonario (*Gasparini, Miari 2017.24*), Padova, Ex Brolo (*Iaia, Moroni Lanfredini 2009.65, 68, 70*).

2 Repentabor (7th and 6th cent. BC) (*Maselli Scotti 1978–1981.Fig. 9.1*); Repnič from the 7th and 6th cent. BC (*Maselli Scotti 1983.T. 54, 214*), Štanjel (*Vinazza 2011.T. 9.103*), and Most na Soči (*Grahek, Košir 2018.315*).

atmospheres exchange (*cf. Aloupi-Siotis 2020.3, 5*). This is made possible by the two-chamber kilns with a separated fireplace and firing parts, which have been already mentioned several times before. One of the most important parts of such kilns is the perforated floor. When determining this type of kilns based on the perforated floor, we need to be careful since such perforated floors were also used in, for example, salt extraction in the area under study in this work.[3] Such a ceramic *situla* was also found at the Štanjel site (*Vinazza 2011.T. 9. 103*), and is part of the present study.

Methods and sampling

For the present study, which is first of this kind in the studied area, we analysed 18 samples. The archaeological pottery comes from two hillforts, Tabor near Vrabče and Štanjel (for more details, see *Vinazza 2021.422–425*). Other samples were produced during archaeological experiments. Besides experimental archaeology, we also carried out additional analysis, such as AMS measurements, ceramic petrography analysis, and X-ray diffraction analysis (see Tab. 1).

We conducted experiments on the construction and use of a single-chamber kiln in order to better understand why the remains of kilns are so poorly preserved in the archaeological record in the studied area, and to get samples for observing changes in material under different temperatures. The kiln was built on the model of a Late Bronze Age kiln from the Oloris site near Dolnji Lakoš (*Horvat Šavel 1988–1989.130–131*). We were thus able to observe its manufacture, material, construction, and use during firing, as well as its decay.

Clay,[4] straw, and hazel branches were used for the construction of the kiln (16.6.2020). We prepared the mixture of clay, water, and straw (40%). The bottom of the 10cm deep pit was first covered with a clay mixture. After that, a construction from hazel branches, which was covered on the outside with clay strips of 20x15x5cm, was built. Seven people built the kiln in 5 hours (the preparation of the material and the construction). After 4 days, the kiln was dried by burning spruce chips (we used up 12kg), which took 6 hours and 30 minutes. After that, the kiln was ready for pottery firing.

The firing of the pottery took place after two months (28.8.2020). The kiln was loaded with 57 vessels that we formed from different local clays.[5] Two thermoelements[6] were installed onto the kiln, one along the kiln wall and the other in the centre, just below the vessels. We wanted to understand if there was any change in temperature in the kiln during firing.

To obtain different types of data and their possible application to the archaeological remains, we measured the AMS of the kiln.[7]

The magnetic susceptibility of the ground[8] or sediment is determined by the amount of magnetic minerals present. During burning, the magnetic susceptibility increases because iron minerals are bound. If the ground or the sediment does not contain iron minerals, the magnetic susceptibility is not high. The iron content depends on the geological background (*Goldberg, Macphail 2006.350–351*; see also *Mušič 1999.363*). If magnetite is present in the clay, magnetic susceptibility is naturally high (*Macphail, Goldberg 2018.236*). Measurements were taken in the laboratory on soaked clay (the Renče clay) (mixed with water and straw: 0.850) from which the kiln was built, on samples from the kiln after drying, and on samples from the kiln after firing (Fig. 3). The values given are average values.[9]

Clay from Renče that was used for building the kiln was also fired in a controlled atmosphere. We have

3 A perforated floor from the Ellerji hillfort has been interpreted several times before as the remains of salt production (*Lonza 1981. T. 44–45; Zendron 2018*), while the remains of a perforated floor from the Monkodonja site in Istria were among the earliest in the wider area (Early and Middle Bronze Age) (*Mihovilić 2020.36–39, Fig. 31*). This means that they appear significantly earlier than in the entire Italic peninsula, which indicates the supra-regional role of Monkodonja.

4 The Renče deposit: GKY 396454, GKX 83339.

5 Griže: GKY 417619, GKX 69497; Veliki Dul: GKY 411812, GKX 70871; Lukovica: GKY 476504, GKX 112322, and Renče: GKY 396454, GKX 83339.

6 Thermoelement type MTC500 with a Ni-Kr-Ni tip.

7 The Kappameter KT-7 (GF Instruments) instrument was used.

8 Values of AMS were measured on various samples of clays and present the results that do not enable simplified conclusions, since the values range from 0.1 to $8 \cdot 10^{-3}$SI. Location near Tupelče (GKY 407902, GKX 73627): clay to $6–8 \cdot 10^{-3}$SI; Vrabče (GKY 409555, GKX 77491): clay $0.063–0.207 \cdot 10^{-3}$SI; Veliki Dul (GKY 409555, GKX 77491): $0.532–0.666 \cdot 10^{-3}$SI; Ostri vrh (GKY 409555, GKX 77491): $0.766–0.966 \cdot 10^{-3}$SI.

9 Three measurements were taken for every point and the average value was calculated.

Sample ID	Petrolab ID	Source	Description	Clay	Add informations	Manipulation	Firing	Method
Sample 1	2020-6	Archaeological pottery, site Štanjel	Neck of the pot	Unknown	US 52	0	0	Macroscopic technological analysis; XRD analysis
Sample 2		Experiment	Rim of the bowl	Renče		Added water	670 °C	Arch. experiment; ceramic petrography analysis; XRD analysis
Sample 3	2022-3	Experiment	Bottom of the kiln	Renče		Added water and straw	670 °C	Arch. experiment macroscopic technological analysis; XRD
Sample 4	2021-24	Experiment	Wall of the kiln	Renče		Added water and straw	670 °C	Arch. experiment; ceramic petrography analysis; XRD analysis
Sample 5		Experiment	Chimney of the kiln	Renče		Added water and straw	670 °C	Arch. experiment; macroscopic technological analysis; XRD
Sample 6		Experiment	cube	Renče		Added water	600 °C	Arch. experiment; macroscopic technologigcal analysis; XRD
Sample 7		Experiment	cube	Renče		Added water	800 °C	Arch. experiment; macroscopic technologigcal analysis; XRD
Sample 8		Clay	No manipulation	Renče		0	0	Arch. experiment; macroscopic technological analysis; XRD
Sample 9	2020-10	Archaeological pottery, site Štanjel	Neck of the pot	Unknown	US 52	0	0	Macroscopic technological analysis; XRD analysis
Sample 10	2020-10	Archaeological pottery, site Štanjel	Neck of the pot	Unknown	US 52	0	0	Macroscopic technological analysis; XRD analysis
Sample 11	2020-10	Archaeological pottery, site Štanjel	Neck of the pot	Unknown	US 52	0	0	Macroscopic technological analysis; XRD analysis
Sample 12	2022-2	Experiment	Rim of the bowl	Renče		Added water and calcite	670 °C	Arch. experiment; macroscopic technological analysis; XRD
Sample 13		Experiment	No manipulation	Renče		Added water and straw	670 °C	Arch. experiment; macroscopic technological analysis; XRD
Sample 14	2022-1	Archaeological pottery, site Štanjel	Bottom of ceramic situla	Unknown	US 28	0	0	Macroscopic technological analysis; ceramic petrography analysis
Sample 15	2022-4	Archaeological pottery, site Štanjel	Silos	Unknown	US 28	0	0	Macroscopic technological analysis; ceramic petrography analysis
Sample 16	2020-18	Clay	No manipulation	Štanjel		0		Macroscopic technological analysis; ceramic petrography analysis
Sample 17	2020-1	Archaeological pottery, siteTabor near Vrabče	Rim of the pot	Tabor near Vrabče	US 18	0	0	Macroscopic technological analysis; ceramic petrography analysis
Sample 18	2020-12	Archaeological pottery, siteTabor near Vrabče	Rim of the pot	Tabor near Vrabče	US 9	0	0	Macroscopic technological analysis; ceramic petrography analysis

Tab. 1. Samples 1–12 are part of the present study.

prepared two samples (Tab. 1.6, 7) by adding water to the clay and firing them at the temperatures of 600 and 800°C in an electrically operated kiln (70kW, with Shimaden FP93 programme controller).

For ceramic petrography analysis, we chose samples on the basis on the results from the macroscopic technology analysis. We chose this method for various reasons. We wanted to observe changes in pottery recipes between Late Bronze and Early Iron Ages at the sites Tabor near Vrabče and Štanjel, changes during different temperature stages comparing archaeological material and material from our archaeological experiments (see *Cultrone* et al. *2001.629*), and compare pottery paste with local clays (*Quinn 2015*) in the case of the Štanjel site. The selected samples (Tab. 1) were prepared as polished thin sections, 30 microns thick, mounted on glass slides and analysed under the polarizing light microscope, Zeiss Axiocam 305 colour, using standardized descriptions (*Quinn 2015; 2022. 98–124*).

X-ray diffraction is used to characterize archaeological pottery in terms of the minerals present and their relative abundance and allows the characterization of minerals that cannot be recognized in thin-section petrography, such as clay minerals or new phases formed during firing. The XRD analysis of minerals present in pottery can help identify the temperature interval at which pottery was fired, as certain minerals are indicators of changes that occur during the firing process – examples include haematite, magnetite, cristobalite, mullite, calcite, montmorillonite, illite, vermiculite, and feldspars (*Quinn, Benzonelli 2018.2; Amicone* et al. *2020.526–527*).

The mineral composition of the pottery samples was determined using a Philips PW3710 X-ray diffractometer. It was recorded at a voltage of 40kV and a current of 30mA in the range from 3° to 70° 2θ at a speed of 3°/min. The wavelength of the Cu Kα X-ray wavelength was 1.5460Å. A secondary graphite monochromator and a proportional counter were used. The detection limit for minerals was between 0.5 and 3%. The Rietveld method was used to quantify the mineral phases. Diffractograms of the recorded samples were processed using the computer program X'Pert HighScore Plus 4.8v and the PAN-ICSD database.

Results

In carrying out the archaeological experiments, firing in the kiln took a total of 10 hours. First, we started heating slowly at the entrance and only began to increase the temperatures after four hours (Fig. 2). Initially, the temperature along the kiln wall increased more rapidly than in the centre, while from 500°C onward the temperature in the centre started rising more rapidly than along the wall. We were burning fuel in the front and to the left and right of the vessels. The drop in the temperature along the kiln wall (Fig. 2.15, 35) is the result of clearing the charcoal from the kiln. During firing up to 0.75m^3 of beech wood was burned and a temperature of 670°C was reached. The soaking time at this temperature lasted 30 minutes. The total time of the firing process was 10 hours. After this time, we did not measure the temperature further. On the third day (31.8.2020), we opened the kiln and took out 56 vessels (98% of them were successfully fired, unbroken). To date, some of the vessels have been used for cooking over an open fire seven times and are still undamaged.

The AMS measurement results show that temperatures that would affect the increased AMS are not reached during drying. The change occurs at higher temperatures, but mainly at the areas where the kiln surface was in direct contact with the fire. We thus have the highest values at locations where the fire was burning (9.524·10^{-3}SI, 12.54·10^{-3}SI, and 17.91·10^{-3}SI), and on the inside of the chimney (15.21·10^{-3}SI) where the fire directly touched the kiln. High values were also recorded on the inner wall of the kiln (5.852·10^{-3}SI) and on the outer side in the centre of the kiln (7.316·10^{-3}SI), where the kiln wall was thin. From this part towards the ground, the values decrease, while at the same time the kiln walls were significantly thicker towards the bottom.

The next goal of our study was the observation of the kiln's decay. The kiln was covered over a month after firing and then we left it in the open air, under the sun, rain, and snow. The dome collapsed half a year later, on 9.12.2020. The floor of the kiln was still as hard as when the firing was finished and covered with the ruins of the dome. Pieces of the dome and kiln walls were still very compact. The kiln walls were preserved only at the edge of the kiln. Over the next six months (Fig. 4.A), the most compact parts of the kiln softened and gradually began to merge into the depositional matrix. On 31.1.2022 (Fig. 4.B), parts of the kiln wall were still standing, but softened, while the kiln floor was still equally as hard as it had been six months earlier. Major visible changes occurred over the next five months (Fig. 4.C). The preserved walls weakened,

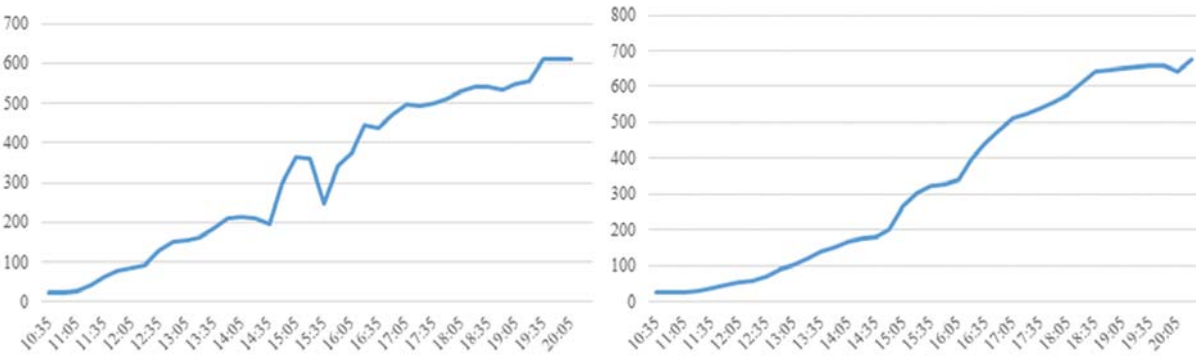


Fig. 2. Measurements of temperature in the kiln during firing. Left: along the wall, right: at the bottom of the kiln, under the vessels.

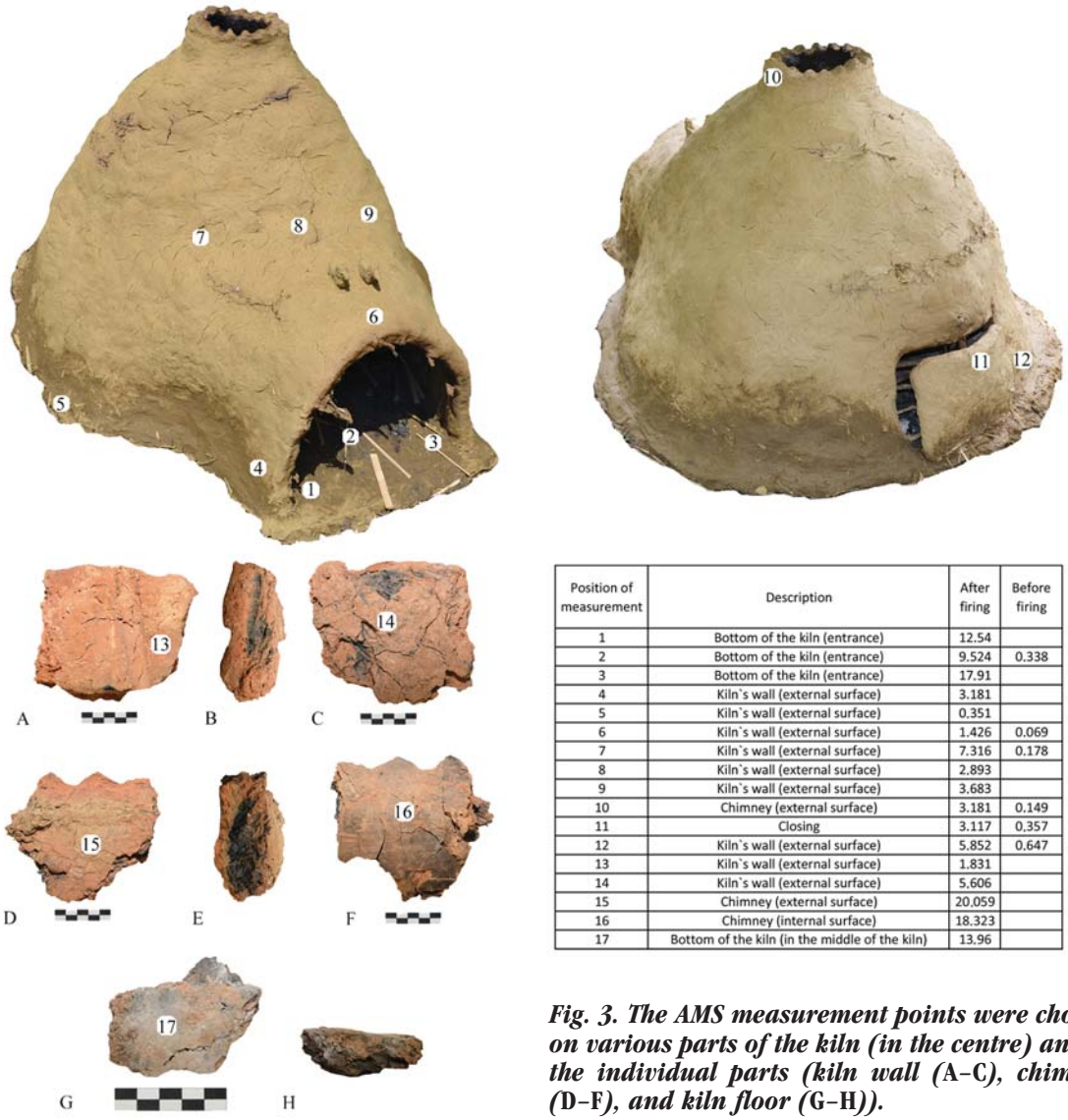
and the outer and inner edges were only sporadically preserved. Most of the dome turned into the depositional matrix, while the underlying slab was also preserved, being protected by the material. Today (October 2022) more and the more depositional matrix is forming, and the kiln floor is still hard as it was before.

The analysis of pottery thin sections from Tabor near Vrabče shows that at the transition to the Late Bronze Age grog (20%) predominates as a temper. We could detect different types of grog in one vessel (20%); there is some organic temper (2%) and some planar voids. Individual calcite (1%) and quartz (5%) grains we understand as inclusions (Fig. 6.1; Tab. 1.17). Slightly later, in the 8th and 7th cent. BC (Phase 2), the pottery paste changes (Fig. 6.2; Tab. 1.18) and calcite predominates as the only temper (30%). There are a lot of visible voids and some small parts of organic matter (>1%). Sharp calcite edges (rhombohedral cleavage) indicate intentional crushing (Fig. 6.2–3). Calcite also predominates as a temper in the final stage of the Early Iron Age, in the 6th and 5th cent. BC (40%), as pottery from Štanjel shows (Tab. 1.1). The difference is visible in the size of the calcite temper. The grains are bigger in pastes from the 8th and 7th cent. BC than in those from the 6th and 5th cent. BC. In the later period there is a finer temper of calcite. The temper is still poorly sorted, but in comparison with older material there are no voids.

The kiln wall pottery thin section (Fig. 5) corresponds to the basic characteristics of such objects found at archaeological sites. Here we have in mind the main micromorphological features of mudbricks, such as the presence of organic elongated fragments and randomly oriented channels and voids, reflecting the addition of straw into the otherwise very compact structure during the preparation (*cf. Friesem* et al. *2018.99–100*). In our case (Sample 4) the are many planar voids and channels, indicating that straw is the only temper used for kiln paste. Other features are inclusions, such as Fe-oxides, clay pellets, quartz grains, and some other opaque minerals.

In order to determine the origin of the classic *situla* from Štanjel and thus the possibility of the presence of the two-chamber kilns, we conducted a comparative study of the pottery masses using pottery thin sections. We took samples of local clay (Fig. 7B; Tab. 1.16), *silos*[10] (Fig. 7.D; Tab. 1.15), and pottery from the Štanjel site. One from the local form (Fig. 7.A; Tab. 1.1) and one from a presumably imported ceramic *situla* (Fig. 7.C; Tab. 1.14). *Silos*, such as ceramic rings, loam weights, and house plaster, are generally made from the clay closest to the site, making them a good comparison for determining local/imported products. Even a quick look at the pottery thin section of a *silo* (Fig. 2.4) and the ceramic *situla* (Fig. 7.3) shows that we are dealing with different clays. The *silo* contains muscovite/illite (up to 20%) and polycrystalline and monocrystalline quartz (25%), while the muscovite/illite is not present in the ceramic *situla*. The latter also did not include clasts of trachyte, which is typical of such forms from the Euganean area (see *Saracino 2014.120, 144*). The clay matrixes of the local vessels, the *silo*, and the local clay, sampled near Štanjel are very close in composition, while the ceramic *situla* stands out.

10 A *silo* petrographic thin section (Fig. 2.4) indicates the presence of certain carbonates, which are unchanged, meaning that firing took place at a temperature from 675 to 870°C. The same is true for the pottery from Renče (Sample 2), fired at 670°C. The *silos* as such is also solid (7 according to the Mohs scale), which reflects firing at a high enough temperature and at the same time changes the idea that such pottery forms were fired at low temperatures (*Vinazza 2016.7*).



Position of measurement	Description	After firing	Before firing
1	Bottom of the kiln (entrance)	12.54	
2	Bottom of the kiln (entrance)	9.524	0.338
3	Bottom of the kiln (entrance)	17.91	
4	Kiln`s wall (external surface)	3.181	
5	Kiln`s wall (external surface)	0.351	
6	Kiln`s wall (external surface)	1.426	0.069
7	Kiln`s wall (external surface)	7.316	0.178
8	Kiln`s wall (external surface)	2.893	
9	Kiln`s wall (external surface)	3.683	
10	Chimney (external surface)	3.181	0.149
11	Closing	3.117	0,357
12	Kiln`s wall (external surface)	5.852	0.647
13	Kiln`s wall (external surface)	1.831	
14	Kiln`s wall (external surface)	5,606	
15	Chimney (external surface)	20,059	
16	Chimney (internal surface)	18.323	
17	Bottom of the kiln (in the middle of the kiln)	13.96	

Fig. 3. The AMS measurement points were chosen on various parts of the kiln (in the centre) and of the individual parts (kiln wall (A–C), chimney (D–F), and kiln floor (G–H)).

The XRD analyses were performed on 12 samples (Tab. 1.1–13). The objective of the analysis was to determine the comparison of the XRD analysis results with the firing temperature in the kiln, which was measured with thermoelements during firing. We also tried to show that the firing temperatures of individual kiln parts do not reflect the temperature of the pottery firing, which consequently cannot be applied to the archaeological material. Third, following the lead of Thèr (*2020*), we sought to determine whether we could detect differences between the results of XRD analysis at the fracture and on the outer surface of the pottery, and thus determine the use of a bonfire and/or kiln at the site. The analyses were carried out on the samples of the kiln from the Renče clay, which is of the illite-chlorite type (*Rokavec 2014.35*), and on the pottery from the Štanjel site, which belongs to the end of the Early Iron Age (Tab. 1; Fig. 8).

Renče clay (Samples 2–8, 12)

Clay from Renče (Sample 8) has a higher amount of kaolinite (Fig. 8) which is not present in the other samples (Samples 2–5), meaning that the latter were fired at over 550°C. Comparing the parts of the kiln (floor/walls/chimney), most kaolinite is found in the kiln walls (Sample 4), less in the floor (Sample 3), while no kaolinite is present in the sample from the chimney (Sample 5). It is therefore understandable that most of it is in the wall where the temperature in the kiln was the lowest. Sample 6 (firing at 600°C) contains very little kaolinite, while Sample 7 (firing at 800°C) and Sample 12 (firing at 670°C) contain no kaolinite. Illite, which begins to decompose at 900°C, is present in all samples, while only Sample 7 contains less because it was fired at 800°C. Quartz is also present in all samples. Calcite is also present in Samples 6 and 8, which we attribute to its natural occurrence in the clay. Sample 12 (Fig. 8) has an ele-

vated calcite value, which we attribute to the intentional addition of the temper of calcite to the clay, which is also confirmed from pottery thin sections. It is no longer present in Sample 7, as it begins to decompose above 670°C. Dolomite is found in Samples 6 and 8, but in small amounts and is no longer present in Sample 12.

Štanjel pottery (Samples 1, 9–11)

Calcite is present in all samples indicating that the pottery was fired at temperatures below 870°C, at which calcite decomposes completely. Sample 1 (Fig. 8) has an increased value of calcite, which we attribute to the intentional admixture of the temper of the calcite to the clay (Fig. 8), which is also confirmed by pottery thin sections. At the same time, kaolinite is no longer present, indicating that the pottery was fired at over 550°C. The samples from Štanjel contain very little illite, which is due to the mineralogical composition of the clay. A comparison of the calcite in the vessel's core (Sample 10) and in the outer (Sample 9) and inner surfaces (Sample 11) shows that the vessel's core contains more calcite.

Discussion

Archaeological finds that would indicate the firing of the pottery in Kras and the Posočje region in the Bronze and Iron Ages are not known for either a bonfire or a kiln. There are at least two possible reasons for this. First, slow sedimentation at Kras is very problematic from a stratigraphical point of view. In most cases, the sites have very thin archaeological layers and only rarely do we discover a longer stratigraphic sequence (*cf*. Monkodonja in Istria; *Hänsel* et al. *2015.75*). The soil at Kras is characterized by the bedrock, various limestones and dolomites, their decomposition and dissolution, and the leaching of debris into relief depressions. On karstified hills and in higher areas there is less soil, while in depressions, *e.g.*, dolinas (*Habič 1979.150*), there are uniform and thicker layers. The discussed pottery originates from the hillfort sites of Tabor near Vrabče and Štanjel (*Vinazza 2021*), where there is in both cases less soil.

The second reason is connected with the firing structures and the question of how to recognize them in order to understand the firing process. Structures

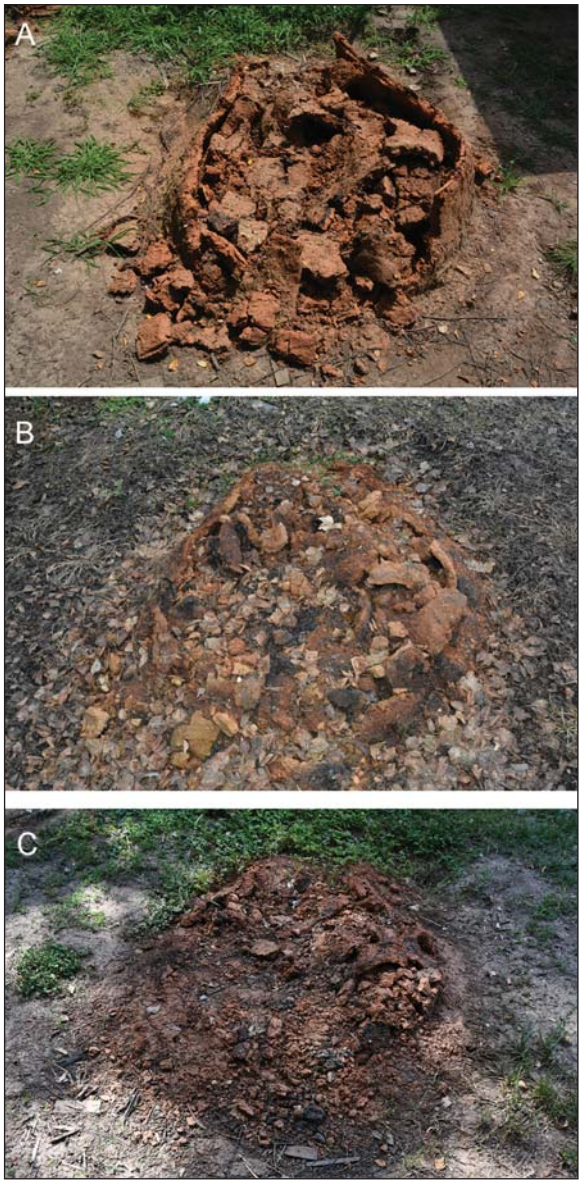


Fig. 4. A year's decay of the kiln. **A** ***27.07.2021,*** **B** ***31.01.2022,*** **C** ***16.06.2022.***

such as bonfires do not leave any significant traces behind, and are thus difficult to discern. If we consider a burned layer of soil, a large pile of plant charcoal, wooden charcoal, burned-through soil, and burned lumps of soil as the key indicators of the remains of a bonfire for firing pottery (*Guo 2017.184*), then some of the structures found at several sites from Eneolithic to the Early Iron Age in central and north-eastern Slovenia could be interpreted as bonfires.[11] We are still missing this kind of data for the Kras area.

11 The Eneolithic: Kalinovjek, SE 171, 174, 176, 178, 257, 259 (*Kerman 2013.58, 59, 62*); the Early Bronze Age; Nova tabla, PO 29, PZ 24 (*Guštin* et al. *2017.112, 115*); the Middle and Late Bronze Ages: Nedelica pri Turnišču SU 344/343, 372, 381 (*Šavel, Sankovič 2013.78*), Svetje, SU 41/42 (*Leghissa 2011.86*); the Late Bronze Age: Pod Kotom – sever pri Krogu, SU 347 (*Kerman 2011.71*); Orehova vas, SU 160M, 191A, 81R (*Grahek 2015.53, 59, 88*)); the Early Iron Age: Nova tabla, PO 223 (*Guštin* et al. *2017.127*); Hotinja vas near Maribor, SU 271/272 (*Gerbec 2015.43*).

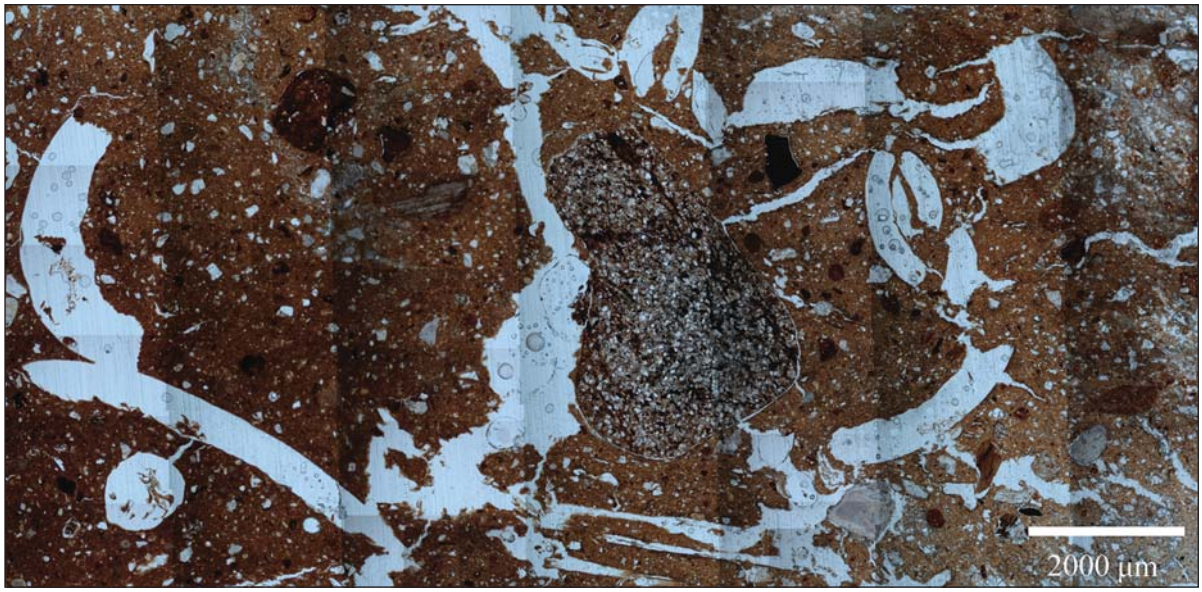


Fig. 5. Panoramic view of a pottery thin section of the kiln wall. The voids are the result of the burned-out organic material, straw. Photos taken under plain polarized light.

The situation is a different matter with kilns. They decay in a certain phase, but their remains depend on different situations. Today's climate in the discussed area is too dry, and poorly fired structures decompose into the matrix of the archaeological deposit (*Amicone* et al. *2020.522*), and it is also possible that the space is reused at a later date.

We believe one of the reasons why these kilns have not been preserved is also due to the use of these structures. Our archaeological experiments have shown that different parts of kilns are exposed to different temperatures, which is consistent with the results of the AMS. The most exposed parts were the kiln floor and the chimney. Higher values of the AMS mean that these parts were fired better, which affects the degree of preservation of these parts of the kiln. In the exposure to different temperatures, we see the reason for the poor preservation of the kilns, which can be applied to the wider area.[12] From this, we can say that we can mistake the remains of the kiln floor with, for example, a hearth. Hence we believe that we should focus our attention on possible remains of an interlacement that could have belonged to the former dome,[13] which will significantly contribute to the final interpretation of whether it is a kiln or a hearth.

Consequently, we believe that the firing temperatures of vessels cannot be determined by analysing the temperature of the parts of kilns. As already mentioned, different values of AMS indicated different temperatures of the firing of different kiln parts. Since kiln parts are usually randomly preserved, it means we do not necessarily obtain the best-fired part when sampling. Moreover, in the case of kilns the soaking time plays an important role, since bricks, for example, are fired for several days before they are properly fired. When macroscopically observing the core of cubes made of Renče clay (App. 1: Samples 6 and 7) it can be seen that the core is still grey at 600°C, while at 800°C the grey part shrinks.

Evidence of this is the results of the XRD analysis of vessels and kiln parts from the Krašnja site in Slovenia, which showed that the vessels were fired at about 800°C, while samples of the wall and bottom of the kiln indicate a temperature of no more than 500°C (*Žibrat Gašparič* et al. *2014.232, 234*).

We can also apply these results to pottery firing. As Thér *et al.* (*2018*) have already shown, the soaking time needs to be considered when comparing firing in a bonfire with firing in a kiln.

12 Here we always need to compare AMS measurements of the local clays, since the values may depend on the natural composition and the presence of, for example, magnetite.

13 We have found five pottery kilns at the roman site Otok pri Metliki in southeastern Slovenia. Above the perforated floor there was a red layer full of small pieces of burned clay. There were no visible marks of the construction made with branches (see *Udovč, Vinazza 2018.147–149*).

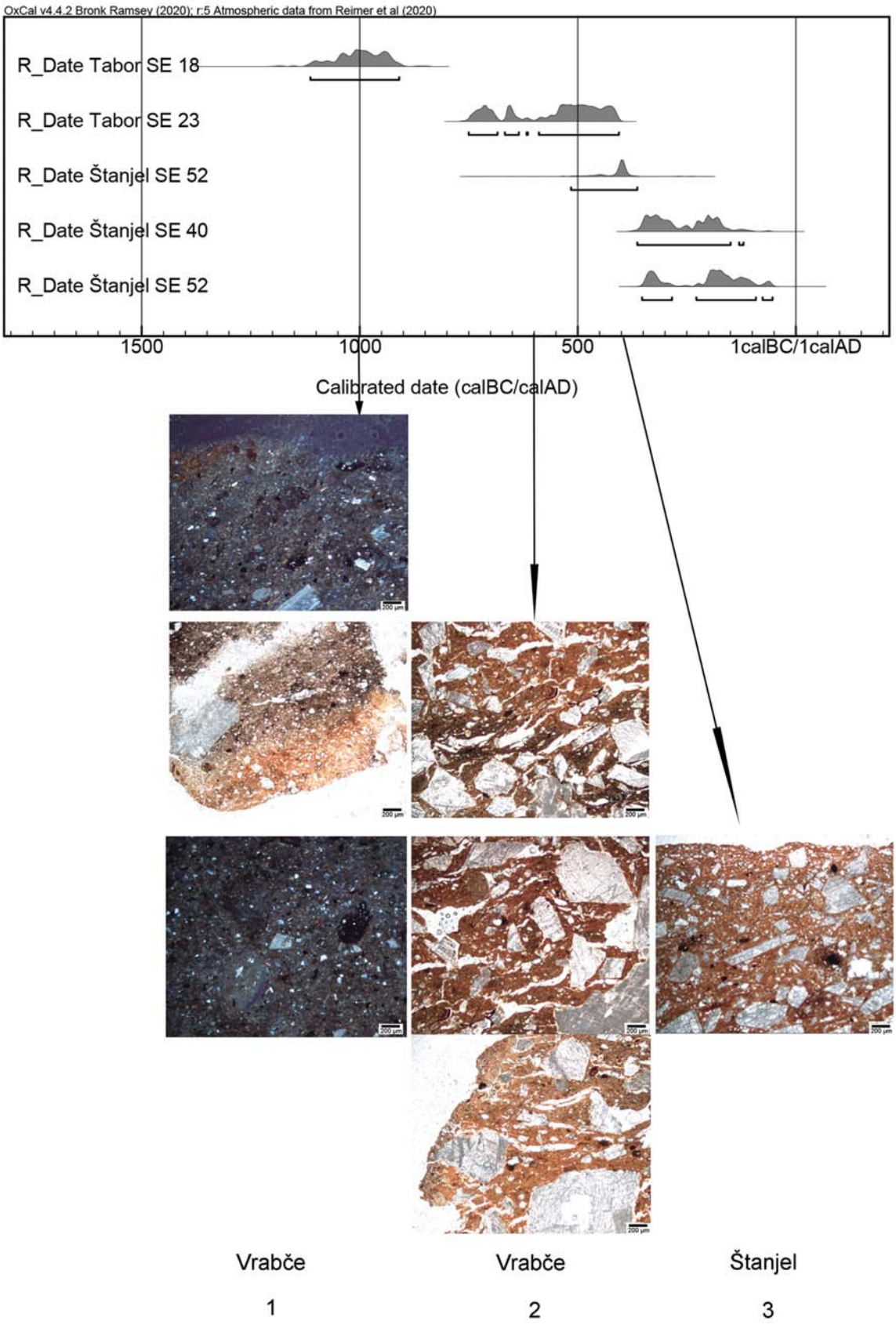


Fig. 6. Changes in the pottery recipes (petrographic thin sections and site phases (1 Late Bronze Age; 2 Early Iron Age; 3 end of Early Iron Age)) in combination with radiocarbon dates from the sites of Tabor near Vrabče and Štanjel. Photos taken under plain polarized and cross polarized light.

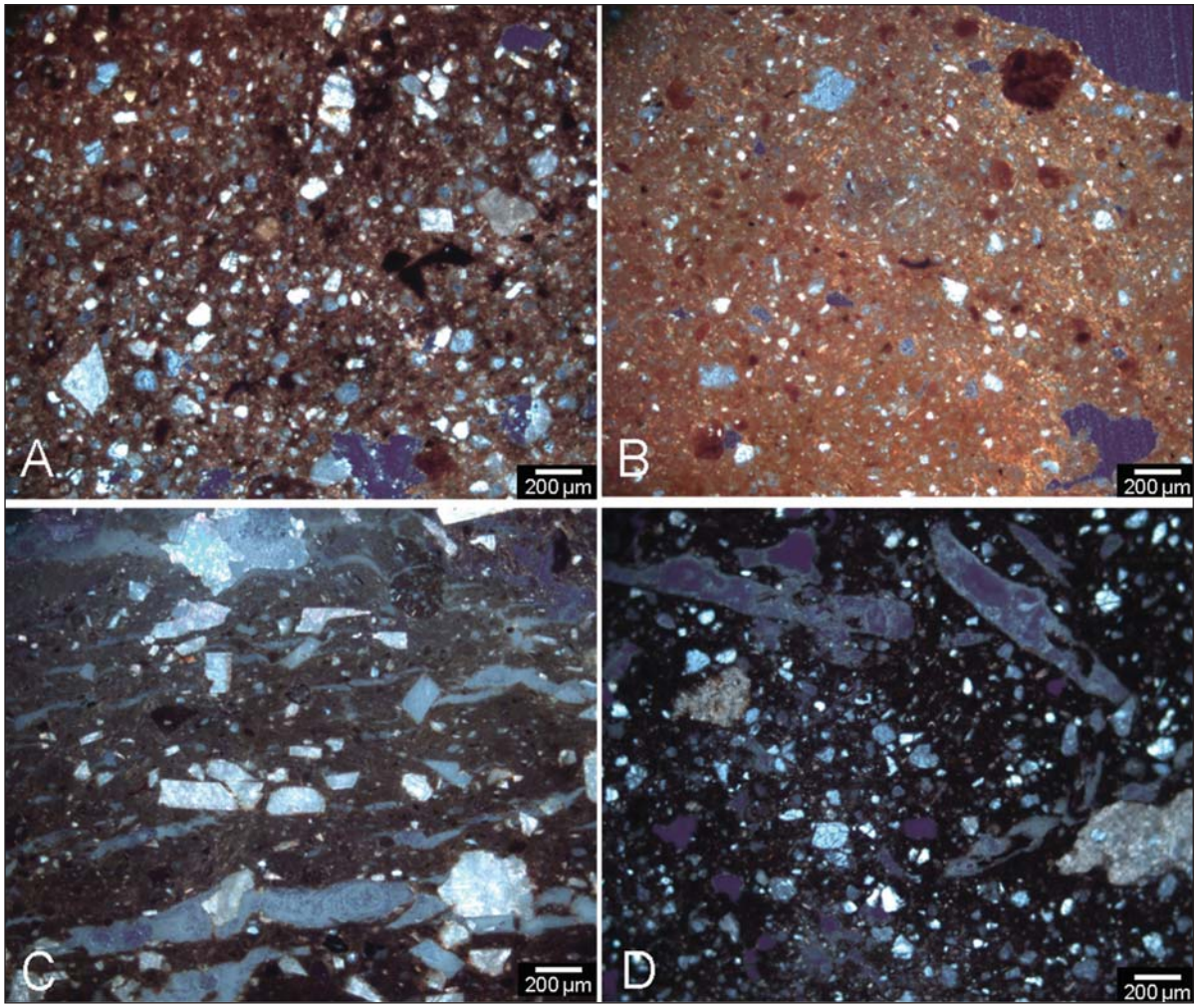


Fig. 7. A comparison of clay-matrix archaeological pottery – vessels (*1, 3*), with a* silo *(*4*) and clay from the vicinity of Štanjel (*2*). Photos taken under plain polarized and cross polarized light.

There are no differences in the mineralogical composition of the Štanjel pottery when comparing the vessel's core and inner and outer surfaces (Samples 9–11). We take the lack of variation in these values as evidence that the pottery was fired in a kiln. The calcite values have not changed, which means that the decomposition of the calcite has not started at a temperature that has not exceeded 850°C.

Here, we would like to point out that the increase of calcite that was already shown by macroscopic technological analysis (*Vinazza 2021*) and confirmed with pottery thin sections in this study, in pottery from sites Tabor near Vrabče and Štanjel is not linked to a particular vessel type, but is noted in various forms, such as pots, dishes, and lids. This means the reason for the addition of calcite is not only related to the functional properties, which increases the resistance to thermal shock (*Bronitsky, Hamer 1986.95–99*), but also to the firing process, since calcite acts as a flux that allows carbonate clays to be fired at lower temperatures (*Shoval 2016.12*). Since calcite decomposes at a temperature of up to 870°C and since the XRD results for Štanjel pottery show that the temperature did not exceed 870°C, we assume that the use of kilns makes it easier to control the temperature and thus the use of such an amount of calcite.[14]

Finally, we analysed ceramic *situla* from Štanjel in order to find confirmation of ORO firing of this type of vessel and consequently the potential use of two-chamber kilns with a perforated floor in the Kras area. As the ceramic *situla* from Štanjel was not made from the same clay, as the other samples show, we see it as an imported vessel. Samples from Most na Soči from Posočje (*Grahek, Košir 2018.309–311, 314–315*; sample MNS D or Most 4) suggest the pos-

14 This material is ubiquitous in the discussed area (see *Jurkovšek 2013*).

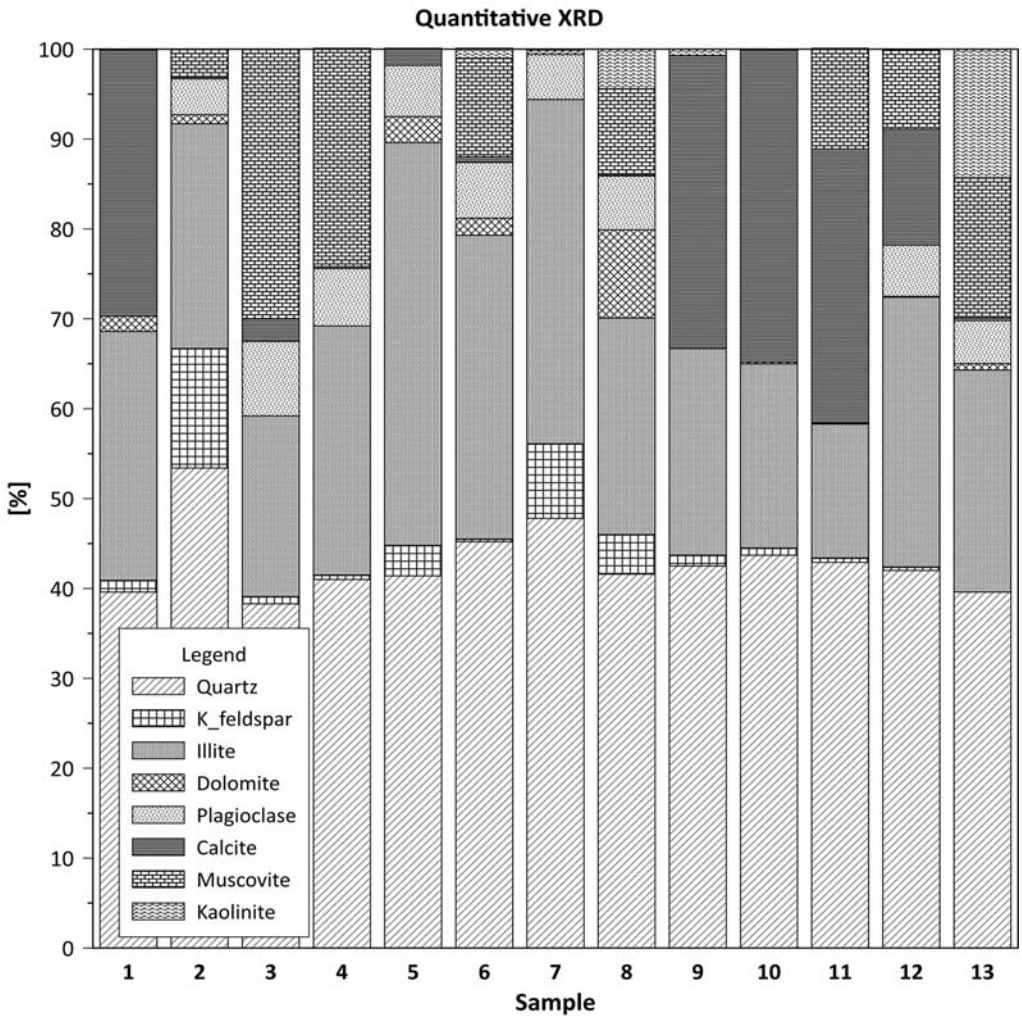


Fig. 8. Mineralogy distribution (XRD results).

sibility that some of the pieces were imported from workshops in the Este area, while others are probably the product of local workshops. In our case, no pieces of trachyte were found in the pottery mass, which is typical for the Euganean area (see *Saracino 2014.144*). We believe that the area of origin of the ceramic *situla* from Štanjel is elsewhere and the possibility of local workshops is still open to discussion, since the XRD results also show no or a very small amount of muscovite in pottery from Štanjel (Fig. 8.samples 9, 10).

Conclusion

With the help of various research methods and scientific analyses, we have tried to determine whether the use of kilns for pottery firing can be expected in the Early Iron Age in western Slovenia. The pottery-manufacture technology of this period suggests this possibility, and the same is true for the results of XRD analysis, which do not reveal major temperature deviations between the outer surface and core of the vessel, which means that the soaking time was long enough to allow gradual and uniform firing of the vessels. The XRD analyses of the pottery from Štanjel show that the temperature did not exceed 870°C, while the addition of calcite as a temper, which did not decompose, suggests that the firing took place under controlled conditions, which can be better controlled in a kiln (*e.g.*, no sudden temperature rise due to the wind blowing). The prevalence of oxidative firing, which is much more controlled in a kiln, is also supported by the macroscopic analysis of pottery in western Slovenia at the end of the Early Iron Age. Based on the above, we assume that in western Slovenia at the end of the Early Iron Age (the 6th and 5th cent. BC) only single-chamber kilns for the firing of pottery were known, even though archaeological excavations have not (yet) brought them to light. We need to point out that a single-chamber kiln from the Early Iron Age was found in the Dolenjska region (site Dobrava near Otočec), as mentioned above, but for the area of Friuli Plain in Italy we still have no evidence. In

the future, we will have to pay more attention to the excavations of such structures, and in the Kras area there is a lack of scientific research. Only with such an approach will we be able to understand more about pottery technological practices in the Early Iron Age.

However, the non-local origin of the ceramic *situla* from Štanjel does not suggest the use of two-chamber kilns with a perforated floor for the firing of the pottery at the end of the Early Iron Age in the Kras area. Since the clay for ceramic *situla* does not originate from the Eugaeum area, we still need to find a closer production area for this type of vessel. Some additional local clay sampling in a broader area close to key Early Iron Age sites (*e.g.*, Tomaj, Most na Soči, Gradisca di Spilimbergo in Italy) thus needs to be done.

Finally, we would like to point out that the level of technological knowledge was also determined by the properties of the raw material available in a certain area. Thus, the final results must also be understood in light of the natural resources (*e.g.*, clay quality) of the area and not only in terms of the level of technological development, as is often the case in archaeological studies.

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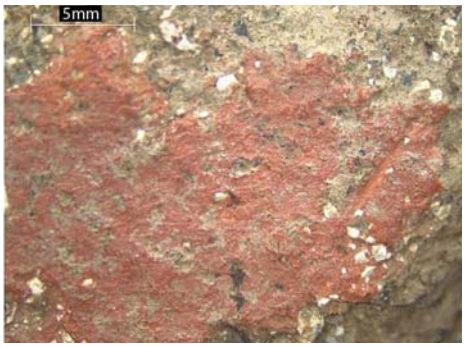
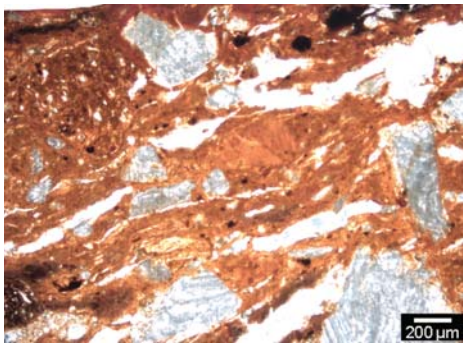
Appendix



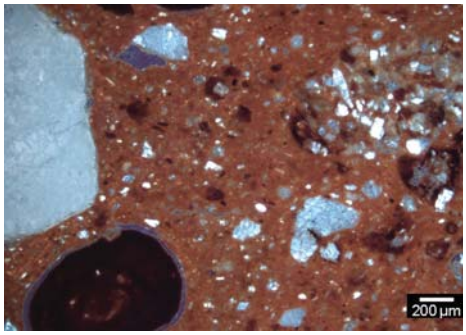
1. Štanjel, red slip coating on the situla, outer surface. 8x magnification Leica Stereomicroscope EZ4.



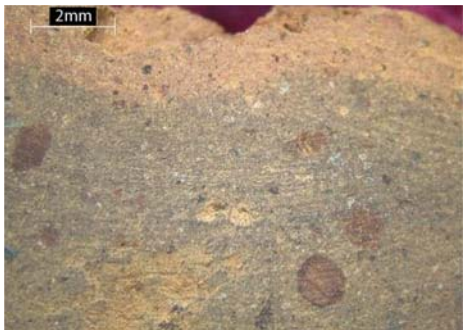
2. Štanjel, coating thin section, a fracture (orange colour). 40x magnification. PPL with Zeiss Axiocam 305 color.



3. A thin section of a vessel fired in a kiln at 670°C. 8x magnification Leica Stereomicroscope EZ4.



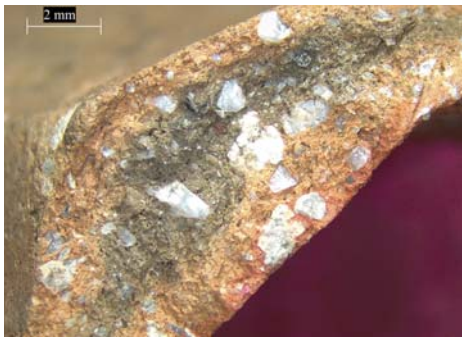
4. A thin section of Sample 2. XPL with Zeiss Axiocam 305 color.



5. Renče clay, fired at 600°C, Sample 6. 8x magnification Leica Stereomicroscope EZ4.



6. Renče clay, fired at 800°C, Sample 7. 8x magnification Leica Stereomicroscope EZ4.



7. Štanjel, Samples 9 (outer surface), 10 (fracture), 11 (inner surface). 8x magnification with Leica Stereomicroscope EZ4.



8. Renče clay with admixed calcite, Sample 12. 8x magnification Leica Stereomicroscope EZ4.

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Between object and subject: multiple approaches to a prehistoric human-shaped pot from Romania

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ABSTRACT – *The current paper aims to reveal the potential of combining multiple approaches (techno-functional analysis, experimental archaeology, and X-ray Computed Tomography) when it comes to studying unique earthenware artefacts, such as the prehistoric human-shaped pot discovered within the tell settlement from Sultana-Malu Roşu (Romania), that belongs to the Kodjadermen-Gumelniţa-Karanovo VI civilization (KGK VI) which thrived during the 5th millennium BC. This human-shaped pot, also known as 'The Goddess of Sultana', is an emblematic artefact that fascinates with its shape, gestures, and decoration. It was apparently made from a standard clay paste recipe and using basic forming techniques, with little care for the internal surface. This vessel also has several hidden cracks and some manipulation traces on its backside. In order to explore its relevance, our approach to this particular human-shaped pot included the use of archaeological data in correlation with other techniques in order to decipher the manufacturing process for such vessels, the possible way of using them, but also the meanings that they might have had for past human communities.*

KEY WORDS – *Balkans; Eneolithic; anthropomorphic pot; CT scans; technological analysis; experimental archaeology*

Med objektom in subjektom: različni pristopi k preučevanju prazgodovinske antropomorfne posode iz Romunije

IZVLEČEK – *V članku predstavljamo potencial združevanja različnih pristopov (tehnično-funkcionalna analiza, eksperimentalna arheologija in računalniška tomografija) pri študijah unikatnih glinenih predmetov, kot so prazgodovinske antropomorfne posode, kakršne so bile odkrite na tell-naselbini Sultana-Malu Roşu (Romunija) iz stopnje Kodjadermen-Gumelnita-Karanovo VI v 5. tisočletju pr. n. št. Antropomorfna posoda, znana tudi kot boginja Sultane, je značilna najdba, ki izstopa po obliki, potezah in okrasu. Oblikovana je bila iz običajne lončarske mase z uporabo osnovnih tehnik oblikovanja in dodelavo zunanje površine. Na notranji strani so vidne številne razpoke in sledovi izdelave. V raziskavo smo vključili arheološke podatke in jih povezali s tehnično-funkcionalnimi analizami, eksperimentalno arheologijo in računalniško tomografijo z namenom prikaza procesa izdelave tovrstnih posod, možnega načina uporabe ter njihovega pomena za pretekle skupnosti.*

KLJUČNE BESEDE – *Balkan; eneolitik; antropomorfna posoda; rentgenska računalniška tomografija; tehnološka analiza; eksperimentalna arheologija*

DOI: 10.4312/dp.49.3

Introduction

The emergence of fired clay human-shaped pots is undoubtedly a technological breakthrough and a clear evolution of the artistic conception of human communities and that of the social development of humankind. This type of object is generally considered part of the spectrum of figural art in prehistoric communities (*Schwarzberg, Becker 2017*). It represents a particular category of vessels, undoubtedly different from 'everyday pottery' (*Opriş* et al. *2017*).

Currently, it is evident that the meaning of these anthropomorphic vessels, alongside all human figurines documented in the Neolithic and Eneolithic (Chalcolithic or Copper Age) in different parts of the world is related to corporeal identities, and the way that people from the past understood existence and perceived the human body (*Bailey 2013; 2015*). The old assumptions regarding their religious or mythological meanings (*e.g.*, cult items, representations of divinities, Mother-Goddesses, *etc.*) are no longer in use, as proved by critical approaches postulated over time (*e.g., Meskell 1995; Biehl 2006; Bailey 2013; 2015; 2017*).

The current paper will explore the technological background of an emblematic human-shaped pot for the prehistory of the Balkans, known as 'The Goddess of Sultana', in order to trace its meanings and how it actually was used by people in the past.

Our approach on this particular human-shaped pot from Sultana-Malu Roşu will include using archaeological data in correlation with techno-functional analysis and use-wear analysis, along with experimental archaeology and X-ray Computed Tomography (XCT). The main goal is to decipher the manufacturing process of such vessels, the possible way of using them, and their implied meanings. The use of multiple approaches is very effective, as demonstrated by our previously published studies (*Ignat* et al. *2017; 2018; 2019; Manea* et al. *2019*).

Archaeological background

The tell settlement from Sultana-Malu Roşu is located in southeastern Romania (N 44°15'41.5853", E 26°52'15.3378"), near the Danube River and the border with Bulgaria (Fig. 1.a). Archaeologists have known the site since 1923, when the first excavations began. The tell settlement is located on the high terrace of the Mostistea River, and it was used

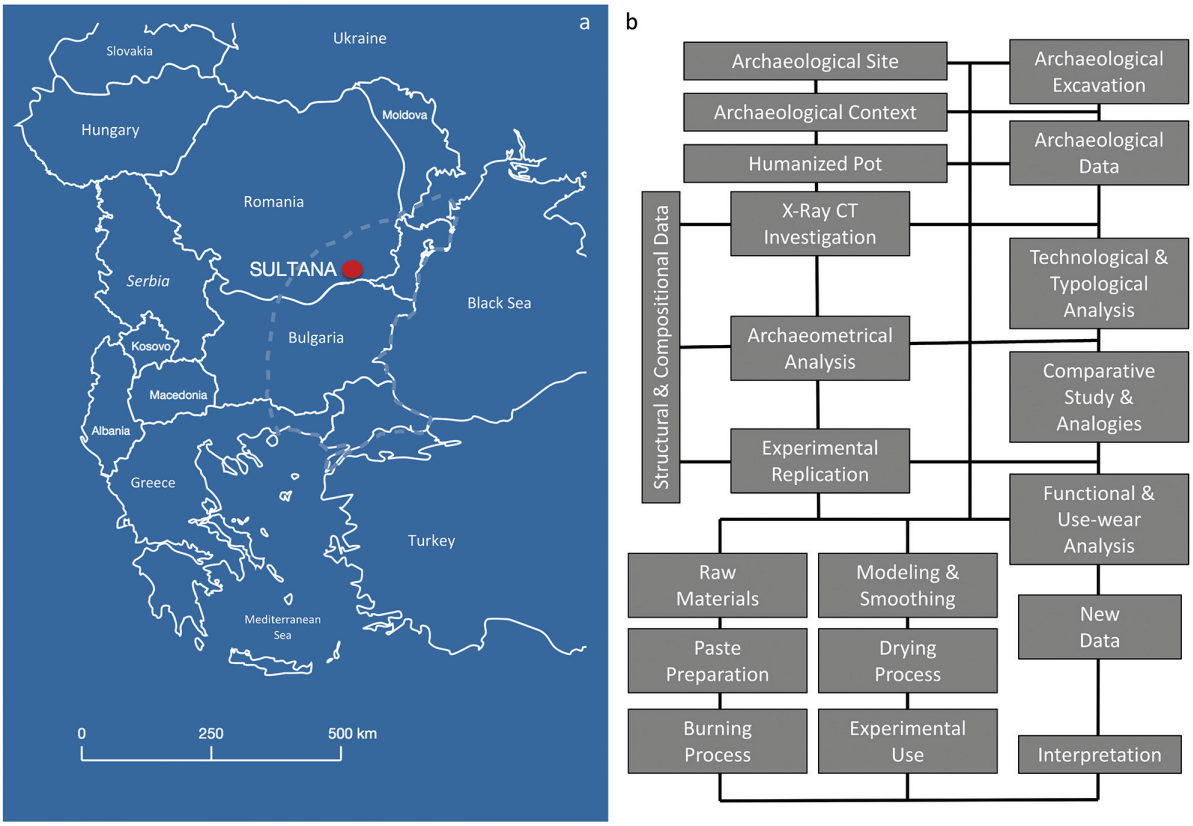

Fig. 1.* a *location of the tell settlement from Sultana-Malu Roşu in the area of the Kodjadermen-Gumelniţa-Karanovo VI civilization;* b *the research algorithm used in our paper.

for more than 500 years by the Kodjadermen-Gumelniţa-Karanovo VI (KGK VI) communities in the second half of the 5th millennium BC (*Lazar* et al. *2016*).

In 1965 a human-shaped vessel known as 'The Goddess of Sultana' (Fig. 2.a) was discovered by chance in the area of the tell settlement (*Marinescu-Bîlcu, Ionescu 1967*). The name given to this artefact reflects the Gimbutasian interpretation of the archaeologist who discovered this vessel and attributed a meaning that is currently considered out of date, as suggested by various criticisms formulated by different scholars (*Bailey 2013; 2015; 2017*).

Unfortunately, there are not many details about the archaeological context of this discovery. Most probably, as we previously noted (*Opriş* et al. *2017*), the secondary burning traces observed on the exterior of this vessel represent strong indicators that it was found in a burned house. Unfortunately, any other data regarding the association of this human-shaped vessel with other features or artefacts are missing. However, from a typological point of view, it fits well in the humanized pottery series characteristic of KGK VI communities (*Voinea 2005*). The absence of any data regarding the stratigraphic context made impossible its assignment to a specific phase (*e.g.*, A1, A2, or B1) of that civilization, but based on available radiocarbon data, we could set the possible timeframe between 4546–3973 cal BC (2σ calibrated) (*Lazar* et al. *2016; 2018*).

This particular human-shaped vessel is internationally renowned and has been included in numerous catalogues of collections and exhibitions (*Marinescu-Bîlcu, Ionescu 1967; Wielen-van Ommeren* et al. *2008; Anthony, Chi 2010; Lazar 2015*) but also in synthetic works dedicated to Neolithic and Chalcolithic anthropomorphic representations (*Andreescu 2002; Ignat, Opriş 2015; Opriş* et al. *2017*).

Currently, the pot is part of the National History Museum of Romania collection in Bucharest, Romania (inv. nr. 102236).

Materials and methods

The multiple approaches used on the human-shaped pot from Sultana-Malu Roşu were based on the research algorithm illustrated in Figure 1.b.

Generally, this kind of interdisciplinary investigation has the potential to reveal different relevant information regarding the technological background of the artefacts that, in correlation with other data types (*e.g.*, archaeological context, functional and use-wear traces, *etc.*), could offer an integrative interpretation about past human's material culture and its multiple meanings.

The archaeological investigation of the anthropomorphic pot was made by following the recommendations regarding ceramic analysis available in various studies published over time (*Rye 1981; Rice 1987; Skibo* et al. *1989; Skibo 2013; Orton, Hughes 2013; Hunt 2016*), and considered a technological-typological study, but also the examination of use-wear traces (*Skibo 2013*). This approach involved measuring the vessel's dimensions (length, height, diameter, *etc.*), weight, and volume (Tab. 1). A binocular magnifier was used for use-wear investigation, along with photos taken with a camera and a macro lens.

Prehistoric archaeological discoveries represent a significant challenge compared to other chronological periods (*e.g.*, antiquity, medieval age, *etc.*) due to the lack of complementary sources of information (*e.g.*, written sources, oral information, inscriptions,



Fig 2. The human-shaped vessel known as 'The Goddess of Sultana':* a *the original (left – frontal view; right – lateral view);* b *the experimental replica (left – frontal view; right – lateral view).

etc.). Under these circumstances, the data provided by archaeological investigations remain the only ones that can help us understand these prehistoric communities and their material creations. Unfortunately, these are also limited, far from encompassing all the information needed to fully understand the behaviour of past individuals and their decision-making regarding different aspects of daily life (*e.g.*, food procurement, production of material goods, raw material exploitation, basic choices, *etc.*). Experimental archaeology aims to verify the techniques, procedures, and processes involved in obtaining certain objects or structures and then assess the theories and hypotheses based on archaeological data, thus facilitating the possibility of providing new contributions to knowledge and understanding of the past (*Lazar 2015*).

For the experimental replication of the anthropomorphic pot from Sultana-Malu Roşu, we applied the methods and protocols developed by our team and previously published (*Ignat* et al. *2017; 2018; 2019*). Generally, this kind of approach could offer us essential data about the invisible elements of the past, regarding the technological process (*e.g.*, *chaîne opératoire* employed in making these prehistoric clay items), which are not identified in the archaeological excavation (*Lazar 2015*). Therefore, the primary aim was to verify the manufacturing process, with all technological segments (*e.g.*, gathering raw materials, paste preparation, the drying and firing methods) involved.

When it comes to XCT investigations, during the last few decades this kind of imaging method has been increasingly applied in archaeological research (*Kahl, Ramminger 2012; Thér 2016; Kozatsas* et al. *2018; Ross* et al. *2018; Park* et al. *2019*). This type of analysis can provide details about the internal structure of the artefacts that cannot be otherwise disclosed but through destructive investigations. Naturally, the more that is known about the inner structure of an object then the more speculations about the way it was manufactured or about the roles it might have played can be made. In particular, the application of XCT for the study of prehistoric clay artefacts proved to be an excellent non-invasive approach, being especially relevant to investigate the internal structure and/or hidden details of unbroken/intact archaeological objects.

The XCT scans reported in this paper were performed with a Nikon XT H 225 device that contains a micro-focus X-ray source (225kV maximum voltage, 1mA maximum current, focal spot size: 3µm below 7W and up to 225µm at 225W) that provides a conical X-ray beam, a Varian 2520 flat panel detector (127µm pixel size; 1900x1516 active pixels), and an accurate 5 axes positioning system, that allows the movements of the sample in the X, Y, and Z direction, as well as its rotation with 360° and tilting by ±30°. The average voxel size is roughly 1.5x 10^5µm^3. This equipment allows the inspection of relatively large volume objects with high image resolution and an ultrafast CT reconstruction. The X-ray tube working parameters were optimized for the tomography of clay artefacts, namely a tube voltage of 100kV and a current intensity of 45µA. The entire volume of the objects was scanned in 360 steps, representing the full rotation of the object around its central axis. The acquisition time for the full tomographic scan was roughly 6 minutes, while the image reconstruction performed with VG Studio Max 3.0 software took several hours. The XCT image analysis was carried out to inspect the reconstructed images visually. This approach was followed because VGStudio Max 3.0 software is a general-purpose tool for 3D reconstruction. The analysed voids result from a visual inspection of the slices, and therefore not all the identified voids are perpendicularly oriented concerning the orthoview planes.

The interpretation of the XCT images was made according to the methodology developed in the latest studies that involved the analysis of archaeological clay artefacts by XCT-images (*Kahl, Ramminger 2012; Green* et al. *2017; Ignat* et al. *2017; 2018; Kozatsas* et al. *2018; Manea* et al. *2019; Park* et al. *2019*).

Results

Archaeological data

From the preservation point of view, the human-shaped vessel from Sultana was discovered in a complete state, without visible cracks, with only an ear missing (the right one, now restored with plaster) and some secondary burning traces on the exterior surface (*Opriş* et al. *2017*).

This particular human-shaped pot represents a person in a standing position. The bottom is disproportionate compared to the top. The thighs, buttocks, pelvis, and hips regions are highlighted, showing clear elements of steatopygia. The upper limbs are stylized, placed very high, and stuck to the body. The elbows are bent, the right arm resting on the left, which in turn has placed its fingers under the

chin. The facial area is well represented. An arched projection renders the eyes. The nose is outlined, and the mouth is shown by a triangular notch, underlined with holes. Two large ears are added on the sides, pierced with four holes. On top of the figurine, the round neck of the vessel is attached, with a threshold for supporting a lid (missing). The vessel was fully painted with white decoration (*e.g.*, spirals, circles, stripes, palmettes, and a triangle for the genital area). The attitude of this character, represented as a standing human with one hand brought to the mouth, seems a meditative one, which reminds us of the 'Thinker of Cernavoda' (*Marinescu-Bîlcu, Ionescu 1967*). However, according to a new interpretation, it can represent a human in a 'dead position' based on gestures and wear-trace analysis (*Opriş* et al. *2017*).

If we consider the anatomical elements presented, the humanized pot can be considered realistic only to a small extent because it does not reflect a complete representation of the human body. Certainly, the general shape of the pot suggests a human in a standing position with most anatomical features presented (*e.g.*, head, body, hands, legs). Some of them are designed very schematically (*e.g.*, hands) to a scale that does not correspond to a natural body and is disproportionate to the other anatomical elements. The other ones (*e.g.*, head, legs) are represented on a proportional scale and are much more realistic. Regarding the facial attributes of the vessel from Sultana-Malu Roşu, it displays sufficient elements, highlighting the most relevant facial physiognomy (eyes, nose, mouth, eyebrows, ears), placed anatomically correctly. The eyes and mouth are depicted as incised lines, and the hands, nose and ears are embossed. There are four holes in the left ear and another ten under the mouth, possibly signs of some form of body piercing (*Opriş* et al. *2017*).

Although it was previously discussed that the represented person would be a woman (*Marinescu-Bîlcu, Ionescu 1967*), we have already shown that the piece does not present sufficient anatomical elements to assign it to this gender because some relevant body parts for this category (*e.g.*, breasts, vulva) are missing (*Opriş* et al. *2017*).

Nevertheless, the analysed vessel presents a series of features that make it a true masterpiece of prehistoric art.

Techno-typological analysis

Strong evidence about the technique used to make this vessel is missing since the inner surface was smoothed and the external surface was polished. The macroscopic analysis of the surfaces allowed us to observe that the paste was tempered with grog and contained natural non-plastics like rare, rounded and sub-rounded, calcareous inclusions (up to 5mm) and fine white mica (*Opriş* et al. *2017*). This paste recipe is widespread for the Eneolithic pottery discovered within the Sultana-Malu Roşu tell settlement (*Ignat* et al. *2013*). Moreover, since the vessel

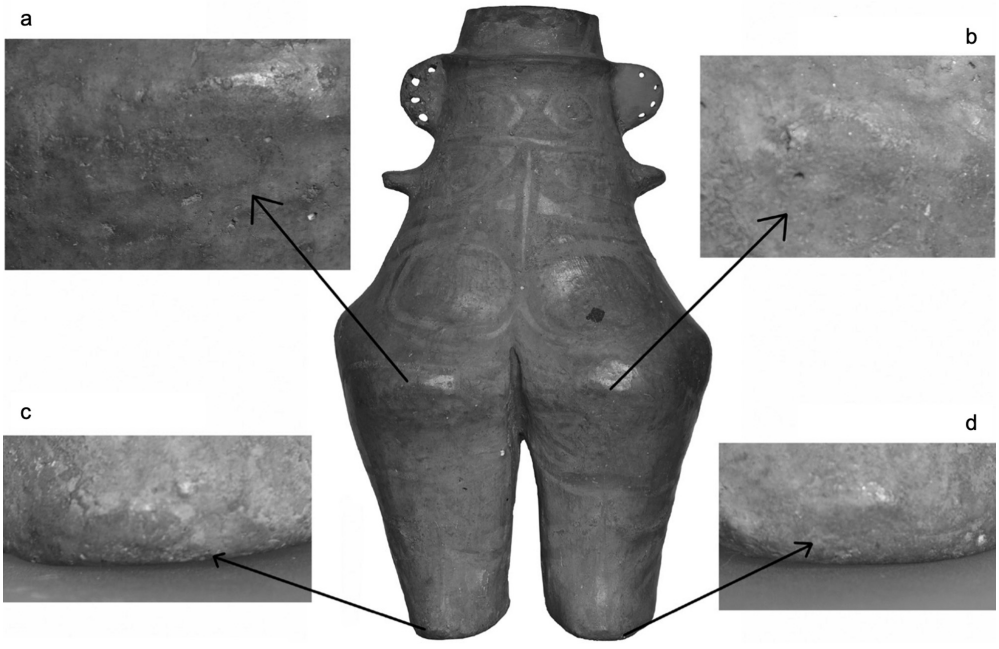

Fig. 3. The use-wear analysis: the abrasion traces on buttocks (*a-b*) and heels (*c-d*) areas of the human-shaped pot. Without scale (after* Opriş *et al.* 2017*).

is intact, unbroken, and represents an artefact catalogued in the collection of national heritage, it is impossible to take samples for a different kind of archaeometrical analysis. The non-destructive XCT scans performed on this item thus offered supplementary data (see the dedicated section below).

All external surfaces were painted with specific motifs in white dye before the initial firing, but the secondary firing partially damaged it. There is a hypothesis that the painted motifs represent some form of tattoo art (*Marinescu-Bîlcu, Ionescu 1967*).

From a typological perspective, the investigated pot falls into human-shaped vessels that represent a standing person. The item is similar to other humanized pots discovered within the tell settlement from Sultana-Malu Roşu (*Opriş* et al. *2017*) or other contemporary sites belonging to KGK VI communities (*Andreescu 2002; Voinea 2005*).

Functional and use-wear analysis

One of the main functional features is represented by the storage capacity of the recipient, in our case 2 litres, an element that places it in the type of medium storage vessel. According to the morphometric analysis and experimental replication, it can be used very well as a container, especially for liquids or 'flowing solids' (like cereal grains) (*Opriş* et al. *2017*).

The use-wear analysis (*Schiffer, Skibo 1989; Skibo 2013*) made on this humanised pot indicates that it was used repeatedly, this being proved by the presence of some abrasion traces on different sides of the pot. Interestingly, even though we are dealing with a vessel that, according to its shape, should be used in a vertical position, most abrasion traces are not on the base (soles) but mainly on the back of the heels and buttocks (Fig. 3). This fact demonstrates that this vessel was used most of the time on its back position. Moreover, the lack of some specific marks on the soles could be evidence that while complete, the vessel was not moved (*Opriş* et al. *2017*).

The experimental replication

In order to identify the invisible elements of the past technological process and follow the features of the humanized vessel from Sultana-Malu Roşu, we tried to make an experimental replica (Fig. 2.b) using a local source of clay and prehistoric technologies. The experimental replica was made prior to the XCT analysis of the original pot, using only available macroscopic data and the potter's experience and intuition.

The previous archaeometrical analyses performed on both Eneolithic pottery from the tell settlement and local clay sources around the site (*Ignat* et al. *2019*) indicated a local source for the clay used for making pottery. The source that had the most common features with the pottery from the site is located on the shore of the Mostiştea Lake, about 300 meters north-west of the tell settlement. This source was denoted as Source nr. 8. From there, we collected two types of clay: one brown with sparse (<5%) carbonate concretions and one greyish-white in colour also with sparse (<5%) carbonate concretions in composition (*Ignat* et al. *2019*).

The paste recipe used for modelling the experimental human-shaped pot was a mix made out of greyish-white clay (75%) and grog (25%, with granules <5mm).

The vessel's shape was modelled by hand by an archaeologist with limited experience in pottery making. The forming sequence was performed outdoors, in a shaded place during a day with moderate wind. According to the primary forming typology developed by Owen Rye (*1981*), coiling combined with pinching were the methods used. Thus, the bases of the feet were the first to be modelled, the process performed by hand and with the help of a bone spatula used for scraping. Afterwards, the whole body was built by using small coils of clay. After every two or three coils were added, the outer part of the vessel in that area was scraped with a bone spatula and then smoothed with a dried reed stem and water. The thickness of the walls was maintained at about 0.5cm. The anthropomorphic features such as arms, mouth, nose, eyes, eyebrows and ears were added and modelled right after the vessel was shaped. The whole vessel was built in a single sequence giving that the lower constructed parts had been gradually drying during the forming process that took six hours. The final height of the vessel was 37cm. After one day of drying, a crack appeared in the area where the legs join, visible from both the outside and inside of the pot.

The finishing method used was polishing the external surface with a fine river pebble after the vessel was dried indoors for two days. This process lasted one hour and a half (90min).

A wood stick with human hair bound at an end was used as a brush to decorate the vessel. The paint was made of crushed carbonate concretions (*c.* 75%), collected from the shore of Mostiştea Lake, mixed

with egg white (*c.* 25%). Painting the decoration took almost three hours (170 minutes). However, the process was not very complicated, involving only some basic artistic skills and an experimental brush to replicate the painted motifs documented on the original item.

After one year, the vessel was fired in a big kiln with two chambers that replicated an Eneolithic pottery kiln discovered in Ukraine (*Tencariu 2015*). The fire was powered with 85kg of dry wood, and the maximum temperature obtained was 786°C in the centre of the kiln after three hours of the firing. The maximum temperature measured on the Goddess replica was 623°C. The firing temperatures recorded on the experimental human-shaped vessel during the combustion process are shown in Figure 4. After three hours of firing, the access door in the back of the kiln was opened, and no more wood was added. The grill under the vessel was crushed by the end of the firing, but the replica of 'The Goddess of Sultana' remained unbroken.

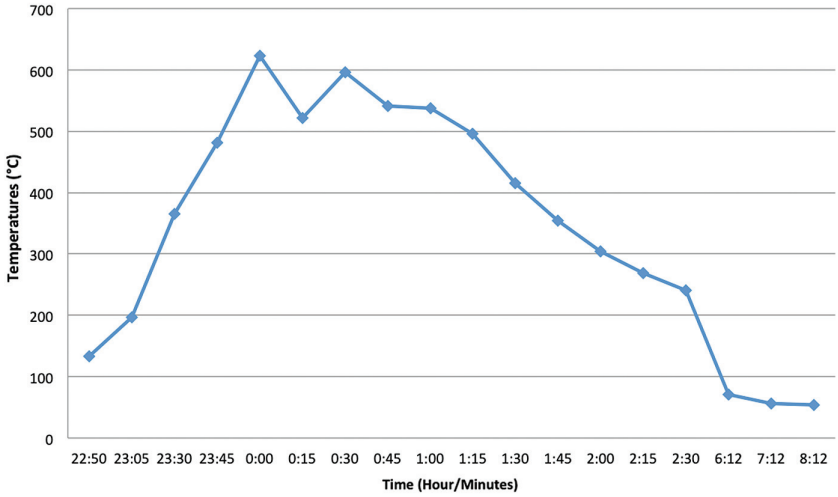

Fig. 4. The firing temperatures recorded on the experimental human-shaped vessel during the combustion process.

Imaging investigations

The XCT approach involved scanning the original archaeological object, as well as the experimental replica. In the latter case, for correct and complete control of the recorded data, following the objective to trace the technological elements related to the production of the humanized vessels, we made several XCT-scans both on the object after drying and also after its firing. In this way, we tried to record how the object transformed during the two major processes involved in making prehistoric ceramic vessels. Moreover, the imaging investigations performed on the experimental replica offer the great advantage of analysing an object made under controlled conditions, for which all the production sequences and quantities of raw materials used have been recorded, thus allowing a reasonable interpretation of the resulting imaging data and their correlation with the structural and composite data of the analysed item. Moreover, this type of information becomes an accurate reference index that can be used in the case of archaeological artefacts for which this kind of data is missing.

Due to the large dimensions of both the original pot and experimental replica compared to the measurement capacity of the X-ray detector, the imaging investigations were made in three stages for every pot (lower, middle and upper parts, applied on original pot, dried replica and fired replica, respectively).

Generally, considering the potential of the imaging investigations to answer different questions regarding pottery technology (*Berg 2008; Kahl, Ramminger 2012; Ignat* et al. *2017; 2018; Kozatsas* et al. *2018; Manea* et al. *2019*), our approaches aimed to identify the following aspects: (i) characteristics of ceramic paste; (ii) primary forming techniques; (iii) joins of the anatomical elements on the pot; (iv) surface finishing; (v) cracks or repairs.

Goddess of Sultana pot	Weight (g)	Capacity (l)	Max. pot diameter (cm)	Height (cm)
Original	1873	2.0	19.8	32.3
Replica (after modelling)	3335	n/a	23.6	37.0
Replica (after drying)	2790	n/a	22.5	35.2
Replica (after firing)	2540	3.3	22.0	34.5

Tab. 1. The size and weight of the experimental human-shaped vessel at different stages of production compared to the original pot.

Characteristics of the ceramic paste

The most visible non-plastics in the clay recipe of the original pot and experimental replica were the *carbonate concretions* inclusions (Fig. 5). Their density, shape, size and distribution (Tab. 2) indicate their presence in the clay matrix as natural in-

Characteristics of ceramic paste	Original human-shaped vessel	Experimental replica (after drying process)	Experimental replica (after firing process)
Natural inclusions	*Carbonate concretions:* • whitish or light grey in colour • rare density (1–2%) • size 1–5mm • high sphericity • well-rounded, rounded or sub-rounded *Organic matter:* • black in colour (voids) • rare density (<1%) • elongated, ovoid or spherical	*Carbonate concretions:* • whitish or light grey in colour • sparse density (2–5%) • size 1–10mm • high and low sphericity • sub-rounded, sub-angular or angular	*Carbonate concretions:* • whitish or light grey in colour • sparse density (2–5%) • size 1–10mm • high and low sphericity • sub-rounded, sub-angular or angular
Tempers	*Grog:* • hardly noticeable • light grey or ash grey in colour • undeterminable density • dimensions 1–2mm • low sphericity • angular	*Grog:* • hardly noticeable • light grey or ash grey in colour • undeterminable density • dimensions 1–2mm • low sphericity • angular	*Grog:* • hardly noticeable • light grey or ash grey in colour • undeterminable density • dimensions 1–2mm • low sphericity • angular
Clay matrix	• no particularities could be distinguished	• no particularities could be distinguished	• no particularities could be distinguished
Voids	• black in colour • sparse density (3–5%) • size 1–15mm • irregular, elongated, ovoid or spherical shapes • vertical, diagonal or horizontal orientation	• black in colour • rare density (1–2%) • size 1–15mm • irregular, elongated or ovoid shapes • vertical or mostly random orientation	• black in colour • rare density (1–2%) • size 1–15mm • irregular, elongated or ovoid shapes • vertical or mostly random orientation

Tab. 2. Characteristics of ceramic paste resulted from the X-ray CT performed both on the original human-shaped vessel and experimental replica (dry and fired).

clusions specific for the clay sources. There are slight differences in density, roundness, and shape between the original pot and the experimental replica. The high sphericity and the rounded shapes of the carbonate concretions show that the clay source used for the original pot was a redeposited sediment gradually washed and eroded by the alluvial waters. The clay used for the experimental replica was collected from the base of the loess deposit near the site (from a depth of about 4m). The movement of the carbonate concretions from this layer was slower over time, and thus their roundness and shape are of both high and low sphericity, and many of them have sub-angular and angular shapes. Nevertheless, the presence and characteristics of the carbonate concretions in the original pot point out to a local clay source exploited in the vicinity of the Sultana-Malu Roşu tell settlement.

The presence of grog in the original pot was observed when both surfaces were analysed in detail with the naked eye and the digital reconstruction of the scraped interior areas (Fig. 7.A1). As was already stated, the clay recipe used for the experimental replica contained 25% grog. Knowing this information, it was interesting that grog was hardly noticeable as non-plastic inclusions in all the tangential sections of the analysed pots (Fig. 5), even though the digital images were processed in various light intensities in order to highlight the non-plastics from the clay matrix. The difficulty of identifying grog inclusions in pottery through XCT analysis has also been reported by Wolf-Achim Kahl and Britta Ramminger (*2012*). According to them, this is a consequence of the similarity between the attenuation coefficients of the grog and fired clay matrix. In the case of the tangential sections of the unfired replica, the observations were identical (Fig. 5.B1-3) and showed no noticeable differences when unfired and fired clay was analysed using XCT images.

The fine clay matrix had no different particularities in the radiographic images of the analysed vessels.

The voids were observed in radial sections (Fig. 6) and are marked by black patches inside the vessel's walls. Their sources can differ depending on the technological variation in the production chain (*Kahl, Ramminger 2012*). The ones in the original pot have a sparse density and various sizes and shapes (Tab.

2). The ovoid and spherical ones (Fig. 6.A1-2) could have been organic grains (possible seeds) that vanished during the firing process. Some of the elongated voids from the feet walls seem to be formed due to the disappearance of organic matter during combustion (Fig. 6.A3). The sparse frequency shows that the organic inclusions were natural or accidental in the clay and not intentionally added as temper. Other elongated and irregular voids were formed during the modelling of the pot and will be discussed in the section assigned to primary forming techniques. The void network in the experimental replica remained virtually the same after the firing process (Tab. 2; Fig. 6.B1-3,C1-3).

Firstly, this situation is due to the absence of organic inclusions in the clay used for the experimental replica. Secondly, this is a solid clue that no significant changes in the clay fabrics occurred during the firing. Consequently, the primary void network in the experimental replica was formed during the modelling and drying process.

Primary forming techniques (Tab.3)

The identification of primary forming techniques (*Rye 1981; Rice 1987; Thér 2016*) has been mainly based on a visual analysis of the inclusions and void orientations observed in the radial sections (*Kozatsas* et al. *2018*). The tangential and horizontal sections were also analysed, but their examination brought a minor contribution to the final interpretation of the forming techniques. The observations were made on three different parts of the vessels (lower, middle and upper) according to the XCT-images obtained for each part (Fig. 6).

The elongated and irregular voids in the core walls of the lower part of the original pot (the feet) predominantly have a vertical orientation or more rarely a diagonal one (Fig. 6.A3). Their morphology and orientation can be recognized as traces left by coiling combined with sequential pinching, a technique that uses coils to build the walls followed by pinching for modelling the shape and to control the thickness of the walls (*Thér 2016*).

Both horizontal and vertical voids are detectable in the middle part of the original pot (Fig. 6.A2). The horizontal ones attest to the coiling technique, while the vertical ones indicate pinching after adding the coils. A flattened patch was used to reinforce the back of the vessel (Fig. 6.A2, down left). In the case of the experimental replica, the coiling technique is more noticeable in the XCT-images of the middle part, considering the presence of horizontal cracks and voids.

The upper part of the original pot has voids that are relatively vertically oriented (Fig. 6.A3), similar to those identified in the lower part of the vessel. The most probable technique used for the primary forming of this part of the vessel was coiling and pinch-

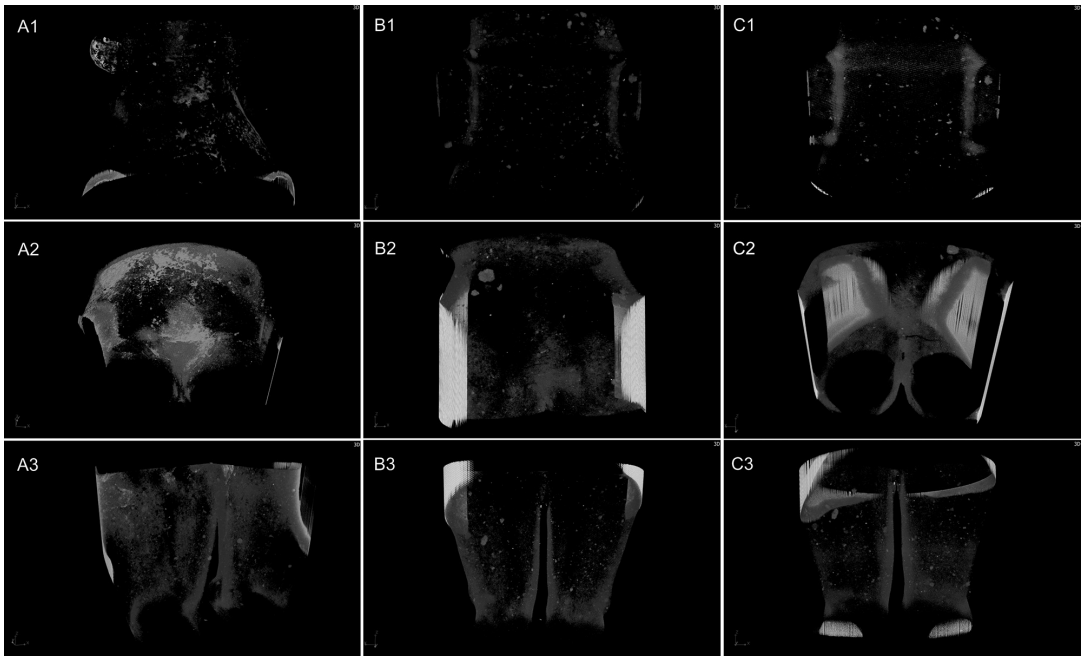

Fig. 5. CT-images of tangential sections of the original pot (*A1-3*), dried experimental replica (*B1-3*) and fired experimental replica (*C1-3*).

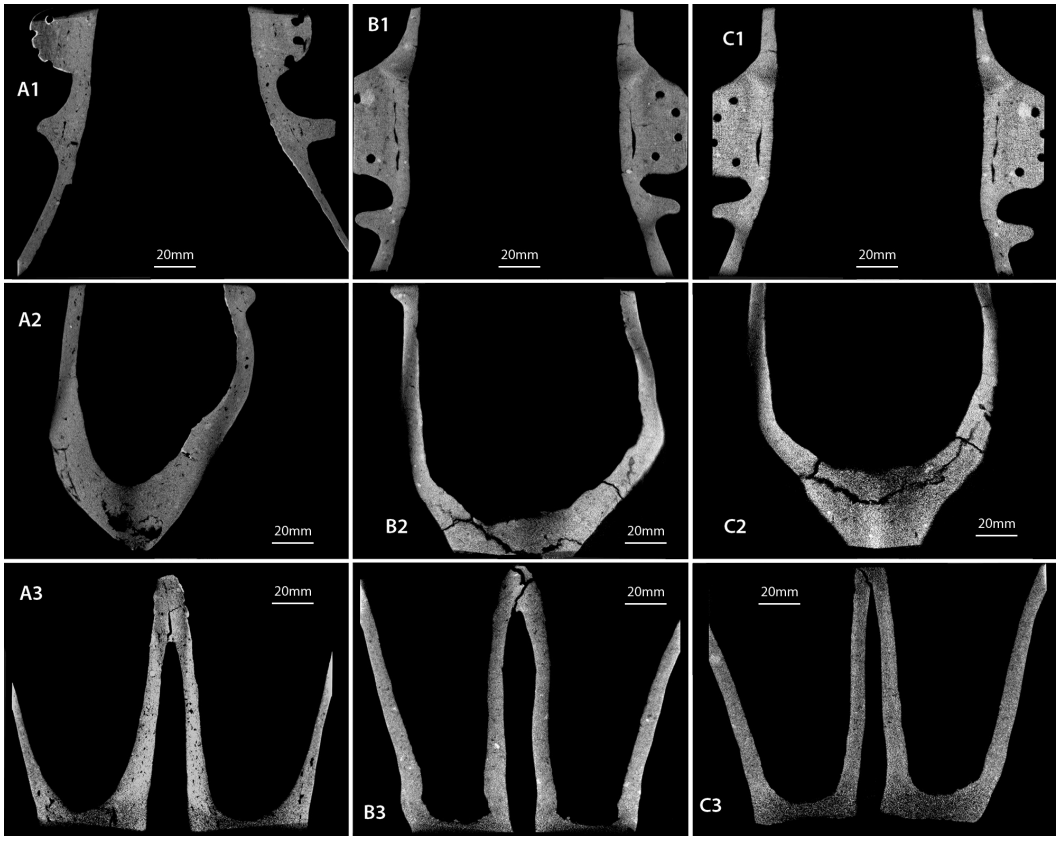

Fig. 6. CT-images of radial sections of the original pot (*A1-3*), dried experimental replica (*B1-3*) and fired experimental replica (*C1-3*).

ing. The coiling used to build the upper part of the experimental replica was detectable only in specific areas of the XCT-images. The application of the rim as a separate coil is the most visible, while the rarely encountered horizontal voids can be interpreted as traces left by the use of the coiling technique.

Joins of the anatomical elements on the pot (Tab. 3)

The embossed anatomical elements on the original pot (hands, nose, ears) could have been made in three ways: (a) by dragging clay from the vessel's walls, (b) separately modelled and then attached to the vessel or (c) gradually formed by attaching small pieces of clay modelled in place. Right after the vessel was built, the anatomical elements of the experimental replica were attached as pieces of clay that were subsequently modelled into the desired shape. Prior to joining the anatomical elements, the vessel's surface was prepared by scraping and moistening with water. The radial section of the upper part of the original pot (Fig. 6.A3) shows elongated voids in the joining areas of the hands and ears, indicative of a wet join performed while both the vessel's walls and anatomical elements were wet and moist (*Kozatsas* et al. *2018*). In the radial section of the experimental replica (Fig. 6.B3,C3), the same pattern is visible for the joining of the ears, but there are no noticeable traces to indicate the joining of the hands. The joining of the nose was not visible in the XCT-images, neither for the original pot nor the experimental replica.

Surface finishing (Tab. 3)

The XCT-images for the internal surface of the original pot (Fig. 7.A1-3) showed multiple traces of scraping and smoothing in vertical and diagonal paralleled stripes that can be interpreted as traces left by the potter's hand. In contrast, the external surface was well polished (no tool traces left) and then decorated by painting (Fig. 8.A1-3). The interior of the experimental replica was constantly scraped with a bone spatula and then smoothed with a reed stem during the vessel's building process. Consequently, the traces left and identified on the XCT-images consist of small lines of horizontal or diagonal orientation (Fig. 7.B1-3,C1-3). Inside the pot, traces of fingers can only be spotted in the middle area (Fig. 7.B2,C2). The external surface of the replica vessel was well polished using a river pebble, and the traces left are not detectable in the XCT-images (Fig. 8.B1-3).

Repairs or cracks (Tab.3)

The original pot has no visible cracks when examined by the naked eye. However, the investigation of the images obtained by XCT revealed several cracks that appear mainly in the joining area of the feet but also on the middle part of the pot (Figs. 6. A2-3; 7.A2). The first ones are related to the pressure exerted on the joining area of the feet while the upper part was built, and the standing pot was slightly moved during the work. The same cracks appeared on the experimental replica during the building process (Figs. 6.B2,C2; 7.B2,C2). The horizontal crack from the middle part (Fig. 7.A2) of the original pot was most probably formed due to a deficiency in joining the coils used for the primary forming. Other diagonal cracks in the same area could result from the secondary firing of the pot. The horizontal cracks in the experimental replica also appear in the middle part (joining of the coils) and at the joining of the rim with the vessel's body (Fig. 6.B1,C1).

Discussions

The multiple approaches used to examine the inside and the outside of a human-shaped pot from Sultana-Malu Roşu allowed us to obtain a specific data set regarding the characteristics of the humanized pottery produced by these prehistoric communities.

Our goal was to focus on the manufacturing process that past potters followed to make such humanized vessels. This approach allows us to record some exciting data and identify the invisible elements about the *chaîne opératoire* undocumented in the archaeological record. Firstly, it should be noted that despite the complex appearance of the vessels with human morphological attributes, the manufacturing process would not be a great challenge for a potter with regular experience in the field. As we previously showed, various stages of collection and preparation of raw materials alongside the modelling process fit well in the pottery production standards manufactured by hand. Moreover, the anatomical components are easy to achieve and do not require special skills. The painting decoration process is also included in the production standards previously observed (*Ignat* et al. *2012; 2013; 2017; 2018; Ignat, Opriş 2015; Opriş* et al. *2017*). The time required is imposed not by the shape of the ceramic vessel but by the complexity of the painted motifs, for which some artistic skills are needed.

However, beyond these general observations there was a series of changes in how the experimental container behaved in different stages of production. Thus, according to the data presented in Table 1, we observe that the object's size and weight changed in

Forming features	Original human-shaped vessel	Experimental replica (after drying process)	Experimental replica (after firing process)
Primary forming techniques	• coiling + pinching (?), flattened patches in the lower part of the feet • horizontal coiling and flattened patches for the middle part of the pot • coiling + pinching (?) for the upper part	• no particularities could be distinguished for the lower part (feet) • hardly noticeable horizontal coiling for the middle part • horizontal coiling for the rim	• no particularities could be distinguished for the lower part (feet) • hardly noticeable horizontal coiling for the middle part • horizontal coiling for the rim
Joins of the anatomical elements on the pot	• ears and hands added after the primary forming of the pot	• ears clearly added after the primary forming of the pot	• ears clearly added after the primary forming of the pot
Surface finishing	*Internal:* • vertical scraping with the fingers on the feet • diagonal and vertical scraping and smoothing with the fingers in the middle and upper part *External:* • polished with a hard tool	*Internal:* • horizontal and diagonal scraping and smoothing with a hard tool • fingers prints in the middle part *External:* • polished with a hard tool	*Internal:* • horizontal and diagonal scraping and smoothing with a hard tool • fingers prints in the middle part *External:* • polished with a hard tool
Cracks or repairs	• crack in the feet joining area • horizontal crack in the back of the middle part • no traces of repairs	• multiple cracks in the feet joining area • no traces of repairs	• multiple cracks in the feet joining area • no traces of repairs

Tab. 3. Forming features resulted from the X-ray CT performed both on the original human-shaped vessel and experimental replica (dry and fired).

the different stages of the manufacturing process. All the recorded changes are related to the chemical-physical characteristics of the paste used for the pot making process, and its evolution during the drying and firing stages.

More valuable data regarding the compositional and structural aspects of the original pot were provided by the XCT investigation and comparison with the experimental replica. The XCT-images have allowed for the first time to view inside the walls of the original pot and consequently helped us characterize its ceramic paste. The presence of natural non-plastic inclusions such as rare spherical carbonate concretions and sparse organic matter, followed by the comparison with the inclusions from the experimental replica that was made with clay collected near the site, are indicative of a raw clay collected from a local deposit of alluvial nature. The hypothesis that the original pot was manufactured locally is strengthened by the presence of grog used as temper, a long-term tradition in making ceramic paste recipes observed for most of the Eneolithic pottery found within the tell settlement from Sultana-Malu Roşu. The shape, size and orientation of the voids indicate that the original pot was primarily formed by coiling followed by pinching, and in some cases, the flattened patches were used to reinforce the walls. However, some questions on this topic still remain, mainly because when these primary forming techniques (*e.g.*, coiling and pinching) were applied on the experimental replica, their specific traces were only partially revealed by the XCT analysis. More clearly, results were obtained regarding the joining of the anatomical elements. The arms and ears of the original pot were attached after the building of the vessel's walls, while the nose, mouth and eyebrows did not bear any traces indicative of joining to the pot. The internal surface of the original pot was only scraped and smoothed by fingers. This little care for the internal surface made it unusable for liquid contents, even if its shape recommends it for this kind of use (*Skibo 2013*). In contrast, the external surface was well polished and decorated by painting. The XCT-images also revealed hidden cracks in the joining area of the feet and the middle part of the original pot. The high similarity with the cracks observed in the experimental replica can be a solid argument that both vessels were built using comparable steps and construction techniques.

When it comes to the possible functional attributions that the analysed human-shaped pot could have fulfilled, we were able to identify some features that might suggest certain functions. However, a clear interpretation is difficult to achieve based only on the structural and typological particularities of the archaeological artefact and the experimental replica. As mentioned earlier, certain elements (such as the volume or the shape) may suggest a distinct function for this particular vessel, for example, its use as a recipient for short-term storage of liquids or for

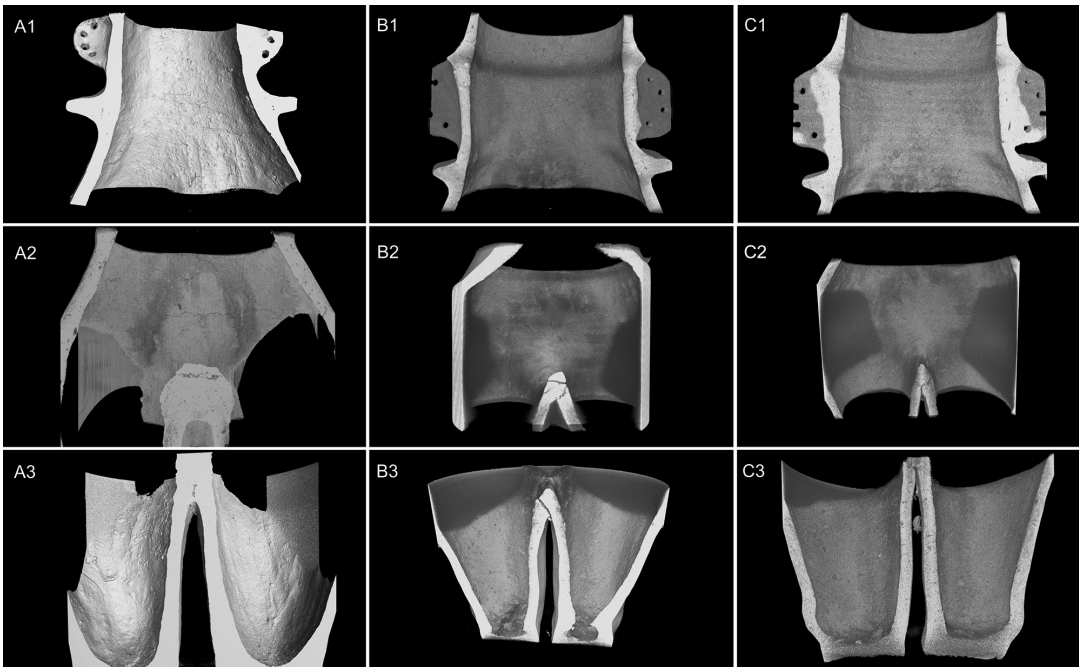

Fig. 7. 3D CT-images of the internal surfaces of the original pot (*A1-3*), dried experimental replica (*B1-3*) and fired experimental replica (*C1-3*).

gathering and transferring them to another container. However, other characteristics (such as the little care for the internal surface or the multiple cracks inside the walls) make it impractical for liquid-related uses and indicate other functions. At the same time, its usage as a storage container for different types of 'flowing solids' (*Opriş* et al. *2017*), even if it is a more viable option, at some point may also become questionable due to the wear traces that suggest the use of this vessel for gathering rather than storage. Therefore, while several features may suggest one or more functions, the presence of other elements may dismantle the previous assumptions, thus creating a vicious circle in interpreting the function of such a pot. In this context, for an interpretation as accurate as possible regarding the function of this particular human-shaped vessel, further experiments must be conducted by using several replicas of it under different conditions (for example, using them for gathering different types of goods, transporting the vessels in different ways while empty or/and full, *etc.*). This approach, in correlation with the functional and use-wear information provided by the current study, may ultimately lead to a better understanding of how this vessel was used in the distant past.

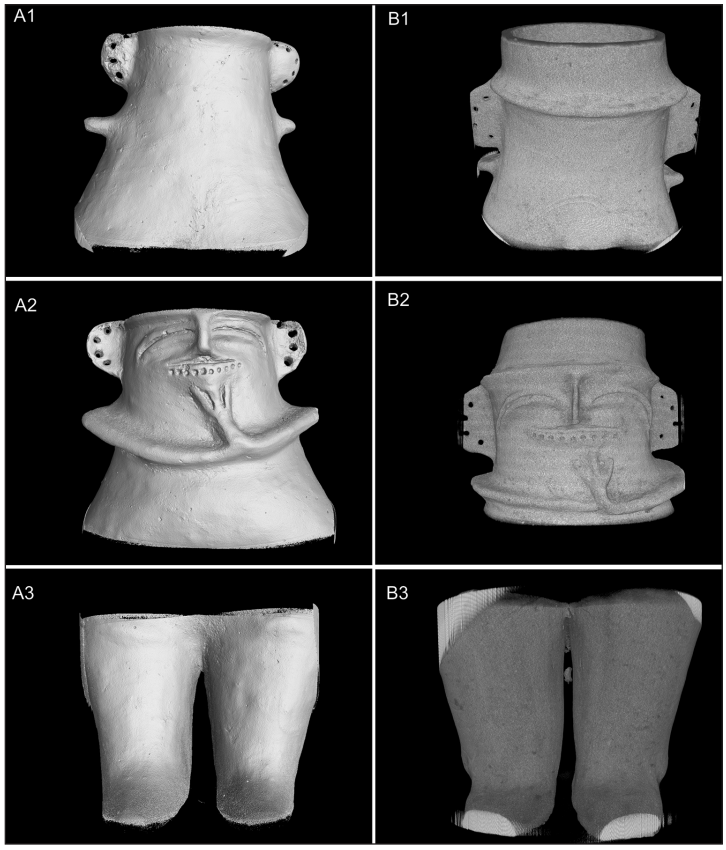

Fig. 8. 3D CT-images of the external surfaces of original pot (*A1-3*) and fired experimental replica (*B1-3*).

Conclusion

The present study revealed the potential of combining multiple approaches in investigating a unique Eneolithic pot discovered at Sultana-Malu Roşu. Thus, with the help of archaeological data and experimental archaeology, coupled with X-ray Computed Tomography, we have been able to identify multiple invisible aspects regarding the manufacturing process of the human-shaped pot known as 'The Goddess from Sultana'. By carefully following and analysing all the operational sequences (harvesting and preparation of raw materials, modelling and decoration of the pot, the drying and afterwards the firing process) in terms of the technology, time and skills required for the different stages of production, we managed to shed some light upon the methods used to obtain this final product and on what the entire process implied for the potter. Furthermore, the XCT investigation facilitated a detailed examination of the archaeological pot's internal structure, as well as that of the experimental replica, thus offering the possibility of identifying technological elements (characteristics of ceramic fabric, primary forming techniques, surface finishing, repairs or cracks) related to the chain of production. Moreover, the techno-functional analysis provided a small but interesting set of data, which allowed us to set up some new research goals for the near future to investigate how this human-shaped vessel – or similar ones – was used in the past.

Unfortunately, the correlation of all typological-stylistic, experimental, XCT-scan and techno-functional data about this unique humanized pot suggests a controversial function that at the moment can be framed neither as special nor as ordinary. However, this particular vessel, 'The Goddess from Sultana', indirectly reflects the ideology, beliefs, wishes, desires, visions about the world, humans, nature, daily life cycles and differing technological, organizational, and social approaches of past peoples. The tendency of human communities to represent the familiar silhouette of the human body or give objects a human (or quasi-human) form is a natural process of expressing the visual identity perceived by these

people in the past. The act of adding typically human anatomical elements (*e.g.*, eyes, ears, hands, *etc.*) to inanimate objects is well documented in KGK VI communities. This seemingly technological act transforms inanimate objects into living objects, and thus active tools that are part of, live with and contribute to the daily setup of these people's lives. Some particular elements found in this study (*e.g.*, the use of the vessel in a horizontal position, not in a vertical one (which is the anatomical orientation of the figure), prove the complexity of the vision and imagination of prehistoric people, but also the high amplitude of the abstract dimension of the past minds that created and enlivened these artefacts. The way these abstract ideas are manifested through the material culture that these peoples created led (indirectly) to drawing inferences about the factors that governed the daily lives of those communities, and reflected their collective and individual identities. Moreover, humans do not behave under the influence of their senses alone but also through their individual and collective past experiences such as their upbringing correlated with the technological level of expression, beliefs, traditions, ideas, aims, fears, desires, symbols, and myths. These experiences contribute to each individual's unique view of the world, and in this way human groups that live together tend to develop a shared view of the world, which in turn influences their group material culture (*Henley* et al. *2020*).

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AUTHORS' CONTRIBUTIONS

CL supervised the study. VO, BM and TI performed the technological analysis of the human-shaped pot. ML, FC, and RB performed the X-ray Computed Tomography scans. BM, VO, and ML analysed and/or helped to interpret the XCT-scan data. VO made the experimental replicas, and quantification of the data. VO, BM, and CL wrote the manuscript with input from all co-authors. All authors read and approved the final manuscript.

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The Neolithic worked bone assemblage from Ulucak Höyük, Western Anatolia

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ABSTRACT – *In this investigation we detail the results of a systematic analysis of worked animal bone from Ulucak, one of the earliest Neolithic sites in western Anatolia. The collection exhibits a wide range of types, including points, needles, spatulas, bevelled tools, perforated objects, and other unique objects. A study of the raw material shows a preference for sheep and goat long bones, while large-sized animal rib bones were also utilized. Manufacturing techniques employed included splitting, grooving, and abrasion, while a contextual analysis of the material underscores an intricate connection with other objects made from stone and clay. Items found in buildings relate to textile, leather, and ceramic production, while personal ornaments may have played a part in abandonment rituals. Examination of this assemblage is understood as a common set of regional tool types with some localized variations.*

KEY WORDS – *Early Neolithic; Western Anatolia; animal bone artefacts*

Neolitski zbir koščenih izdelkov iz Ulucak Höyüka, zahodna Anatolija

IZVLEČEK – *V razpravi predstavljamo rezultate sistematične analize obdelanih živalskih kosti iz Ulucaka, enega najzgodnejših neolitskih najdišč v zahodni Anatoliji. Zbir predstavlja široko paleto orodij, konic, igel, lopatic, prirezanih orodij, prebodenih predmetov in drugih unikatnih izdelkov. Analiza surovin kaže, da prevladujejo ovčje in kozje dolge kosti. Uporabljali so tudi rebra velikih živali. Tehnike izdelave vključujejo razcepljanje, žlebljenje in brušenje. Kontekstualna analiza je pokazala na povezave z drugimi predmeti, narejenimi iz kamna in gline. Koščeni predmeti, ki so bili najdeni v zgradbah, so povezani s tkanjem, izdelavo usnjenih izdelkov in lončenine. Koščen osebni nakit je bil morda uporabljen v obredih opuščanja bivališča. Predmete razumemo kot regionalen zbir orodij, ki vključujejo tudi lokalne različice.*

KLJUČNE BESEDE – *zgodnji neolitik; zahodna Anatolija; izdelki iz živalskih kosti*

Introduction

The systematic study of worked animal bones at Neolithic and Chalcolithic sites in Anatolia has increased in the last two decades (*Russell 2016*). No longer a neglected sub-discipline, studies have shown how new avenues of scientific testing (*Bradfield* et al. *2019*), use-wear analysis (*Campana, Crabtree 2018*) and spatial analysis (*Samei, Alizadeh 2020*) can add to our understanding of sedentary communities. However, some long-standing excavations from Anatolia are yet to undergo the first element of systematic analysis: the establishment of a typology, raw material identification, and technological, contextual,

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and comparative investigations of their collections to establish a foundation for these further studies.

One of these sites is Ulucak, located 25km east of Izmir. Continuous archaeological excavations since 1995 have uncovered a vast amount of material culture (*Çevik, Erdoğu 2020; Çevik 2019; Çilingiroğlu* et al. *2004; 2012*). Uninterrupted occupation at the site occurred between Level VI (6850/6830–6500 cal BC), Level V (6500–6000 cal BC) and Level IV (6000–5700 cal BC), with habitation in Level III (5600–5460 cal BC) occurring after a brief cultural break. Later levels belong to the Early Bronze Age (Level II) and Middle Bronze Age (Level I), with evidence of Late Roman/Byzantine remains on the surface.

The earliest occupation at Ulucak, Level VI, has been exposed in trenches L13 and partly L12 and K13. This period is known from two adjacent buildings (Buildings 42 and 43), which has a possible communal function, lime plastered and red painted floors and open spaces with fire installations around the buildings (Fig. 1). Level V has five sub-phases (Va-e) and is exposed in trenches L13, L12 and K13. This level consists of rectangular single-roomed domestic buildings with either mud-slab or post-framed walls. After 6000 cal BC, in Level IV, distinctive changes occurred both in the construction technique and size of the buildings. Of the 10 sub-phases of Level IV, only IVb has been exposed in a wider area of about 1000m^2. In Level IVb one- or two-roomed substantial domestic buildings with sun dried mudbrick walls on stone foundations were divided by narrow streets. Level IVc is known from a specialized ceramic workshop with six rooms built of post-framed walls (*Çevik 2016*). The inventory of the workshop consists of several clay loaves, hematite lumps, unfinished vessels, bone tools and grinding stones possibly used for powdering hematite, which indicates the whole sequence of pottery manufacturing (Fig. 2).

Pottery has been attested starting from Level V onwards, while the earliest occupation at Ulucak is devoid of pottery and any other clay objects. Ceramics of the earliest periods include cream, brown and grey burnished wares, with an increase in red-slipped burnished wares in Level IV (*Çilingiroğlu 2012; Çevik, Vuruşkan 2020*). Other items recovered at the site include stone tools (with obsidian mostly originating from Melos), figurines, stamp seals, spindle whorls and loom weights (*Sevindik 2018*). The faunal assemblage (*Pilaar Birch* et al. *2019; Çakırlar 2012*) consists mainly of domestic sheep and goat, with cattle and pig frequently recorded. Deer (most commonly fallow), small mammal (such as hare, fox, and tortoise), bird and fish remains are documented in lower numbers.



Fig. 1. Architectural remains Levels VI, V, and IV.



Fig. 2. Level IVc ceramic workshop.

The worked animal bone collection constitutes a sizeable part of the small finds at the site. Analysis of this material has been limited in previously published accounts (*Çilingiroğlu A.* et al. *2004.50; Çilingiroğlu Ç. 2012.21*), with reports outlining common types such as awls, spatulas, and perforated items. Subsequent systematic analysis of the material has been conducted in more recent unpublished studies (*Paul 2016; Sivil 2017*).

An initial assessment of the worked animal bone was made by Jarrad W. Paul during the 2014 and 2015 excavation seasons. The objects analysed were recovered from the 1997–2015 excavation seasons. An emphasis during the initial assessment was on recording all items stored onsite, establishing a typology, and identifying raw material. A study based on this initial recording of items, which number 268 from Levels VI–III, is included in a comparative analysis of worked animal bone from sites in the north Aegean (*Paul forthcoming*). Coşkun Sivil has further conducted a contextual analysis of the material, a vital step in placing the material within its setting. Sivil's research was based solely on worked bone items from the Neolithic, Levels VI–IV. In his assessment 549 items were recorded, including those stored in the local museum. In this paper, Neolithic material will again be the focus of investigation from the uninterrupted Levels VI–IV, uniting the work of both Paul and Sivil to illustrate a complete picture of the Neolithic worked bone assemblage from Ulucak.

The typology below is informed by Paul's initial analysis combined with Sivil's typological categorization, with a description accompanying each type and subtype. Identification of manufacturing techniques was conducted on-site by Paul using both macro (viewing distinct markers on the object or tool, for instance colouration and breakage patterns) and micro (using a x3 magnifying eye-piece to detect striations left on the object or tool) techniques. The analysis of raw material was also conducted on-site by Paul, with the assistance of Evangelia Pişkin. The contextual analysis is based on research conducted by Sivil. Discussion and interpretation in the present study is conducted by Paul, Sivil, and Çevik. Items are inclusive of those uncovered from 1995–2017.

Typology

A total of 554 worked animal bone items have been placed in Levels VI–IV. The typology created for this assessment was informed by previous research in the region, especially the work of Nerissa Russell (*2016*), Alexandra Legrand and Isabelle Sidera (*2007*) and Marcella Marinelli (*1995*). Objects have been sepa-

rated based on their surmised functional attributes (for example, tools used for piercing). Raw material was then used to further separate objects within types (referred here as sub-types) when necessary. The 554 items identified within this typology do not include any preforms, items too fragmentary to identify, or manufacturing waste as a by-product of worked animal bone manufacture found at the site. Although these items are found on site and mentioned later in this paper (see Context) they are not included in this assessment as the typology only includes items that have been positively identified. The typology includes six types and 23 subtypes (see Tab. 1).

Type	Subtype	Number
1. Point	1A. Metapodial points	115
	1B. Ulna points	7
	1C. Other long bone points	62
	1D. Oval-bodied points	35
	1E. Square-bodied points	54
	1F. Fragments	40
	1G. Flat bone points	6
2. Needle	2A. Perforated needle	24
	2B. Notched needle	2
3. Spatula	3A. Flat spatula	92
	3B. Spatula-spoon	15
4. Bevelled tool	4A. Smoother	26
	4B. Chisel	39
5. Perforated object	5A. Flat bone perforated objects	2
	5B. Long bone perforated objects	6
6. Other	6A. Comb	6
	6B. Bipoint	2
	6C. Bone handle	10
	6D. Antler handle	5
	6E. Worked antler	3
	6F. Fastener	1
	6G. Hook	1
	6H. Arrow/spearhead	1
Total		**554**

Tab. 1. Ulucak Höyük animal worked bone and antler object typology from Levels VI–IV.

1. Points

The most common type in the assemblage are points (n=319). Points are characterized by their pointed tips (Fig. 3). Their primary function was as a piercing tool. They are likely to have been used in textile manufacture, sewing animal hide, scraping ceramic surfaces and in basket weaving. They are separated into seven subtypes.

1A. Metapodial points

These points are made from metapodial (metacarpal and metatarsus) bones and have mostly polished surfaces. Manufactured by splitting along a whole bone, the base of these objects is often left intact. They are the most numerous subtype point (n=115) in the collection.



Fig. 3. Type 1. Points.

1B. Ulna points

Points made from ulna bones are uncommon, with only seven examples recorded. Their natural form lends itself to use as a perforator, with an area to grip to the tool at its base. They would have been a suitable tool for processing soft material.

1C. Other long bone points

These points are made from undetermined long bones. The base of these tools is often rounded and smoothed, making further identification difficult. They are the second most frequent subtype (n=62).

1D. Oval-bodied points

Points in this subtype have their base missing and are defined by the form of their shaft, in this case oval-shaped (n=35). They are made of long bone fragments.

1E. Square-bodied points

As with subtype 1D, square-bodied points have their base missing and are defined

by the shape of their shaft (n=54). They are also made of long bone fragments.

1F. Fragments
Points in this subtype were made hastily, most with asymmetrical shafts, with little polishing on their surface (n=40). The construction of these points included minor morphological changes to the natural structure of the bone fragment. Based on their manufacturing techniques and less elaborated shapes, they may have met immediate needs.

1G. Flat bone points
Flat bone points are made from rib bones. They are the least common subtype, with only six examples, and were used intensively, as indicated by their burnished surfaces. They may have been better suited to working on soft materials, such as hide and textiles, due to their form. They share similar properties with spatulas and may be in fact more akin to the pointed spatula type used for ceramic shaping (*Mărgărit 2017*).

2. Needles
Needles are made from both long and flat bones and include two subtypes: those that are perforated (2A) and those that are notched (2B) (Fig. 4). Perforated needles were drilled either on one side or both and are the preferred subtype, with 24 examples recorded. They are mostly made from rib bones. Notched examples are less frequent, with only two objects noted. The notches for these objects appear at the base. Needles would have been used to combine materials together, with wider and flatter examples associated with basket weaving.

3. Spatulas
Spatulas are also separated into two subtypes: those made from flat bones (3A) and those with a handle (3B) (Fig. 5). Those made from flat bones, rib bones in this case, are the second most frequent subtype in the collection (n=92). They would have been used



Fig. 4. Type 2. Needles.

for pottery moulding, stripping any excess material. Less frequent are spatulas with a handle (n=15), also known as spatula-spoons (*Paul, Erdoğu 2017*). They are made on long bones. All subtype 3B spatulas at Ulucak were located within domestic structures and open spaces. Further use-wear and trace analysis needs to be conducted to determine the function of these tools.

4. Bevelled tools
Tools in this type are sturdy and recovered mostly intact. They are grouped together here for their scraping function and are further separated into two subtypes. The first (4A) are smoothers made from tibia bones (n=26). They have a bevelled tip, unworked base, and a hollow shaft. They are associated with leather manufacture; in particular, the preparation of animal hide. The second subtype (4B) are chisels made from long bones (n=39). They are strong and robust tools, with a thick cortex and bevelled tip (Fig. 6). These tools are associated with wood working activities, ideal for carving and chipping.

5. Perforated bone objects
This type includes any object of worked bone that has been perforated and not considered a needle. They are not common in the collection, with only eight examples (Fig. 7). They are separated into two subtypes based on their raw material: those made



Fig. 5. Type 3. Spatulas.

from flat bones (5A) and those made from long bones (5B). For those made from flat bones (n=2), they may be considered a type of pendant, but due to their fragmented condition it is difficult to assign function. Perforations are drilled from either side of the object. For the long bone examples, they may have been related to weaving activities due to their size (n=6). Further use-wear analysis is needed to determine function.

6. Other

Included in this type are eight subtypes that do not fit into the categories above. They are often unique tools or objects for specific purposes.

6A. Comb

Six objects contain serrated edges, giving the appearance of a comb (Fig. 8). All are recovered from open areas in Late V and IV levels. They are made from long bone fragments and may have been used in textile manufacture to separate fibres, or possibly in pottery decoration, to incise ceramics. However, incised ceramics from the site have deeper and wider lines and dots than bone comb tips. Additionally, the teeth of these combs are often squared and flattened at their ends. Their use in textile production is thus more plausible.

6B. Bipoint

There are two items defined by their flat surface and double active tips. They are found in levels VI and V (Fig. 9).

6C. Bone handle

Also known as a shaft/sheath, these items were used to protect the user's hand during use. Inside the handle would fit an additional tool, such as a sharp stone tool. They are made from long bones (n=10) (Fig. 9).

6D. Antler handle

Similar to the objects above, antler handles, or shafts/sheaths, where made from antler and used to hold an additional tool, most likely a stone tool (n=5) (Fig. 9).



Fig. 7. Type 5. Perforated objects.



Fig. 6. Type 4. Scrapers.

6E. Antler tools

Three additional tools were manufactured from deer antler. Further use-wear analysis is needed to ascertain the function of these variously shaped tools (Fig. 9).

6F. Fastener

This object was recovered on the floor of Building 43 in Level VI. This object has been expertly constructed, delicate, and is fragmented at one end. Its suggested use is as a clothes fastener due to its size and shape. This bone object may have been deliberately placed to the building's floor together with a scapula as part of closing ritual since the building appears to have been left clean (Fig. 9).

6G. Hook

This item was uncovered in Level Vc and could have been used as a hook, owing to its shape and dimensions. It has a perforated tip which curves into a wide and flat shank, akin to fishhooks found in similar Neolithic contexts in the region (*Powell 1996*). However, its functional status is not entirely certain, as a similar item found at Çatalhöyük has been interpreted as a belt hook (*Russell, Griffitts 2013*) (Fig. 9).

6H. Arrow/spearhead

A single arrow or spearhead belongs to Level IVb. It has an oval-bodied shaft, with a pointed and flat tip (Fig. 9).

Not included in this assessment are an additional nine decorated

worked animal bones, which contain several patterned incisions, including zigzags, dots, and chevrons. These items are currently being examined in detail in a separate study.

Raw material

Analysis of the Ulucak raw material occurred on site. It is often difficult to identify species of worked bone items, especially if the objects are extensively worked. As a result, the number of positively identified species is substantially less than the overall number of worked bone items. Moreover, the number of species identified can then be limited when conducting an initial identification in the field. In this case, 95 items were positively attributed to a species from Levels VI–IV (Tab. 2). The results below are summarised from this sample.

Results from this sample show that medium-sized animals (n=61) are favoured for bone tool construction, with large-sized animals also often utilised (n=32). Bones from small-sized animals (n=2) are seldom used. Sheep/goat and sheep-sized animals are most prominent for their use in constructing points, the most frequent tool type. Bones of cattle were also used repeatedly (n=32), while pig, hare, bird, and dog/wolf bones are rare. For the deer (n=14), roe deer are most common, with possible fallow and red deer examples in the collection. In terms of element selection, from the sample (n=95) of tibia bones were used most frequently for bone tool and object creation. Metapodials, including both metatarsal and metacarpal bones, were also used often, along with antler and rib bones. The use of ribs was also not constrained to a certain type; used to construct points, spatulas, and perforated objects. Deer antler was also used in far greater numbers than deer bones.



Fig. 8. Type 6. Other. Subtype 6A combs.

Animal species selection for bone tool and object construction are similar when viewing the zooarchaeological record for Levels VI through IV (see *Pilaar Birch* et al. *2019*). That is, the most common species in the zooarchaeological record, sheep/goat, is also favoured for tool manufacture. Cattle is also frequent, although to a lesser extent, in both the worked and unworked bone groups. Suzanne E. Pilaar Birch and colleagues also note an increase in deer bone frequency over time at Ulucak, which mirrors species selected tool manufacture. From the n=14 items made from deer antler and bone investigated in this sample, n=12 are contextually placed in Level IV, with one in Level V, and one in Level VI.



Fig. 9. Type 6. Other. Subtypes 6B–H, bipoint, bone handle, antler handle, worked antler, fastener, fish related item, arrow/spearhead.

Manufacturing techniques

Craftspeople at Ulucak used a range of manufacturing techniques to construct individual tool types. The most common technique for point manufacture was the splitting and grooving of metapodial bones, before shaping the tip into a point (subtype 1A). Separation of the bone was via bipartition as a result of percussion followed by grooving. The creation of ulna points (subtype 1B) was less labour

intensive with abrasion of the tip to create a point with the base left unworked. Other bone points in the assemblage (1C, 1D, 1E) were created by splitting a bone into irregular splinters and then through the process of grooving and abrasion creating a pointed object. The practice of splitting was also used to create flat spatulas (3A), where a rib bone was split in two and the inner spongy bone was smoothed via abrasion. Tibia bones were used for smoother (4A) items, with the base and shaft of the bone left unworked, while the tip was fractured via percussion then bevelled through abrasion. Objects that were perforated are also mostly drilled from both sides of the tool, evident in the slanted areas around the drill hole, although this may also be an indicator of extensive use-wear.

While most tools contain the usual amounts of soil staining, some show evidence of intense burning, turning some objects black, grey, white, and blue. Bone colour can be an indicator of the degree of burning, with white and blue colouration suggestive of intense heating (*Gilchrist, Mytum 1986.32*). Tools with traces of burning are associated with contextual units that were destroyed by fire, also evident on damaged clay objects. One example, a pointed tool, shows evidence of controlled burning at the tip of the object, a technique used by the Ulucak craftspeople to strengthen the bone. This procedure requires specialized knowledge, as too much exposure to heat will result in damage.

For use-wear, due to time constraints liner striations were only observed under x3 magnification, and this produced limited results. Due to this, we focus here on two subtypes: metapodial points (1A) and smoothers (4A). For metapodial points, the direction of the striations (when positioning the object with the base at the bottom) ran transversely across the body in 21 examples. Nine points showed evidence of longitudinal striations, with less occurrences of diagonal striations (n=6) and no discernible direction (n=5). The remaining points contained no evidence of striation pattern or direction under x3 magnification. For smoothers, most had a collection of random directional striations (n=10) with some exhibiting either longitudinal (n=2) or transverse patterns (n=2). The remaining smoothers showed no evidence of striation pattern of direction under x3 magnification. Further microscopic analysis is needed to ascertain whether striations where the result of use or manufacture wear, and the types of techniques involved in the process, such as scraping or abrasion.

	Species							
	Large-sized	Medium-sized				Small-sized		Total
Elements	cattle	deer	sheep/ goat	dog/ wolf	pig	hare	bird	
antler		12						12
tooth				1	1			2
rib	15							15
mandible	1							1
scapula	1							1
vertebrae	1							1
long bone	5						1	6
radius			2					2
ulna			1					1
tibia		1	21					22
metapodial		1	6					7
metacarpus			4					4
metatarsus			5					5
undetermined	9		6			1		16
Total	**32**	**14**	**45**	**1**	**1**	**1**	**1**	**95**

Tab. 2. Positive species and element identification of worked animal bone objects from Levels VI–IV at Ulucak.

Context

Level VI (6850/6830–6500 cal BC)

Worked bone objects from this period are found in Buildings 42 and 43 and in open areas surrounded by hearths. Low numbers of worked animal bone objects are attributed to Buildings 42 and 43, both of which have red painted lime floors and walls. The buildings are believed to have been deliberately emptied during an abandonment ritual (*Çevik 2019*). This ritual act is supported through evidence of object placement, particularly grinding stones, positioned directly above the location in the previously built structure. As a result, any worked animal bone objects found after cleaning may have been associated with this abandonment ritual. In Building 42 these objects include two points (1A, 1D), and a spatula (3A), while in Building 43 a bone fastener (6F) was found with a scapula. Due to its find context, the bone fastener may therefore be considered an important personal ornament, and due to its connection with the burial of the building, possibly a communal building, may have played a part in wider burial traditions.

Far more worked animal bones are attributed to open areas in this level, found in connection with several hearths and ovens. Points are most frequently found here, with spatulas and

bevelled tools also numerous (Fig. 10). The level of skill used to produce spatulas and bevelled tools is lower when compared to examples in later levels. Similarly, their used surfaces have less abrasion and deformation. The types of tools suggest a mixed production area of leather and textile manufacture. The presence of a high number of animal bones around fire installations may suggest the processing of animals (butchering and hide processing) also took place in the same area. As such, an immediate need for an item may have been met with these opportunistically made tools.

Level V (6500–6000 cal BC)

Ten buildings from this period (22, 23, 27, 30, 33, 40, 47, 51, 54 and 59) contain evidence of worked animal bone tools.

Buildings 40 and 59 represent the earliest buildings from this period (Level Ve). Both buildings contained a low number of processed bone items, following the trend in Level VI. Three items were recovered from Building 40: points of subtypes 1A, 1C and 1E. Associated with Building 59, to its south, is a shallow lime-covered pit, that is believed to be another deposit connected to ritual abandonment. A single bone point (subtype 1G) was found in the pit alongside chipped stone tools, animal bones, and a ceramic sherd. Use-wear on the point suggests its function as a possible scraper involved in ceramic production. Building 54 (Level Vd) shows an increase in worked bone, and material more generally, with the inclusion of four metapodial points (1A), one oval-bodied point (1D), one perforated needle (2A) and one spatula (3A). Among the finds in this building was a higher than usual collection of spindle whorls (a total of 20). The appearance of the needle and spindle whorls together suggests textile production was one important activity carried out in Building 54.

The frequency of worked bone items found in buildings increases towards to end of this period. In Level Vb, Building 30 includes five worked bone pieces (three subtype 3A spatulas and two subtype 4A bevelled tools) and may have been linked to ceramic production given the types of tools recorded and absence of other textile-related items such as bone points and spindle whorls. Building 33 contains three worked bone items (subtype 1A point, subtype 1E point and subtype 3A spatula), while in Building 47 four points are found: one made from a metapodial bone and three from other long bones. Building 51 contained a high density of bone tools (n=17), a standout for this period due to its breadth of types: seven subtype 1A points, one subtype 1E point, a perforated needle (2A), five subtype 3A spatulas, two bone handles (6C) and one antler tool (6E). A stone chisel found in the building was able to be inserted into one of the bone handles, providing a direct link between the two material groups. In addition, an unworked metapodial bone and unworked rib bone were found at the south of the building, perhaps stored for future tool production. The end of Level V (Va) is seen in Buildings 23, 23 and 27. Building 23 contained a single perforated bone needle among 21 spindle whorls and 31 stone slingshots, while in Building 22, a metapodial point, two spatula-spoons, and an antler tool were uncovered. A single bone point was found in Building 27.

Level IV (6000–5700 cal BC)

Buildings in this period are placed in two categories: the specialized ceramic production of Level IVc and residential buildings of Level IVb.

Regarding structures in Level IVc, Building 55 contains the most evidence of worked animal bone. Eighteen items include: two metapodial points (1A), a point made from a long bone (1C), four square-bodied points (1E), a perforated needle (2B), six spatulas (3A), two chisels (4B), a perforated object (5B), and an antler tool (6E). Most items were made from the bones of large-sized animals. One of the points, made from a deer long bone, contained red pigment on its tip. This tool was therefore used for a different purpose than the other bone points in the assemblage, and suggests that at least some tools may have been used haphazardly for mixing/diluting

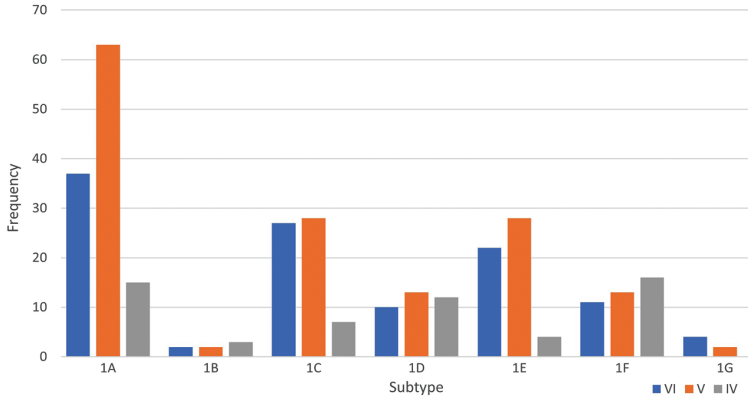

Fig. 10. Point distribution (subtypes 1A–1G) across Levels VI–IV at Ulucak.

paint, not necessarily its originally intended purpose. Worked bone preforms and manufacture waste in relation to wider on-site tool creation are the focus of an additional ongoing study, but it is worth mentioning that Building 55 contained a variety of preformed worked bone tools including a tibia that had been divided into equal parts by splitting but was discarded, and a split long bone with its epiphysis cut.

Other buildings in this category contain fewer worked bone objects. Building 56 contains a single point made from a rib bone (1G), while in Building 61 a metapodial point (1A), an oval-bodied point (1D), a square-bodied point (1E), and two spatulas (2A) were recorded. For Building 62 the types of tools are varied: two metapodial points (1A), a long bone point (1C), a fragmented point (1F), two perforated needles (2A), a spatula (3A), a chisel (4A), and a perforated object (5B).

The worked bone objects in the residential buildings of Level IVb offer an interesting insight into daily tool types. Building 6, for example, contains four worked bone tool objects (a metapodial point, two spatulas, and a perforated needle) among other small finds, such as figurines, pendants, and spindle whorls. Building 13 also records figurines and pendants with the inclusion of two metapodial points and a spatula. Points are the only type found in Building 12, with four made from long bones (1C) and two that are square-bodied (1E), with other objects including a stone tool, a pendant, and 13 beads. A figurine, stone tools, pestles, a grinding stone, and a spindle whorl are seen in Building 52, along with eight worked animal bone items: two metapodial points (1A), a square-bodied point (1E), a perforated needle (2A), two spatulas (3A), a chisel (4B), and a perforated bone object (5A). Four worked bone items were also found in the street between Building 52 and Building 12, although they are too fragmented to be identified.

Regional parallels

From a typological standpoint, the collection at Ulucak is consistent with other collections found in western Anatolia from the Neolithic. For instance, pointed tools are also common at Yeşilova, where deer antler was also used to create tools, including antler handles (or sheaths) (*Derin 2012.180–182*). Points dominate the Ege Gübre collection (*Sağlamtimur 2012.200*), while similar types of objects are found at Çukuriçi Höyük, including points, spatulas, smoothers, and spoons, common after 6500 cal BC (*Horejs* et al. *2015.304*). This trend – the dominance of pointed tools, usually made from the long bones of sheep/goats – is also present in collections in the northwest, at sites such as Uğurlu, Ilıpınar, Barcın, and Aktopralık (*Paul, Erdoğu 2017*), and more broadly throughout Anatolia (*Russell 2016*).

However, there are variations in the Ulucak collection that are unique to the site. For instance, while medium-sized animals were favoured for making bone tools, large-sized animals were also utilized in greater numbers when compared to other sites in western and northwestern Anatolia (*Paul 2016*). Likewise, the under-representation of small-sized animal bones is regionally uncommon. The presence of unique items in the collection, such as the arrowhead/spear, comb, and the intricate fastener, are also rarely seen in the wider region. The number of items in the assemblage is also worth noting, as it is higher than the average for the region (*Paul forthcoming*).

Overall, the Ulucak worked bone assemblage is consistent with other collections in the region. However, when the typology is examined closely on a type-by-type basis and compared with other collections in the region, certain unique trends emerge that illustrate some localization within a regionally established toolkit.

Conclusion

Results of this systematic investigation (including a typology, raw material and contextual analysis) underscore the prevalence and significance of worked animal bone at Ulucak. In the earliest levels of the settlement (Level VI) low numbers and a restricted diversity of types characterize a largely utilitarian toolkit, with production occurring rapidly for short periods of use. As the settlement grew, so did the number and range of tools produced, peaking in Levels V and IV. These tools were also used in conjunction with an increasing number of items made from stone and clay. The tools at Ulucak were produced primarily from the metapodial and tibia bones of medium-sized animals (most commonly sheep/goat), with the rib bones of large-sized animals (such as cattle) also used. A variety of techniques were employed, most notably grooving and splitting of long bones, splitting of rib bones, and shaping via abrasion.

Contextual analysis also provides clues as to the function of these items. Textile manufacture is seen

as the primary role for many of the items in the assemblage. Bone points, needles, and combs in particular formed part of a wider textile toolkit at Ulucak. This is especially clear in Levels V–IV, with evidence of spindle whorls and loom weights (numbering more than 300) at the site being one for the largest collections in western Anatolia for this period (*Sevindik 2018*). However, tool types do not always seem to be restricted to set functions. For instance, the bone point with the painted tip in Level IVc is indicative of an item with an intended function (boring or sewing) that may have been haphazardly used for another purpose, in this case mixing/diluting paint. Leather processing is also suggested to have been conducted using scraping tools, while spatulas could have aided ceramic production. Evidence of preformed items also suggests on-site manufacture.

Tools in use during the Neolithic are also seen to be part of complex abandonment rituals at the site, with items repeatedly placed deliberately on cleaned floors. This may help in understanding the status of worked bone more generally at the site, with scarce evidence of tools found discarded in the streets between buildings after Level IV, perhaps indicative of a possible secondary symbolic importance.

Worked animal bone tools were therefore an important aspect of the social and economic life at Ulucak for over 1000 years of initial occupation. This study has laid the foundation for future worked bone research at the site, with additional analysis needed, such as detailed use-wear analysis, to confirm the results of current interpretations.

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Pattern and variation in jewellery production sequences: analysis of 4th millennium BC amber assemblages from the Latvian coast

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ABSTRACT – *This study considers the production sequences of amber jewellery from Sārnate and Siliņupe, at the coast of present-day Latvia. Differences between the two sites in terms of the relative frequency of items discarded in various production stages may be related to the degree of integration into exchange networks. Within-assemblage variation in terms of the point within the processing sequence when perforation was performed indicates a strong element of heterodoxy with respect to amber processing within the communities, congruent with a domestic setting of production, even though the output consisted of a rather standardized range of forms.*

KEY WORDS – *amber; Neolithic; jewellery;* chaîne opératoire*; Latvia*

Vzorci in variacije pri zaporedjih izdelave nakita: analiza zbira jantarja iz 4. tisočletja pr. n. št. z območja latvijske obale

IZVLEČEK – *V študiji obravnavamo postopek izdelave jantarnega nakita iz najdišč Sārnate in Siliņupe na obali današnje Latvije. Razlike med najdiščema so z vidika pogostnosti predmetov, ki so bili odloženi v različnih fazah izdelave, povezane s stopnjo integracije v menjalni krog. Kljub vidni standardizaciji oblik, ugotavljamo pri obravnavanih jantarnih predmetih močna odstopanja v izdelavi, in sicer v fazi prebadanja, kar je skladno z domačo izdelavo.*

KLJUČNE BESEDE – *jantar; neolitik; nakit; operacijska sekvenca; Latvija*

Introduction

Amber has been a major focus of research into the concluding epoch of the Stone Age at the south-eastern and eastern shores of the Baltic Sea. Amber nodules washed up on the beaches were being widely collected and processed to make jewellery, and distributed via exchange networks far into the continental interior as well as northwards on the eastern side of the Baltic (*Vankina 1970.Fig. 145; Zagorska 2003; Zhulnikov 2008; Núñez, Franzén 2011; Loze 2001; 2003; 2008*). While the role of amber within the social milieu of the time is, as yet, poorly understood, it is evident that the processing and exchange of amber was an important factor in coast-inland contacts and interaction starting from about 4000 cal BC, when this material makes its appearance in archaeological collections.

This article considers, from a comparative perspective, amber assemblages dated to 3600–2900 cal BC from two sites at the Latvian coast, seeking to characterize and interpret processing sequences through the analysis of semi-manufactured ornaments. Following the nomenclature widely utilized in this region of Europe, our sites fall within the

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Neolithic, as defined by the presence of pottery, even though paleaoeconomic data indicate a predominant reliance on wild foods, especially fish and marine mammals in the case of these coastal settlements (*Zagorska 2000; Bērziņš 2008.293–330; Bērziņš* et al. *submitted*).

The sites and amber assemblages

The Sārnate and Siliņupe sites (Fig. 1), providing the amber assemblages discussed here (both held at the National History Museum of Latvia), are coastland habitations yielding abundant evidence for the exploitation of a range of wild food resources, including terrestrial and marine mammals, fish and birds. Both were situated so as to provide good access to freshwater as well as marine environments.

Importantly, amber was a locally available raw material at both sites, since lumps of amber, transported by longshore sediment drift from the Sambian Peninsula, could be gathered on nearby beaches (*Vankina 1970.350; Bērziņš* et al. *submitted*).

This article analyses a subset of the amber assemblages from the two sites, namely the semi-manufactured and finished pieces belonging to the three main jewellery classes: button-shaped beads, tubular beads and pendants (*i.e.* disregarding comparatively rare forms, such as discs, rings and unusual forms of beads, and a small number of figurines and other atypical pieces). The quantities of unworked lumps and flakes are also considered, but without further analysis.

Sārnate

The amber assemblage from Sārnate, located near the north-western coast of the Kurzeme Peninsula, was recovered in the course of excavations directed by Eduards Šturms in 1938–1940 and Lūcija Vankina in 1949 and 1953–1959 (*Vankina 1970; Bērziņš 2008*). It may be noted that this is a peat-bog site with excellent wetland preservation, yielding a diverse array of organic artefact finds. More relevant in the context of amber studies is the clustered pattern of artefact distribution on this extensive site. Distinct clusters of artefacts are in most cases associated with structural remains surrounding a hearth, and on this basis the collection has been subdivided into smaller assemblages relating to individual household units or 'dwellings'. In view of the range of seasonally exploitable food resources, the substantial character of the living structures and the presence of fragile and bulky equipment, Sārnate is thought to have been occupied year round (*Bērziņš 2008.381–383*).

Sārnate has given a very large collection of amber finds, which includes 638 semi-manufactured and finished ornaments along with unworked lumps and a great quantity of debitage (*Vankina 1970.Tab. 6*). Here, however, for the purpose of direct comparison with the Siliņupe assemblage, we shall consider only that part of the Sārnate amber collection which was recovered from dwellings with pottery classed as Early Sārnate Ware, representing one of three phases of occupation on this site.

Importantly, the Early Sārnate Ware phase at Sārnate is also taken to include dwelling no. 2. This particular dwelling is quite exceptional, in that it produced a vastly greater quantity of amber finds than all of the rest. The dwelling consisted of an artefact cluster associated with a spread of sand measuring 4x8m, which seems to approximately reflect the size of the living structure (*Bērziņš 2008.297*). The ceramic assemblage from this dwelling was a very small one. Nevertheless, the distinct prevalence of porpoise tooth stamp (*Bērziņš, Dumpe 2016*; 'tooth stamp' in *Bērziņš 2008.Tab. 10*) among the various kinds of stamped pottery decoration serves to place it in the Early Sārnate Ware phase,

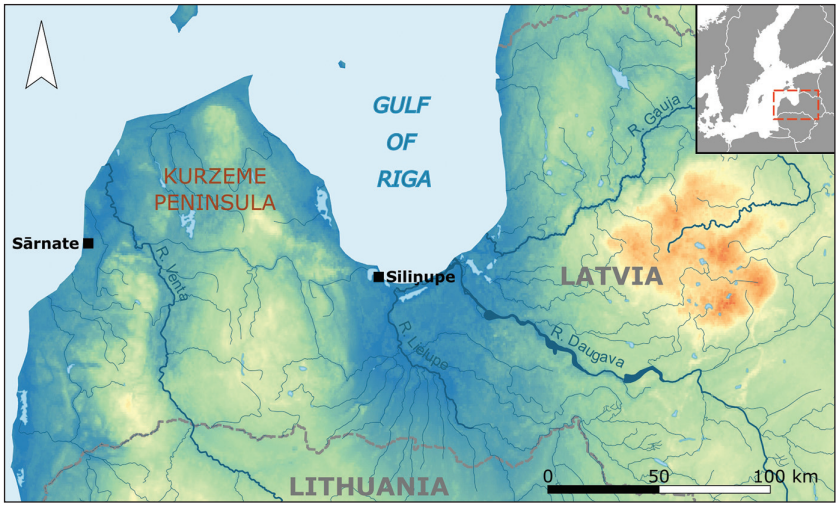

Fig. 1. Map of present-day western and central Latvia showing the Sārnate and Siliņupe sites and the major watercourses.

so that we may usefully compare its amber assemblage with the much smaller assemblages from the other dwellings of this phase.

Five samples from the Early Sārnate Ware dwellings at Sārnate have been dated. If we exclude two dates obtained from residue on pottery (Ua-33828 and Ua-15984), considered to be subject to the reservoir effect, we are left with three dates from charcoal that give an overall date range of 3516–2880 cal BC for the Early Sārnate Ware phase at Sārnate.

The amber ornaments from Sārnate considered here, namely the pieces identifiable as semi-manufactured and finished button-shaped beads, tubular beads and pendants from dwellings of the Early Sārnate Ware phase, number 152 in total. Dwelling 2 alone provides 117 of these, and the remaining 35 come from several other dwellings and one artefact cluster of this phase (dwellings D, E, $M_{ZA}/M_{ZR}/M_D$, P_a, R_Z/R_D, I_Z/I_D, W and the artefact cluster recorded as 'hearth 16'). In addition, seven unworked amber nodules and 2071 flakes were recovered from the dwellings of this phase, as shown in Table 2.

The typology of amber jewellery from Sārnate has been treated comprehensively by Vankina (*1970. 105–114*), which also offers a general discussion of amber processing and exchange. A new analysis was undertaken by Valdis Bērziņš (*2003*), focusing specifically on production stages and intrasite spatial analysis, and evaluating the evidence for craft specialization. The current article utilizes part of the data compiled in Bērziņš's study, reconsidered in the light of recent experimental work and theoretical developments, and viewed from a comparative

Sample description	Lab. no.	^{14}C age BP	Calibrated date, cal BC, 2σ	Notes
Sārnate, Early Sārnate Ware dwellings				
Residue on potsherd with porpoise tooth impressions (A 11416:42), dwelling I_D	Ua-33828	5480±40	4443–4249 (95.4%)	Previously published in *Bērziņš 2008.Tab. 2.* Subject to freshwater and/or marine reservoir effect from vessel contents? (Not adjusted)
Residue on potsherd with porpoise tooth impressions (A 11417:313), dwelling M_D	Ua-15984	5065±75	4036–3655 (95.4%)	
Charcoal, dwelling R_Z/R_D	Tln-2918	4570±65	3516–3036 (95.4%)	
Charcoal, dwelling M	FTMC-UM96-5	4484±29	3342–3090 (92.3%) 3054–3034 (3.2%)	
Charcoal, dwelling D	FTMC-UM96-4	4300±31	3011–2880 (95.4%)	
Siliņupe, Early Sārnate Ware phase				
Charcoal (deciduous wood) extracted from pottery sherd no. 84 (with porpoise tooth decoration), area 7, level 3, 1989	Poz-133269	5330±50	4326–4287 (8.6%) 4266–4043 (85.2%) 4012–3998 (1.7%)	Subject to freshwater and/or marine reservoir effect from vessel contents? (Not adjusted)
Wood charcoal, area 7, central part, level 4, squares 8–11/f-g-h, 1988	FTMC-UM96-3	4791±31	3640–3524 (95.4%)	
Wood charcoal, area 5, level 3, hearth, 1988	FTMC-UM96-2	4743±31	3633–3500 (75.8%) 3432–3380 (19.6%)	
Bark roll – net float? (*Betula* sp.), inv. no. 292/539, area 7, S part, level 4, depth 1.1–1.3m, 25.07.1989	Poz-123665	4690±40	3624–3580 (8.8%) 3532–3368 (86.6%)	
Wood charcoal, area 5, level 3, hearth, 1988	FTMC-UM96-1	4545±30	3370–3306 (32.1%) 3300–3282 (2.5%) 3276–3266 (1.2%) 3243–3102 (59.7%)	
Bone (*Bos taurus*, centrotarsale), area 10, level 3, ~0.5–0.8m, 1989	Poz-137614	4490±35	3351–3089 (91.8%) 3057–3033 (3.6%)	
Bone (*Alces Alces*, phalanx), area 7 (S part), level 3, ~0.6–1.0m, 1989	Poz-137613	4450±35	3337–3210 (40.0%) 3194–3010 (51.9%) 2981–2961 (2.0%) 2951–2935 (1.6%)	

Tab. 1. Radiocarbon datings for the Early Sārnate Ware phase at Siliņupe and Sārnate. Conventional ^{14}C ages have been calibrated using OxCal v4.4 (*Bronk Ramsey 2009*) and the IntCal20 atmospheric curve (*Reimer *et al.* 2020*). Tln-2918 is a conventional radiocarbon dating; all the rest are AMS datings.

perspective, setting it against newly obtained data for the Siliņupe assemblage.

Siliņupe

The Siliņupe site, at the south-western shore of the Gulf of Riga in the present-day village of Lapmežciems, was excavated by Vankina in 1954 and by Ilga Zagorska in 1988–1989 (*Zagorska 2000; 2003; Bērziņš* et al. *submitted*). The site occupies the slopes of a former beach ridge and a dune ridge running parallel to it, as well as a wet hollow between the ridges. Several occupation phases may be distinguished on the basis of ceramic wares, but the great majority of the pottery assemblage may be classed as Early Sārnate Ware. As with Sārnate, consideration of the seasonality of the food resources used at the Siliņupe site suggests year-round occupation (*Bērziņš* et al. *submitted*).

Six samples from strata at Siliņupe containing Early Sārnate Ware have been radiocarbon-dated. If we exclude sample Poz-133269, thought to be subject to freshwater and/or marine reservoir effect, then the remaining five datings give an overall range of 3640–2935 cal BC for the Early Sārnate Ware occupation phase, in good agreement with the date range for the equivalent phase at the Sārnate site, as given above.

A total of 316 semi-manufactured and finished ornaments have been found at Siliņupe, of which 104 pieces identifiable as button-shaped or tubular beads or pendants are considered here. In addition, 288 unworked nodules and 229 debitage pieces were recovered (Tab. 2).

A brief general treatment of the Siliņupe amber assemblage within the regional context of amber-working and exchange has previously been given by Zagorska (*2003*). In the present study, the material has been re-analysed from a technical perspective, determining the form, dimensions, degree of surface treatment and state of perforation, in order to classify the ornaments into specific production stages (*Čakare 2020*), following the approach previously applied to the Sārnate collection.

Jewellery forms

Most frequent in the amber jewellery assemblage from the dwellings at Sārnate belonging to the Early Sārnate Ware phase are button-shaped beads, totalling 80 (Fig. 2.1–5). These beads normally have a V-shaped perforation visible only from the back, although pieces were often repaired by making a simple front-to-back perforation (Fig. 2.3,5). They are generally circular in plan, with the occasional rectangular or oval example, and the cross-section is biconvex or, less commonly, plano-convex.

The dwellings of this phase have yielded 15 tubular beads, almost all of them cylindrical (Fig. 2.6–8). These have a long, straight perforation, which could be drilled by different methods, from one or both ends.

There are 57 whole and fragmentary pendants from the dwellings of this phase (Fig. 2.9–14), the most common forms being trapezoidal and droplet-shaped. A variety of idiosyncratic pendant forms are also represented, as well as fragments of indeterminate form. The pendants have a short, drilled perforation, usually placed in the thinnest part of the margin. The perforation could be made from one or from both faces, thus resulting in a conical or biconical opening.

At Siliņupe, by contrast, amber processing was concentrated mainly on the production of pendants (Fig. 3.6–13), which number 71, constituting two-thirds of the amber jewellery from the site. Most characteristic of this site are trapezoidal and irregular pendants. The high frequency of irregular pendants may have to do with the straightforward production process: they were made from unworked pieces of amber, without any surface processing, simply drilling a hole where the margin of the piece is thinnest (Fig. 3.9). Pendants made in this way predominate among the pendants from sites of this period along the whole of the western shore of the Gulf of Riga (*Zagorska 2003*).

The other amber pendants from Siliņupe were given a specific form during the initial processing stage. Trapezoidal pendants (Fig. 3.8,11,12) are commonest, generally with a straight lower margin, this being a characteristic form of amber jewellery from graves in the Eastern European forest zone, in Latvia as well as further to the east. Trapezoidal pendants with a concave lower margin also occur. Present in smaller numbers are elongated and triangular pendants, as well as rarer pieces: rhombic pendants, pendants with one straight and one convex margin, and idiosyncratic forms that are not typologically classifiable. At Siliņupe, pendants drilled from both faces predominate among the finished, unbroken items.

Relatively large numbers of button-shaped beads (Fig. 3.1–3) were also produced, with a total of 26



Fig. 2. Amber ornaments from Sārnate discarded in various stages of production (photos by V. Bērziņš). Button-shaped beads:* 1 *unperforated, flaked/ground (A11415:542);* 2 *unperforated, ground all over (A11417:100);* 3 *broken at completed V-shaped perforation, with secondary straight perforation, ground all over (A11415:515);* 4 *broken at complete V-shaped perforation, polished all over (A11415: 512);* 5 *broken at completed V-shaped perforation, polished all over (A11415:243). Tubular beads:* 6 *unperforated, ground/polished (A11415: 544);* 7 *broken at incomplete perforation, flaked/ground (A11417:55);* 8 *broken at completed perforation, flaked (A11417:20). Pendants:* 9 *unperforated, flaked/ground (A11421:48);* 10 *unperforated, ground all over (A11417: 17);* 11 *broken at incomplete perforation, flaked all over (A11415:218);* 12 *broken at completed perforation, front polished, back ground (A11421:27);* 13 *broken at completed perforation, polished all over (A11421:26);* 14 *broken at completed perforation, polished all over (A11415:539).

finds. Commonest are circular beads with a V-shaped perforation, although oval beads were also found. They are most frequently plano-convex in cross section, less often biconvex.

The class of tubular beads is represented at Siliņupe by seven fragmentary cylindrical beads, all of them in a partially processed state (Fig. 3.4–5).

Production methods and stages

Our understanding of the processes applied in amber jewellery production and the assignment of the pieces to production stages is based on examination of the artefacts by naked eye, guided by the findings of previous analyses of amber-working by Vankina (*1970*), Ryszard F. Mazurowski (*1984*), Annelou van Gijn (*2006; 2014*) and Erik van Drenth (*2013*), and by the results of experiments performed by Eryk Popkiewicz (*2012*).

First, it was important to select the most suitable raw material for amber ornaments. Only hard and clear amber would be chosen, as it is less likely to fracture and spoil the work. If the natural cortex of the amber lump was to be removed, this could be done using a knife or grinding stone in the form of a sandstone or limestone slab, as attested by archaeological and ethnographic studies. There is ethnographic evidence of pre-processing heat treatment to improve the structure of amber (*Popkiewicz 2012*).

The process of shaping and surface treatment can be divided into several stages: subdivision of the nodule, flaking, grinding, and polishing. In the course of initial processing, a blank of suitable size would be obtained. Before further working, larger pieces of amber would be cut or divided into smaller ones, utilizing tools of bone, antler, flint or other stone (*Mazurowski 1984*). It has been shown experimentally that, when using a miniature axe, by controlling the point where the flint blade will strike the amber, it is possible to determine the size of the amber fragment that will detach (*Popkiewicz 2012*). Amber lumps can also be split by indirect percussion, using an antler punch to apply strong point pressure, or they can be subdivided by cutting with a wet thread (*van Gijn 2006; Popkiewicz 2012*).



Fig. 3. Amber ornaments from Siliņupe discarded in various stages of production (photos by M. Kalniņš and V. Bērziņš). Button-shaped beads:* 1 *perforation complete, front polished, back ground (VI292);* 2 *perforation complete, polished all over (A11399:1);* 3 *broken at incomplete V-shaped perforation, with completed secondary straight perforation, front polished, back ground/polished (A11399: 52). Tubular beads:* 4 *broken at incomplete perforation, flaked/ ground (VI292);* 5 *broken at incomplete perforation, flaked (VI292). Pendants:* 6 *unperforated, flaked (A11399:34);* 7 *broken at complete perforation, flaked (A11399:27);* 8 *broken at complete perforation, ground/ polished (VI292);* 9 *completed perforation, natural surface (A11399:112);* 10 *completed perforation, natural surface, exposed to heat? (A11399:76);* 11 *broken at complete perforation, ground/polished (11399:6);* 12 *completed perforation, partially ground/polished (VI292);* 13 *completed perforation, partially polished (VI292).

Once a suitable-sized piece of amber was obtained, it would be shaped into the desired form. Various kinds of blanks may be distinguished: nodules, blocks, and flakes (*van Gijn 2014*). Unshaped amber lumps could be used for making pendants, but the blanks for more elaborate pendants and beads were shaped after splitting. Amber flaking involved similar techniques and instruments to those used for flint-knapping, with the difference that amber-working requires smaller tools that permit greater precision (*Popkiewicz 2012*). Flaking could be performed with a flint flake or miniature axe. This leaves traces of retouch on the amber surface, where small fragments of amber are detached by the pressure of the tool edge (Figs. 2.1,7,8,11; 3.4–6; *Popkiewicz 2012*). This technique is comparable to retouching on flint (*Vankina 1970.112–114*). The size of the detached fragments depends on the pressure exerted on the amber and on the angle of the tool edge to the surface of the amber (*Popkiewicz 2012*).

Grinding was employed to smooth the surface and round the sharp edges. Grinding stones with different grain sizes could be used for this, leaving regular striations running in various directions (Fig. 2.2, 3,6,10). Subsequently, the surface would be polished using soft leather or fabric (*Popkiewicz 2012*).

Drilling was the most difficult operation in amber processing, and was a frequent cause of breakage. The piece could be drilled at any stage of processing.

Different kinds of drilled perforations may be distinguished, relating to the form of the ornament: pendants most commonly have short perforations; button-shaped beads have V-shaped perforations; and tubular beads have long, straight perforations. A different technique was used for each kind of perforation, and they differ in the degree of difficulty.

Pendants were simplest to perforate, as with such a short perforation, there was less chance of the ornament fracturing. A flint drill could be used for this purpose, drilling from one face or both and obtaining a conical or biconical perforation, respectively (*Popkiewicz 2012*). Drilling from both faces was the most common practice, possibly in order to reduce

the likelihood of breakage (*Drenth 2013; van Gijn 2014*). It was also the most common in cases of repeated perforation, undertaken in repairing items at Siliņupe. Often, however, the placement of the two conical perforations was incorrectly judged, and so it was necessary to drill obliquely, which could lead to breakage (*Popkiewicz 2012; van Gijn 2014*). It has been confirmed experimentally that drilling may also be performed with a pointed piece of wood or antler, using a fine slurry, with this process leaving fine, regular, circular scratches (*van Gijn 2014*).

V-shaped perforations were provided for the button-shaped beads, drilling obliquely from two points on the same side, so that the perforations met to form the V shape.

The tubular beads required a long, straight perforation. Moreover, it was important for the perforation to be symmetrical in relation to the ornament, which was difficult to achieve. In order to obtain a correctly aligned perforation, the first step is to mark the drilling site, so that the drill does not slide across the surface of the amber, which can be done using the sharp edge of a flint tool (*Popkiewicz 2012*). For drilling the perforation itself, a longer instrument was required. In cases where a straight, cylindrical perforation is observable, a hollow drill could have been used, perhaps a bird bone, leaving a smooth perforation (*van Gijn 2006; Drenth 2013*). These perforations were drilled from one or both ends. A flint drill attached to a wooden shaft could also have been used for such longer, more difficult perforations (*Popkiewicz 2012*). The perforations of tubular beads broke or failed more commonly than those of other ornaments (Figs. 2.7; 3.4,5), reflecting the higher degree of difficulty.

The amber ornaments were classified into five production stages, taking into consideration both the character of the surface finish and the state of the perforation (*Bērziņš 2003*).

The following degrees of surface finish were distinguished:
- natural cortex all over;
- partially covered in natural cortex, partially flaked;
- surface entirely flaked;
- partially flaked, partially ground;
- surface entirely ground;
- partially ground, partially polished;
- surface entirely polished;
- front polished, reverse ground (mainly seen on button-shaped beads);
- partially natural cortex, partially polished (irregular pieces not shaped by flaking, only polished).

The following perforation states were distinguished:
- unperforated (piece intact);
- partly perforated (piece intact);
- perforation complete (piece intact);
- broken at the perforation, with perforation clearly incomplete;
- broken at the perforation, with perforation possibly or definitely complete;
- fragmentary piece not showing a perforation (*e.g.*, the lower part of a pendant or the margin of a button-shaped bead).

The pieces were assigned to one of five production stages as follows:
1. *Unperforated pieces:* these are pieces abandoned either without completing pre-perforation working, or else leaving the piece ready for perforation without actually starting this operation. Such finds are taken to indicate shaping/surface treatment before perforation or the stocking of unperforated blanks.

2. *Pieces with an unfinished perforation:* either intact or broken at the perforation. These indicate failed or interrupted drilling. In the case of some broken pieces, it is not evident whether the perforation was complete at the time of breakage. For the purpose of assigning such pieces to a production stage, pieces which have a flaked but not ground surface are included in this stage, taking into account that flaking most commonly preceded perforation (as shown in Table 3). On the other hand, if such a broken piece has a ground surface, the state of surface treatment does not give any indication as to whether it broke during perforation or during subsequent finishing, and such pieces are classed as "*production stage indeterminate*".

3. *Pieces with a finished perforation, but unfinished surface treatment: i.e.* not all of the surface (or the front in the case of button-shaped beads) has been polished. Such pieces indicate that post-perforation finishing was being conducted, and that work on this piece was abandoned before this operation was completed.

4. *Finished products:* pieces with a finished perforation, where the whole surface (or the front in the case of button-shaped beads) has been polished.

5. *Pieces with a secondary perforation:* these are cases of repair after breakage at the perforation.

Production stage	Button-shaped beads				Tubular beads				Pendants			
	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	**Total**	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	**Total**	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	**Total**
1. unperforated	6 (10%)	2 (10%)	3 (12%)	**11 (10%)**	–	1 (100%)	–	**1 (5%)**	1 (2%)	4 (27%)	3 (4%)	**8 (6%)**
2. incomplete perforation	7 (11%)	6 (32%)	17 (65%)	**30 (28%)**	2 (14%)	–	6 (86%)	**8 (36%)**	4 (10%)	1 (7%)	30 (42%)	**35 (27%)**
3. completed perforation, unfinished surface treatment	14 (23%)	2 (10%)	–	**16 (15%)**	8 (57%)	–	–	**8 (36%)**	9 (21%)	2 (13%)	14 (20%)	**25 (20%)**
Total semi-manufactured pieces (stages 1–3)	27	10	20	**57**	10	1	6	**17**	14	7	47	**68**
4. finished artefact	27 (44%)	8 (42%)	5 (19%)	**40 (38%)**	4 (29%)	–	–	**4 (18%)**	6 (14%)	5 (33%)	7 (10%)	**18 (14%)**
5. artefact repaired by secondary perforation	–	–	–	**–**	–	–	–	**–**	–	–	5 (7%)	**5 (4%)**
Production stage indeterminate	7 (11%)	1 (5%)	1 (4%)	**9 (8%)**	–	–	1 (14%)	**1 (5%)**	22 (52%)	3 (20%)	12 (17%)	**37 (29%)**
Total (all stages)	**61**	**19**	**26**	**106**	**14**	**1**	**7**	**22**	**42**	**15**	**71**	**128**

Production stage	Total of 3 ornament classes				Total finished/semi-manufactured items				Unworked nodules				Debitage pieces			
	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	Total	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	Total	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	Total	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	Total
1. unperforated	7 (6%)	7 (20%)	6 (6%)	20 (8%)												
2. incomplete perforation	13 (11%)	7 (20%)	53 (51%)	73 (28%)												
3. completed perforation, unfinished surface treatment	31 (26%)	4 (11%)	14 (13%)	49 (19%)												
Total semi-manufactured pieces (stages 1–3)	**51**	**18**	**73**	**142**												
4. finished artefact	37 (32%)	13 (37%)	12 (12%)	62 (24%)												
5. artefact repaired by secondary perforation	–	–	5 (5%)	5 (2%)												
Production stage indeterminate	29 (25%)	4 (11%)	14 (13%)	47 (18%)												
Total (all stages)	**117**	**35**	**104**	**256**	**126**	**43**	**316**	**485**	**–**	**7**	**288**	**295**	**2027**	**44**	**229**	**2300**

Tab. 2. Amber finds belonging to the main ornament categories from the Early Sārnate Ware phase at Sārnate and from Siliņupe, classified according to production stage.

Table 2 and Figure 4 give the numbers of button-shaped and tubular beads and pendants assigned to each of the production stages in the assemblages from Sārnate dwelling 2, from the other dwellings belonging to the Early Sārnate Ware phase at Sārnate, and from Siliņupe. Out of a total 256 ornaments, 209 (82%) could be assigned to a specific production stage.

The *chaîne opératoire* and its variation

The basic classification according to production stages is a logical starting point for elaborating the *chaîne opératoire*. Analysis of the semi-manufactured pieces reveals, however, that the production steps do not follow a fixed sequence. While shaping/surface treatment proceeds from flaking to grinding to polishing, there is considerable variation in terms of the point within this sequence at which the piece was perforated. This is apparent if we consider the state of surface treatment only for those semi-manufactured ornaments, 41 in total, which clearly display an incomplete perforation (Tab. 3), almost all of them fragmentary pieces that evidently broke during perforation.[1]

Table 3 shows that among the pieces exhibiting a failed perforation, seven had been flaked all over the surface (with no grinding traces) before they were perforated; eight had been flaked and only partially ground; and the greatest number – 12 – had already been ground all over. There are also smaller numbers of incompletely perforated pieces in various other states of shaping/surface treatment, ranging from completely unshaped (with natural cortex all over) to completely polished.

All three ornament classes – both kinds of beads as well as pendants – show considerable variation in the degree of shaping/surface treatment carried out in advance of perforation. And such variation occurs within all three assemblages. Even the assemblage from Sārnate dwelling 2, which must be regarded as representing the output of a relatively restricted human group (a household or small workshop), shows an element of variation in this respect.

Accordingly, the generalized *chaîne opératoire* for amber ornament production on these sites cannot be viewed as a sequence of steps performed in a set order, of the kind often visualized in schematic form in studies on processing sequences for lithic materials (*e.g., Inizan 2008.Figs. 8–10*), bone (*e.g., David 2006.Fig. 2*) or ceramics (*e.g., Perry 2016.Fig. 11*).

The kind of *chaîne opératoire* indicated by the amber assemblages, where a particular operation may come at various points in the processing sequence, is challenging to represent schematically. We have chosen to view it as consisting of two independent sub-*chaînes*: (1) the sequence of shaping/surface treatments, and (2) perforation (Fig. 4).

The same kind of variation in the position of perforation within the order of production steps is noted by van Gijn (*2014*) in her study of a Neolithic amber assemblage from Zeewijk in the Netherlands. It is likewise observed in Stone Age assemblages in Poland and in collections from medieval amber workshops in the Baltic Sea region (*Popkiewicz 2012* and reference therein to *Wojtasik 1990.147–148*).

Proceeding from his amber processing experiments, Popkiewicz (*2012*) highlights the ergonomic and labour-saving aspects of this process: (1) a piece still in the initial stage of processing, and hence larger, is easier to hold or fix in position for drilling the perforation; and (2) because drilling is the most difficult part of the work, presenting the greatest risk of failure, less time/labour will have been wasted in the case of breakage while drilling, if this operation is performed on a little-worked piece than on a piece already in an advanced stage of completion.

This begs the question: why did amber-workers nevertheless often leave drilling until after grinding, or even after polishing? There are evidently technical issues at play here, presumably relating to the particular drilling technique employed and the means of fixing or holding the piece for drilling, as well as the form of the unworked lump, the kind of ornament it was to become, and the kind of perforation required for the particular ornament. All of these aspects deserve attention in future experimental work.

Leaving aside these practicalities, what does the occurrence of variation in the sequence of processing tell us? Following the theoretical approach taken by Gwendolyn O. Kelly (*2016*) in her study of stone bead production in Early Historic South India, we are witnessing an element of *heterodoxy* within the

1 Unlike in the assignment of production stages in Table 2, pieces where the perforation is assumed to be incomplete because the surface is flaked but not ground are excluded from this analysis to avoid any ambiguity.

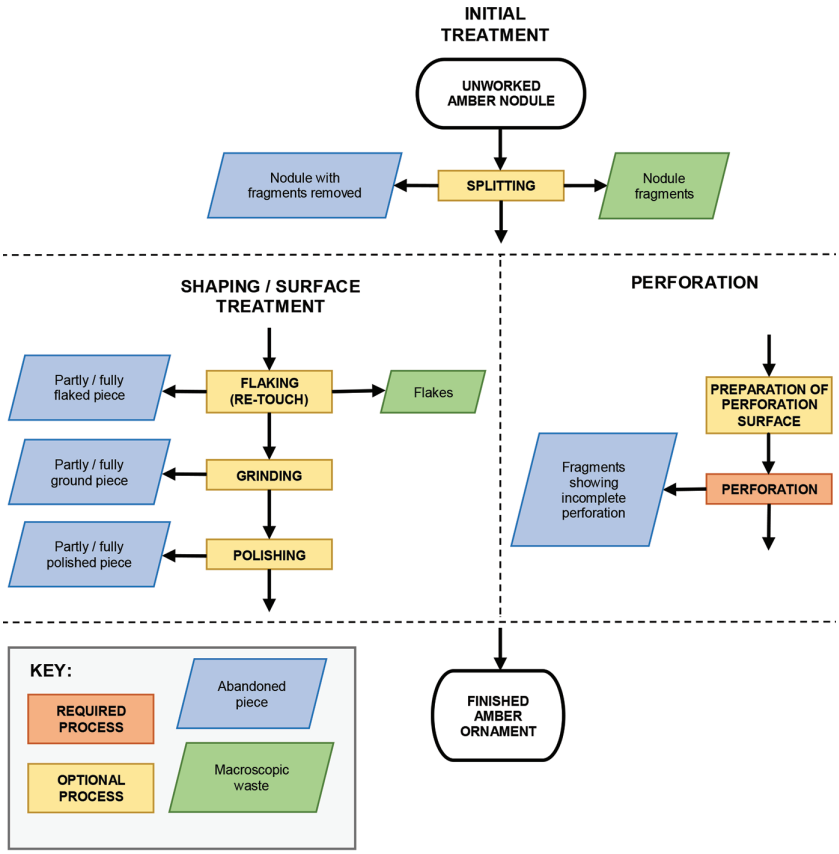

***Fig. 4. Flowchart representing the generalized* chaîne opératoire *of amber jewellery production, where shaping/surface treatment and perforation are viewed as two independent sub-*chaînes.**

communities producing the ornaments. Thus, there was an acceptance of alternative practices, in this case with respect to the order in which the operations of producing an amber ornament were carried out – in contrast to an *orthodox* attitude, where only one set of practices is acceptable.

In her discussion of the Zeewijk assemblage, Van Gijn (*2014*) proposes that the variability observed in the exact production sequence of amber beads supports the assumed domestic production of the ornaments, with different people having slightly different techniques, whereas if the beads had been produced in workshops a more standardized production sequence would be expected.

Such a conclusion may also be valid with respect to amber processing in the Neolithic of the Eastern Baltic. Thus, in addition to the evidence for intensive amber-working from Sārnate dwelling 2 (not just the amber assemblage itself but also grinding stones and certain lithic tool types that probably constitute amber-working gear), this dwelling also yielded a number of flint spear- and arrowheads, two pebble net sinkers and a significant amount of pottery (*Vankina 1970.75–76, Tab. 3, Fig. 133; Bērziņš 2008.Tabs. 10, 18*), providing evidence of engagement in subsistence activities. In other words, amber processing appears to be taking place in what may be described as a domestic context. Lithic debitage was also abundant, showing that not just amber but also lithics were being intensively processed.

It appears that the domestic production of amber ornaments provided a context in which heterodoxy in processing practices could thrive, which is an important observation, if we consider that the output, in terms of the dominant classes of amber ornaments, was actually rather standardized. Thus, the makers of amber ornaments, apparently dispersed across a great many household production settings, were following somewhat different methods, even though they were aiming to produce standard ornament forms of recognized value for participation in a supra-regional exchange network.

Intensity of amber-working and production of different jewellery classes

The absolute quantities of amber recovered (Tab. 2, *'Total finished/semi-manufactured items', 'Unworked nodules', 'Flakes'*) and the number of finds per square metre give at least some indication of the relative intensity of amber-working. In this respect, Sārnate dwelling 2, with an excavated area of 86m², is in a class of its own, with its 126 (1.47/m²) semi-manufactured and finished items and 2027 (23.57/m²) pieces of debitage (but no unworked nodules recorded!). The other Early Sārnate Ware phase dwellings at Sārnate, with a combined excavation area of 524m², are relatively very impoverished in terms of amber finds, together yielding only 43 (0.08/m²) finished/semi-manufactured items, seven (0.01/m²) unworked nodules and a mere 44 (0.08/m²) debitage pieces. Siliņupe lies in between these extremes: here, an excavated area of 336m²

Degree of surface treatment	Button-shaped beads				Tubular beads				Pendants				Total
	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	Total	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	Total	Sārnate, dwelling 2	Sārnate, other dwellings with Early Sārnate Ware	Siliņupe	Total	
natural cortex all over	–	–	1	1	–	–	–	–	–	–	–	–	1
partially natural cortex, partially flaked	–	–	1	1	–	–	2	2	–	–	2	2	5
entirely flaked	1	1	1	3	1	–	1	2	–	1	1	2	7
partially flaked, partially ground	–	–	4	4	1	–	1	2	–	–	2	2	8
entirely ground	5	–	1	6	–	–	–	–	1	5	–	6	12
partially ground, partially polished	–	–	–	–	–	–	–	–	1	–	2	3	3
entirely polished	–	–	5	5	–	–	–	–	–	–	–	–	5
Total	**6**	**1**	**13**	**20**	**2**	**–**	**4**	**6**	**2**	**6**	**7**	**15**	**41**

Tab. 3. Degree of surface treatment on ornaments with an unfinished perforation. Note: the pieces considered here are only those where the perforation is clearly observed to be incomplete, unlike in Table 2, where broken pieces with a perforation not clearly identifiable as incomplete are also classified in production stage 3 if they have been flaked but not ground.

has given 316 (0.94/m²) finished/semi-manufactured items, 288 (0.86/m²) unworked nodules and 229 (0.68/m²) debitage pieces.

It should be added that in the case of Siliņupe (but not Sārnate), the natural strata at the base of the archaeological sequence also contain amber lumps, transported by longshore drift in the sea and deposited along with other sediment (*Bērziņš* et al. *submitted*), so we cannot be certain that all of the recovered unworked amber on this site was actually collected by the inhabitants.

The general situation is clear enough: dwelling 2 at Sārnate was a locus of very intensive amber-working activity, starkly contrasting with a very low level of amber-working in the other dwellings of this phase, while Siliņupe falls in between. Because the Sārnate collection can be subdivided into separate dwelling assemblages which we can equate with small-scale social groups, a pattern is revealed where one such group within a larger community – that associated with dwelling 2 – was engaging much more intensively in amber-working than others. Accordingly, dwelling 2 was previously regarded as an amber workshop (*Vankina 1970.114*), and has subsequently been considered through the theoretical lens of craft specialization (*Bērziņš 2003*). We cannot exclude the possibility that there was a similar concentration of amber-working in the hands of a subset of the community at Siliņupe, too. However, on this site the artefactual remains cannot be split into separate dwelling assemblages, and thus such patterns are not clearly detectable.

We may next compare our three assemblages in terms of the proportional representation of the three classes of ornaments among all the semi-manufactured pieces (Tab. 2, "*Total semi-manufactured pieces (stages 1–3)*"), which should, at least to some degree, reflect how much of the amber production effort was in each case being devoted to the making of particular classes of ornaments. There are also salient differences in this respect. Thus, at Sārnate dwelling 2, button-shaped beads are the most common among semi-manufactured pieces, numbering 27, or 53% of the total number of semi-manufactured pieces in the assemblage belonging to the three ornament classes; tubular beads are somewhat less common, represented by 10 pieces (20%), while pendants number 14 pieces (27%).

The situation is broadly similar for the other Early Sārnate Ware dwellings at Sārnate: 10 semi-manu-

factured button-shaped beads (56%), just one tubular bead (6%) and seven pendants (39%). The main difference from dwelling 2 is the virtual absence of semi-manufactured tubular beads (and no finished examples of such beads occur, either).

From Siliņupe we have 20 semi-manufactured button-shaped beads (27%), six tubular beads (8%) and 47 pendants (64%). Thus, in contrast to both of the Sārnate assemblages, pendant production appears to have dominated at Siliņupe.

These patterns may be considered in relation to the level of difficulty involved in the different kinds of perforation required for the three ornament classes, as indicated by the experimental work of Popkiewicz (*2012*) and by the occurrence of characteristic broken pieces. Pendants would have been the simplest items to perforate: only a straight, relatively short perforation was needed. The V-shaped perforation of button-shaped beads is harder to achieve, while most difficult is the drilling of the long perforation of the tubular beads.

In all three assemblages, the proportion of semi-manufactured tubular beads is lowest among the three ornament classes, and on this basis they may be considered rather 'exclusive', presumably being made only from very good quality amber nodules and only by individuals with advanced drilling skills. The virtual absence of such pieces from the Early Sārnate Ware dwellings other than dwelling 2 suggests that within this community the skills (and perhaps also equipment) needed to make these pieces were only possessed by the people working in this dwelling.

This difficulty of producing tubular beads also colours our view of the sets of amber ornaments provided as grave goods in this period. Thus, for example, the set of 12 tubular beads provided for child burial 194 at the Zvejnieki cemetery (*Zagorska 2001; Zagorskis 2004.Pl. 17*) represents a particularly valuable item of jewellery in terms of the amount of highly skilled labour invested in it. Likewise very valuable from this perspective was a set of tubular beads found on the Abora site in eastern Latvia (*Loze 1975.Fig. 10; 2008.125*).

Representation of different production stages

If we now proceed to examine the production-stage data for our three main ornament classes (Fig. 5; Tab. 2, "*Total of 3 ornament classes*"), then we find that each assemblage shows a somewhat different picture in this respect as well. Sārnate dwelling 2 is distinguished by a large number of pieces with a completed perforation but unfinished shaping/surface treatment (stage 3). The other Sārnate dwellings have a high proportion of unperforated (stage 1) pieces. Meanwhile, Siliņupe has a very large share of incompletely perforated pieces (stage 2); pieces in this stage are also fairly common in the other Sārnate dwellings, but comprise only a small percentage in dwelling 2. Siliņupe stands out in having a much lower proportion of finished ornaments (stage 4) than dwelling 2 or the other Sārnate dwellings.

When considering the button-shaped beads specifically, the pattern is similar but not quite the same: many perforated but incompletely finished pieces (stage 3) from Sārnate dwelling 2; a high proportion of finished pieces (stage 4) from dwelling 2 as well as the other dwellings at Sārnate; and a very marked predominance of incompletely perforated beads (stage 2) from Siliņupe. In this particular ornament class, the proportion of incompletely perforated pieces is also high in the other Sārnate dwellings.

As noted above, tubular beads are much less abundant in general, and are virtually absent from the other Sārnate dwellings. Although the absolute numbers are small, we still see a similar difference between Sārnate dwelling 2 and Siliņupe to that observed in the case of button-shaped beads: namely, at Sārnate dwelling 2 completely perforated but incompletely finished pieces (stage 3) predominate, while Siliņupe has produced almost exclusively pieces with an incomplete perforation (stage 2), which seems to reflect the difficulty of perforating tubular beads – a high proportion were evidently ruined at this stage.

In the case of pendants, within the relatively small assemblage from the other Sārnate dwellings there is a large share of unperforated (stage 1) pieces. Siliņupe has many incompletely perforated (stage 2) pendants. The proportion of pendants with a completed perforation (stage 3) is higher from Sārnate dwelling 2 and Siliņupe than in the case of the other Sārnate dwellings. Finished pendants (stage 4), on the other hand, are commonly represented from the other Sārnate dwellings, while Siliņupe stands out as the only assemblage with pendants repaired by secondary perforation (stage 5). If we consider the proportions of the different production stages for the pendants in relation to the propor-

tions for the other two ornament classes, then the most salient common characteristic to emerge is that Siliņupe has a high proportion of incompletely perforated (stage 2) pieces.

We are not in a position to attempt a comprehensive interpretation of all the patterns identifiable in these statistics. More detailed technical analysis would no doubt permit a clearer understanding of the factors behind the representation of the different production stages. However, the current understanding of Neolithic amber-working and our knowledge of the sites from which the assemblages originate does permit us to try to account for at least some of the variation between them.

The previous treatment of amber-working at Sārnate by Bērziņš (*2003*) noted a degree of complementarity in the data for dwelling 2 and for the other Early Sārnate Ware phase dwellings: thus, the relatively high proportion of pieces in the early stages of processing (stages 1 and 2) in the material from the latter suggested that perforated and unperforated blanks may have been supplied from these dwellings for further processing (by specialists) in dwelling 2. The absence of unworked nodules in dwelling 2 also points to such a scenario. This is still seen as a valid hypothesis – although for a proper appreciation of such patterns we would really need to gain a clearer insight into the small-scale social relationships linking household groups within these communities. It is not, unfortunately, possible to ascertain whether dwelling 2 was inhabited simultaneously with other excavated dwellings of this occupation phase.

The most salient overall difference between the assemblages, applying to all three ornament classes, is that Siliņupe has a much higher proportion of pieces abandoned during the perforation process (stage 2), *i.e.* failed perforations, than either Sārnate dwelling 2 or the other Sārnate dwellings, while both of the Sārnate assemblages are dominated by finished ornaments (along with perforated but incompletely finished pieces in the case of dwelling 2).

In the knowledge that amber ornaments were important as exchange items, distributed from the coast along waterways far into the continental interior, we might indeed expect a high proportion of finished items to have been removed from our production sites, leaving mainly pieces that broke during processing or were considered in some way defective. The pattern seen at Siliņupe appears to accord well with such a scenario: here, it seems that if the perforation succeeded, then the ornament was almost always brought to completion and taken away. But this was apparently not quite so at Sārnate, especially in the case of the intensive amber-working activity in dwelling 2. Here, a high proportion of successfully perforated pieces were also being retained. In many cases post-perforation finishing was left incomplete, but many finished pieces were also kept.

In seeking to explain this difference, we may consider the geographical positions of the two sites in relation to exchange networks in the region east of the Baltic Sea. From such a perspective, Siliņupe appears to be much more centrally located, since it lies close to the mouths of two major waterways, the Daugava and the Lielupe. The River Daugava, in particular, along with its tributaries, has been viewed as a major route for amber distribution – to the Lake Lubāns basin in eastern Latvia as well as much further eastwards into present-day Belarus and Russia (*Loze 2001; 2003; Charniauski 2001*). The Lielupe and its tributaries connect with present-day northern Lithuania. By comparison, Sārnate can be seen as occupying a rather peripheral location: it is fairly close to the River Venta, but this river has a much smaller drainage basin than the Daugava, and is, moreover, oriented southwards, connecting with a region not so distant from the coast of present-day Lithuania, where amber was likewise available locally.

We would expect, then, that the people at Siliņupe had much greater opportunities to engage in the eastwards-oriented exchange networks than the community at Sārnate. Hence, at Siliņupe there would have been a stronger stimulus to maximize amber ornament production and supply the great majority of the finished pieces (perhaps even those considered second rate or slightly defective) to the exchange network. It might also have been an incentive towards the utilization of less-than-perfect amber nodules and to the involvement of a wider circle of individuals in the working of amber, even those with inferior skills – both of which would have increased the frequency of failure during perforation, as reflected in the assemblage.

The relatively high proportion of semi-manufactured pendants at Siliņupe (noted in the previous section) might, once again, be linked to this community's intensive involvement in exchange, in which context it was perhaps advantageous to focus on the simpler-to-make forms.

Meanwhile at Sārnate, with its disadvantageous location for participation in the exchange network, there could have been a tendency for finished pieces to accumulate on the site, perhaps only those considered the best being selected for exchange, and in such a situation we might expect there to have been less incentive to bring to completion all of the successfully perforated pieces by undertaking the laborious process of polishing. This would explain the high percentages of perforated but incompletely finished (stage 3) as well as finished (stage 4) pieces from Sārnate dwelling 2.

There is another important difference between the sites, which must have affected patterns of amber-working and may also partially account for the above-discussed differences between the assemblages – namely access to various lithic raw materials. Thus, recent studies by Mārcis Kalniņš reveal that the inhabitants of the Early Sārnate Ware phase dwellings at Sārnate, including dwelling 2, were largely reliant on Silurian flint, which could be collected from the beaches along that stretch of the coast; at Siliņupe, by contrast, the dominant lithic raw material is Cretaceous flint, which came from present-day southern Lithuania or Belarus, at least 200km away, while the surrounding area apparently lacked good locally available lithic raw materials (*Berg-Hansen* et al. *2019; Kalniņš, submitted; Bērziņš* et al. *submitted*).

The pattern of lithic raw material use thus not only provides additional evidence that the Siliņupe community was more intensively participating in long-distance exchange than the community at Sārnate. It was also much more dependent on exchange, because the exchange networks were providing the lithic material used for toolmaking. And moreover, as described above, flint tools had an important role in amber-working itself.

Zagorska (*2003*), in her initial treatment of the Siliņupe amber assemblage, emphasizes the importance of amber exchange with respect to this site, noting the prevalence of broken semi-manufactured items in the assemblage, and our comparison with Sārnate brings this into sharper relief. One further remark needs to be made here, namely that considerations of geographical location and material flows are in themselves inadequate for a proper understanding of amber exchange (and long-distance exchange in this region of Europe in general). We also require a better grasp of the social context in which exchange was embedded, and this is an important task for future research (see *Zhulnikov 2008* for an attempt to characterize the regional flow of amber ornaments in terms of prestige item exchange serving to establish and strengthen social ties).

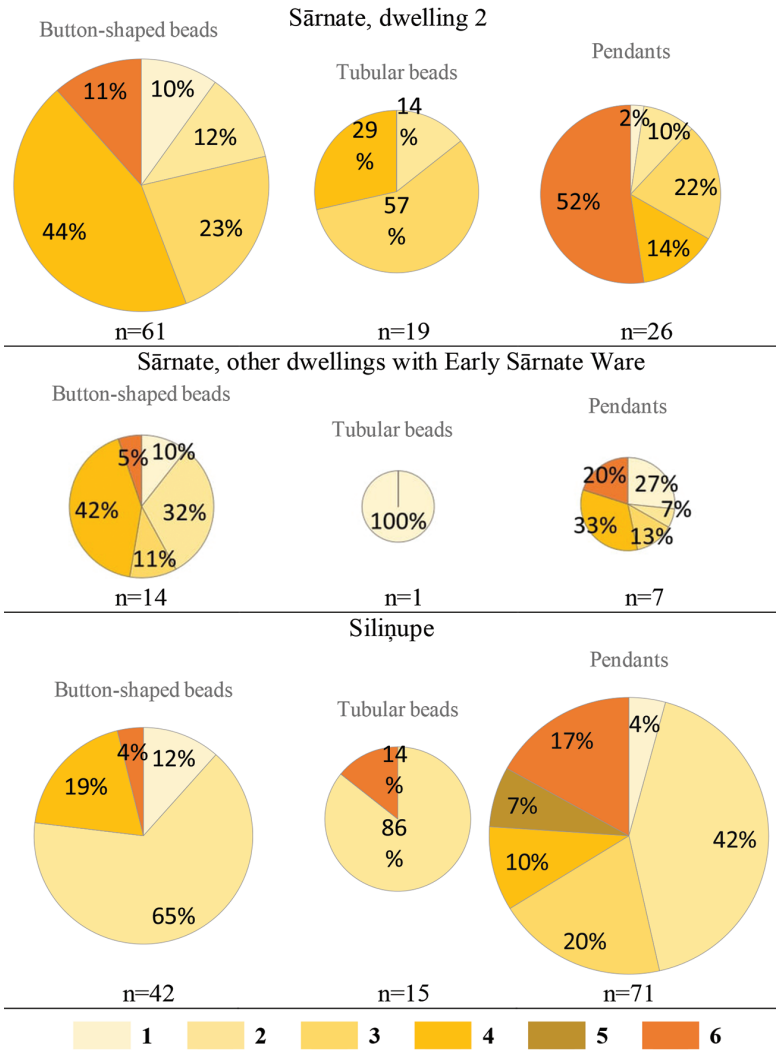

Fig. 5. The representation of different ornament production stages in the amber assemblages from Sārnate dwelling 2, the other dwellings at Sārnate with Early Sārnate Ware and the Siliņupe site (data from Table 2): 1 unperforated; 2 incomplete perforation; 3 completed perforation, unfinished surface treatment; 4 finished artefact; 5 artefact repaired by secondary perforation; 6 production stage indeterminate.

Conclusions

Our approach to amber assemblages from production sites, looking at the relative intensity of production of different jewellery forms, the representation of different production stages among the pieces remaining on the site and the sequence in which the processing operations of shaping/surface finishing and perforation were performed, has revealed major differences in the overall character of the amber assemblages from the two sites as well as intra-site (*i.e.* intra-community) variation in working practices.

The differences in representation of the various production stages of amber jewellery at Sārnate and Siliņupe would appear to be at least partially explicable in terms of the Siliņupe community's closer integration into amber exchange networks, owing to the advantageous geographical location for participation in long-distance exchange as well as the high dependency upon lithic raw materials obtainable through the exchange network.

Meanwhile, the variation within the site assemblages in terms of the point within the processing sequence when perforation is performed indicates a strong element of heterodoxy with respect to amber processing practices within the communities engaged in this activity, congruent with a domestic setting of production – even though the actual output, in terms of the major jewellery classes, was rather standardized.

These questions deserve further attention in future research on the technical as well as the social aspects of ancient amber-working and exchange.

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The emergence of metal use in Greek Eastern Macedonia during the Neolithic period (late 6th–5th millennia BC)

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ABSTRACT – *Copper, gold, and silver artefacts, together with evidence of metallurgical activities, have been retrieved from Late Neolithic strata in several settlements in Greek Eastern Macedonia. Recent excavations at Dikili Tash revealed that gold was further used in paints for the decoration of pottery. It appears that the area's inhabitants had a great familiarity with different metals and the distinct stages of the production-elaboration processes, including those interfering with other* chaînes opératoires*. Considering also the results from geological research, we propose a reflection on the socio-economic role of metal production and consumption for these societies, in their broader Balkan context.*

KEY WORDS – *metalworking; Eastern Macedonia; Greece; Late Neolithic*

Začetek uporabe kovin v grški vzhodni Makedoniji v obdobju neolitika (pozno 6.–5. tisočletje pr. n. št.)

IZVLEČEK – *V več naseljih v grški vzhodni Makedoniji so bili v pozno neolitskih plasteh skupaj z dokazi o metalurških dejavnostih odkriti bakreni, zlati in srebrni artefakti. Nedavna izkopavanja v Dikili Tashu so pokazala, da se je zlato uporabljalo v pripravi barv za okraševanje keramike. Zdi se, da so prebivalci tega območja dobro poznali različne kovine in faze procesov priprave in izdelave, tudi tiste v drugih operacijskih sekvencah. Ob upoštevanju rezultatov geoloških raziskav, predlagamo razmislek o družbeno-ekonomski vlogi proizvodnje in uporabi kovin v širšem balkanskem kontekstu.*

KLJUČNE BESEDE – *obdelava kovin; vzhodna Makedonija; Grčija; pozni neolitik*

Introduction

Northern Greece has been diachronically associated with the exploitation of its mineral wealth. Greek Eastern Macedonia in particular, *i.e.* the area between the Strymon and Nestos river valleys including the nearby Thasos island (Fig. 1), is known for its numerous polymetallic resources, which have been intensively exploited from Antiquity until modern times, with gold, silver, copper, lead and iron being the main metals extracted. Although we still lack direct evidence about their exploitation in prehistoric and protohistoric times (with the remarkable exception of the Palaeolithic ochre mine at Tzines, Thasos, around 20 000 years ago; *Koukouli-Chryssanthaki, Weisgerber 1999*), we have good reasons to believe that many of the gold, silver and copper artefacts retrieved in recent decades from a number of Neolithic, Chalcolithic and Bronze Age sites in the area were produced from local resour-

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ces. Moreover, recent analytical studies in artefacts and metallurgical remains support the use of local ores on Thasos island (*Bassiakos* et al. *2019*).

The geological setting of the area, its metallic resources

From a geotectonic point of view, Greek Eastern Macedonia belongs to the Rhodope Massif, which possesses several small- to large-scale magmatic-hydrothermal ore mineralizations (*Melfos* et al. *2002; Melfos, Voudouris 2017*). Most of these occurrences present traces of ancient mining (*Wagner, Weisgerber 1988; Koukouli-Chrysanthaki 1990; Vavelidis* et al. *1995; 1996a; 1996b; Chiotis* et al. *1996; Vaxevanopoulos 2017a; Vaxevanopoulos* et al. *2022*). Precious metal mineralizations also appear in the Serbo-Macedonian Massif at its borders with Rhodope Massif in the Strymon valley. The Strymon river is well known for its placer gold from ancient writers. Pseudo-Aristotle describes the gold nuggets found in the riversides after heavy rains in the Paeonian territory (*De Mirabilibus Auscultationibus* 45).

The Pangaeon mountain is often mentioned by ancient writers, and ores rich in gold, silver and copper were extracted in many mining areas during Antiquity (*Vaxevanopoulos 2017a; 2017b*). Copper rich mineralizations and metallurgical areas with copper being one of the main extracted metals, especially in Roman times, have also been recorded (*Vaxevanopoulos* et al. *2018*). Placer gold has been identified at several spots in the surroundings of the mountain. Alluvial gold is further reported in the streams crossing the region between Pangaeon and Symvolon (*Baker* et al. *1992*), and limonitic veins with gold occurrences have been located in Alistrati, at the feet of the Menoikion mountain (*Vavelidis* et al. *1995*). Further north, on the Angistron and Orvilos mountains, several gold and silver deposits have been recorded and gold-bearing veins in marble have also been exploited (*Chiotis* et al. *1996*).

Several mineralizations rich in gold and silver have also been identified in the region of Palea Kavala, on the Lekani Mountains, which are considered as the ancient Skapti Yli described by Thucydides (*Photos* et al. *1989; Koukouli-Chrysanthaki 1990*). More than 150 occurrences rich in Fe, Cu, Ag and Au have been recorded, whereas underground galleries are widespread in this area and can be dated from the 6th century BC until the Ottoman period (*Vavelidis* et al. *1996a; 1996b*).

Finally, Thasos island, which as previously mentioned offers the earliest evidence for exploitation of metallic minerals in the Aegean, also has a number of gold, silver-lead and copper deposits. Gold deposits are located mainly on the eastern coast of the island where ancient galleries have been studied (*Wagner* et al. *1979; 1981; Vavelidis* et al. *1988a; 1988b*). Ancient exploitation of silver has been studied in the Marlou-Kourlou, Koumaria and Vouves mining areas, in the opposite southwestern part of the island, with numerous underground galleries, shafts and surface extraction (*Hauptmann* et al. *1988; Pernicka, Wagner 1988; Pernicka* et al. *1992; Wagner, Weisgerber 1988; Sanidas* et al. *2018*).

Brief history of archaeological research in the area

The first Neolithic settlements were established in the area (Fig. 2) in the second half of the 7th millennium BC (*Lespez* et al. *2013; Maniatis 2014.207*). The plains of Serres and Drama were ideal for human occupation as they offered abundant arable land and extended pastures, with sizable rivers or perennial sources of water present (*Fotiadis 1985; Andreou* et al. *1996*). Relative proximity to the wooded slopes of the surrounding metalliferous mountains as well as to the Northern Aegean coastline must have added considerably to the subsistence/economic potential of the area.

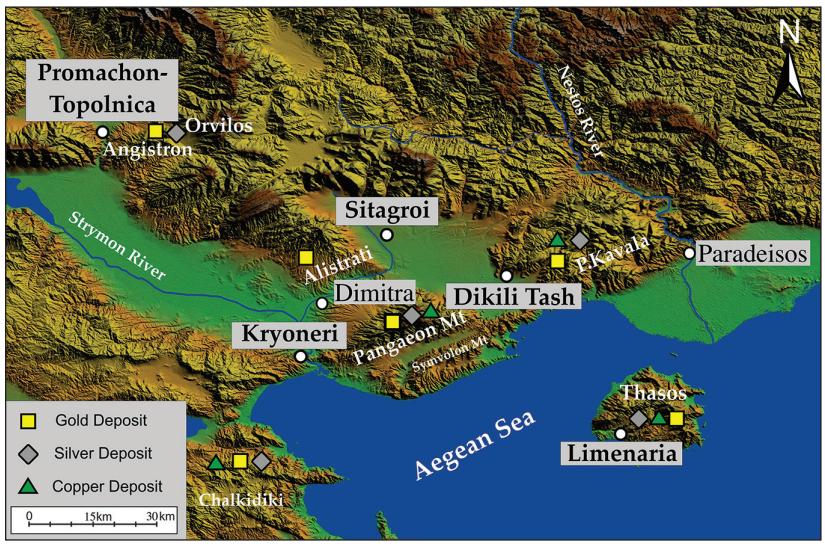

Fig. 1. Map of Greek Eastern Macedonia showing the main locations of gold, silver and copper deposits.

Although both plains comprise many important Neolithic (late 7th–mid 4th millennium BC) sites (*Grammenos, Fotiadis 1980; Grammenos 1991.120–126; Koukouli-Chryssanthaki* et al. *2008*), only a few have been properly investigated. Promachon-Topolnitsa, on the west bank of Strymon on the Greek-Bulgarian border, is the only one excavated systematically to a large extent in the Serres basin (*Koukouli-Chryssanthaki* et al. *2007*). Smaller scale excavations have been conducted in the cave Orpheas-Alistrati (*Kontaxi* et al. *2004*) and the open-air sites at Agio Pnevma (*Tolia-Christakou, Siopi 2008*), Amphipolis-Hill 133 (*Lazaridis 1964; 1965*), Dimitra (*Grammenos 1991; 1997*) and Kryoneri (*Malamidou 2007; 2016*). In the plain of Drama, important systematic excavations have been conducted at the tell sites of Sitagroi (*Renfrew* et al. *1986; Elster, Renfrew 2003*) and Dikili Tash (*Treuil 1992; Koukouli, Romiopoulou 1992; Darcque* et al. *2020* with references; and www.dikili-tash.fr), whereas smaller investigations took place at Polystylo (*Mylonas, Bakalakis 1938. 109–111*), Arkadikos-Drama (*Touloumis, Peristeri 1991; Peristeri 2002; 2004*) and in the cave of Maaras at the Angitis sources (*Trantalidou* et al. *2005*). In the small valley of Pieria, between the Pangaeon and the Symvolon mountains, only the site of Akropotamos has undergone some investigation (*Mylonas 1941*). A small-scale excavation was further conducted at the site of Paradeisos, in the Nestos river valley (*Hellström 1987*). The sites of Kastri-Theologos (*Koukouli-Chryssanthaki 1974; Koukouli-Chryssanthaki, Papadopoulos 2016.342–349*) and Limenaria (*Papadopoulos, Malamidou 2012*) are the only two Neolithic sites excavated so far on Thasos island. Limited remains of the final stages of the period have also been found in the neighbouring site of Agios Antonios (*Maniatis* et al. *2015.810–811*).

Most of these sites have provided evidence in connection with metals or metallurgy, in the form of fi-

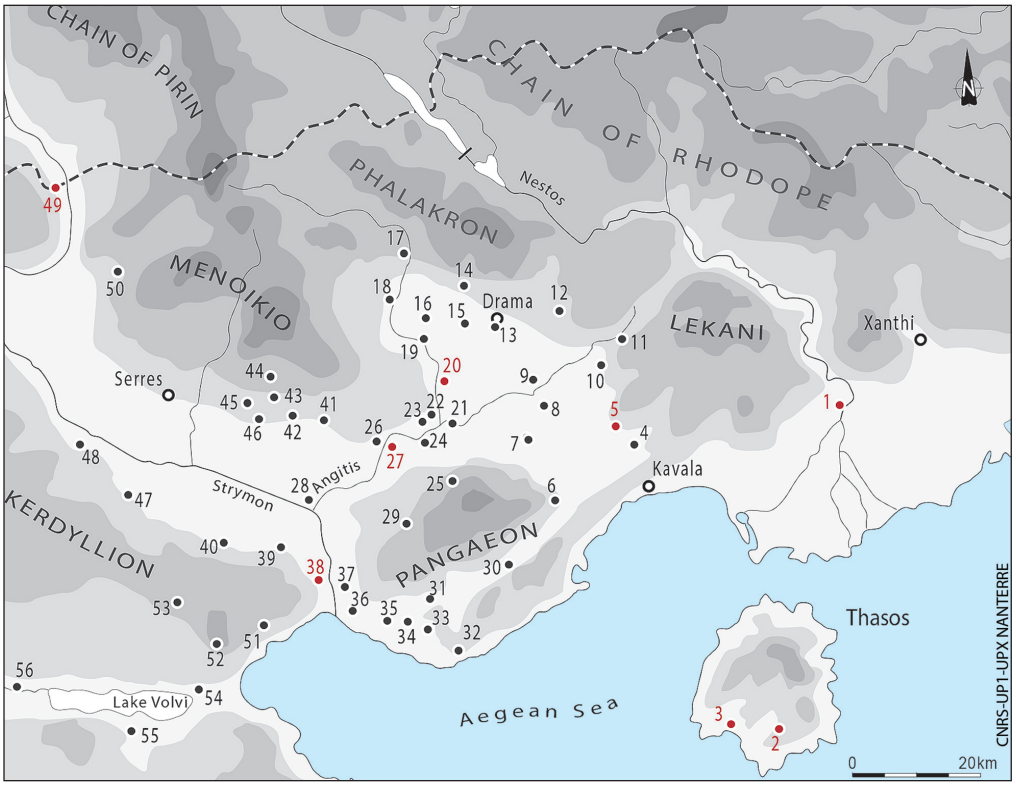

Fig. 2. Map of the area with the main Neolithic and Copper Age sites:* 1 *Paradeisos,* 2 *Kastri,* 3 *Limenaria,* 4 *Polystylo,* 5 *Dikili Tash,* 6 *Eleftheroupoli,* 7 *Kalamonas,* 8 *Kalambaki,* 9 *Doxato,* 10 *Kefalari,* 11 *Adriani,* 12 *Kallifytos,* 13 *Arkadikos-Drama,* 14 *Xeropotamos,* 15 *Mylopotamos,* 16 *Petroussa,* 17 *Maaras-Angitis Sources,* 18 *Kali Vrysi,* 19 *Megalokambos,* 20 *Sitagroi,* 21 *Mavrolefki,* 22 *Symvoli,* 23 *Orpheas-Alistrati Cave,* 24 *Angista R.S.-Paliokostra,* 25 *Nea Bafra,* 26 *Aïri Baïri,* 27 *Dimitra,* 28 *Fidokoryfi,* 29 *Mikro Souli,* 30 *Moustheni,* 31 *Podochori,* 32 *Loutra Eleftheron,* 33 *Akropotamos,* 34 *Kokkinochori,* 35 *Galepsos,* 36 *Ofrynio,* 37 *Amphipolis-Hill 133,* 38 *Kryoneri,* 39 *Kastanochori,* 40 *Zervochori,* 41 *Tholos,* 42 *Toumba,* 43 *Pentapoli,* 44 *Agio Pnevma,* 45 *Fakistra Chryssou,* 46 *Chrysso R.S.,* 47 *Vergi,* 48 *Strymoniko,* 49 *Promachon-Topolnica,* 50 *Katarraktes-Sidirokastro,* 51 *Asprovalta-Agia Lydia,* 52 *Asprovalta-Platoma,* 53 *Arethoussa,* 54 *Mikri Volvi,* 55 *Nea Apollonia,* 56 *Profitis. Sites no.* 51 *to* 56 *belong administratively to the region of central Macedonia. Red dots indicate sites with evidence of metal objects and/or metallurgy.

nished objects, metal-processing installations, instruments or by-products. Part of the evidence relates with later occupation layers (Early or Late Bronze Age), frequently present at the same sites, but much of it comes from secure stratified Late Neolithic deposits and even, exceptionally, from in situ contexts (*Aslanis, Tzahili 1990*). Archaeometric examination of the related finds has produced valuable information on the technology of early copper, gold and silver exploitation in the area (*Mirtsou* et al. *1997; Koukouli-Chrysanthaki, Bassiakos 2002; Renfrew, Slater 2003; Koukouli-Chrysanthaki, Papadopoulos 2009.2; Papadopoulos 2008.67; Bassiakos 2012; Nerantzis, Papadopoulos 2013; Bassiakos* et al. *2019*).

Aim of the paper

Our aim is to go through this available disparate information in order to produce a comprehensive synthesis of our present knowledge on metal production and use in Greek Eastern Macedonia during the late 6th and 5th millennia BC, which is an important formative period not only here but across the entire Balkan peninsula (*Pernicka 1993; Mazanova 2004; Jovanović 2009; Šljivar 2006; Hansen 2013; Kunze, Pernicka 2020a; Radivojević, Roberts 2021*) and the Aegean (*Zachos 1996a; Papadatos* et al. *2004; Bassiakos, Catapotis 2006; Kakavogianni* et al. *2008; Zachos 2010*), as well as in Anatolia and the Near East (*Efe 2002; Maddin* et al. *1999; Özdoğan, Parzinger 2000; Rothenberg, Merkel 1998; Thornton 2001; Yalçın 2000; Yener 2000*). More recent and still unpublished data are also included, mainly from the recent works at the tell settlement of Dikili Tash. We focus on technological information about the *chaîne opératoire* of the different metals, from the acquisition of ores and minerals from local sources and extractive metallurgy through smelting, to the production of finished objects. We combine material and earth sciences with well-established archaeological facts from individual sites, thus hoping to identify patterns of human behaviour in connection with other activities (*e.g.,* other *chaînes opératoires*), in order to better understand the functioning of Neolithic metallurgy and its social background (*cf. Storberg 2002.469; Ottaway, Roberts 2008; Bartelheim* et al. *2015*). By privileging well-dated and secure excavation contexts we try to gather pertinent evidence about metal resource exploitation and consumer choices, taking into consideration the overall practices of local populations, as well as possible networks of contacts and exchange at various geographical scales during the aforementioned period.

Data presentation

Copper

Promachon-Topolnitsa

Copper artefacts and the remains of copper-processing were found in levels of phase Promachon III in the Greek sector, corresponding roughly to the first half of the 5th millennium BC. Excavations yielded several malachite beads (*Koukouli-Chrysanthaki* et al. *2007.51, Fig. 8*), one copper pendant, copper fragments and slags. One heavily burned clay crucible containing traces of copper smelting was found at the bottom of a small pit (*ibid. 48–51, Fig. 7.1, 2,4*). The surrounding area also revealed traces of copper on the floor. In trench B, a series of hollows was discovered in the floor with successive layers of burnt clay in the interior (Fig. 3), which offered clear evidence for copper extraction. These features resemble similar constructions at Dikili Tash (see below). According to preliminary analyses (optical microscope, XRF and SEM), a special feature of copper production at Promachon-Topolnica is the use of a secondary copper ore (carbonate) of high pureness, consisting solely of malachite with >95% CuO. Such a pure copper ore, with no alumina-calcium-silica and iron admixtures, allows the production of copper at temperatures lower than 1000°C without slag being produced (*Koukouli-Chrysanthaki, Bassiakos 2002; Bassiakos* et al. *2019*). Although relevant analysis of the aforementioned pure copper ores is still ongoing, it is clear that the metallurgical activity in Promachon-Topolnica is closely related to technological traditions of copper production in the Balkan hinterland (*Pernicka* et al. *1997; Gale* et al. *2003; Borić 2009; Radivojević* et al. *2010; Radivojević, Rehren 2016; Rehren* et al. *2020; Radivojević, Roberts 2021*).

Dimitra

Metal finds from Dimitra are proportionally numerous (*Grammenos 1997.Pl. II*) as all the soil from the two trenches investigated was sieved. Neolithic strata yielded 38 copper objects – 21 beads, one fishhook (*ibid. 51, Pl. 36.2*), five parts of pins or wires, and 11 undefined fragments. The majority come from 5th millennium BC layers, but some certainly date to the second half of the 6th millennium (*i.e.* five beads from 'Middle Neolithic' layers in trench II). Fourteen copper artefacts have been analysed with several methods, including emission spectroscopy for the estimation of their qualitative composition, proton induced x-ray emission (PIXE) to determine their quantitative elemental composition, and

x-ray radiography in order to confirm the internal metallic structure of the objects (*Mirtsou* et al. *1997*). One copper artefact was sectioned for metallographic examination to obtain information about the manufacturing procedure. All samples had different compositions, with arsenic, zinc and bismuth present in various proportions. Copper beads were produced by cold hammering and annealing at about 600°C.

Apart from the metal objects, small amounts of polymetallic ore (rich in copper, iron, lead) have been collected from both trenches, but they are not yet analysed. No melting or smelting installations have been identified in the excavated areas. Consequently, there is still no direct evidence for on-site metallurgical activity, and we are not aware which metal source was exploited.

Kryoneri

Three copper pins/awls, two fragments of copper rings and some ore fragments were found in Late Neolithic deposits (mid-5th millennium BC), from both domestic context and waste pits (*Malamidou 1997.518, Fig. 11; 2007.302, Fig. 8; 2016.312, Fig. 26*). Preliminary examination of two pins under an electron-scanning microscope (SEM) by Yannis Maniatis at the Laboratory of Archaeometry of the NCSR Demokritos showed that they are made of pure copper. No further analysis has yet been conducted.

Sitagroi

The finds of phases Sitagroi II and III (late 6th and 5th millennia BC) include a copper pin, an awl, five beads and a few copper fragments or lumps (*Renfrew, Slater 2003.305, 319–320, Fig. 8.1.a-d,f-g*). In addition, a marked concentration of sherds with copper incrustation was detected in square MM layer 20 and adjacent levels (phase Sitagroi III). Four sherds with copper remains from square MM, layers 61 and 60, probably belong to an earlier context. Given the nature of the ceramics (coarse, with rough surfaces and curved walls) and the distribution of the remains (mostly inside and on the broken edges), they are interpreted as parts of crucibles or as sherds used to remove or to hold back dross during metal pouring (Fig. 4) (*Renfrew, Slater 2003. 303, 312, Fig. 8.4*). One of the best-preserved is a fragment of an oval-shaped crucible (dimensions *c.* 9x6cm, wall thickness up to 1.7cm) (*ibid. 306, Fig. 8.4.I, Pl. 8.10*). No moulds were recognized.

Sixty-eight samples from Neolithic phases, either metallic or non-metallic but presumably related to metal technology, were sectioned and analysed on a Microscan V Microprobe Analyser (*ibid. 301–302*). It should be kept in mind that these analyses were conducted in the late 1960s using a first-generation microprobe analyser that had limited levels of precision and sensitivity. The five non-metallic samples from the Sitagroi I levels provided no evidence of metalworking. Four out of the 12 analysed samples from the phase II levels were made of copper with no intentional alloying, while the other eight were non-metallic, showing no evidence of on-site smelting. By contrast, phase III finds (11 copper objects and 40 sherds with copper deposits) show clear evidence of smelting and casting. The very low concentrations of impurities in some samples may indicate that smaller pieces of native copper were melted together in order to form an object, whereas objects with higher impurity levels may well be the product of smelting from ores. Other specimens show evidence of cold working and annealing. Three objects contained tin, but not in percentages as high as those normally associated with deliberate alloying, and two contained lead in small amounts.



Fig. 3. Promachon-Topolnitsa, series of hollows in trench B with evidence of use for copper extraction (© Ephorate of Antiquities of Serres).

The question arises of where the activities of melting or smelting, casting, cold working and annealing took place. Five separate contexts yielded sherds with adherent copper deposit. The richest one is, as already mentioned, square MM level 20, which is a rich fill including pottery, figurine fragments, bone, clay and stone objects, as well as two finished copper objects (the roll-headed pin and the awl or fish-hook). All fragments with copper deposit were concentrated around an installation, consisting of a ba-

ked clay surface surrounded on three sides by a packed clay wall and open to the east (*Renfrew* et al. *1986.212, Fig. 8.19, Pl. XXXVII. 2*). This may be interpreted as a pyrotechnological installation. Perhaps crucible melting was carried out in such places, although the smelting process was probably undertaken at or near the mining areas from which the copper ore was obtained.

Dikili Tash

A relatively small number of copper artefacts were found during the first excavation program, conducted by Jean Deshayes and Dimitrios Theocharis between 1961 and 1975. A small copper bead (*Séfériadès 1992.115, Pl. 146.a*) was the only artefact retrieved from a phase I context (end of 6th millennium BC), roughly contemporary with Sitagroi II. The levels of Dikili Tash phase II (contemporary with Sitagroi III) in the sectors excavated by the French team yielded nine copper awls or pins (*ibid. 115–116, Pl. 146.b, 199.e,f*), but no ornaments. Two unstratified copper roll-headed pins from the same sectors might also come from levels of this period (*ibid. 118–119, Pl. 147.b,c; 200.b*).

Five pins from phase II have been analysed by atomic absorption spectroscopy (AAS). They all contain minor percentages of lead, iron, silver, and nickel, and in two cases tin (*ibid. 114, Tab. 12*). All these elements can be present in small percentages in copper oxides such as malachite.

A few occurrences of copper oxides and copper fragments are reported in the archives of Jean Deshayes in contexts of both phase I (square X29-niv. 13) and II (squares W29-niv. 9 and W30-sol 6). Interestingly, the last of these contexts shows heavy traces of combustion around a clay-plastered pit, which has been interpreted as a possible hearth (*Treuil 1992. 23*). A heavily burnt sherd with copper traces is also recorded in phase II (square X30-niv. 7).

Sectors I and II, excavated by Theocharis in 1961 and 1967, respectively, have yielded some 10 copper artefacts and a sherd with copper incrustation, most probably a crucible fragment, and these are all unpublished. At least two of them (one pin and a flat sheet of copper) found in sector II/1967 could date from the Late Neolithic.

The second and third excavation programs (1986–2016) added further copper objects to the site's inventory. Parts of four pins or awls were retrieved from late-5th millennium contexts in sector 6 (which

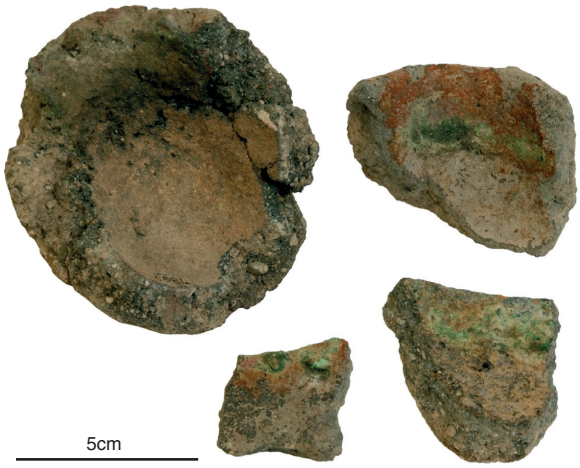

Fig. 4. Sitagroi, fragments of crucibles (© Ephorate of Antiquities of Drama).

is an extension of Theocharis' sector II), although none in an entirely secure position. A fifth one was stuck on the outer surface of a sherd found in a slightly earlier level in sector 5 (level V/East/1, *c.* 4700–4500 BC). A copper bead (Fig. 5) was found near a hearth or oven in House 2, again in sector 6.

The best-contextualized copper artefacts are however two other beads and an awl (Fig. 6) found in the neighbouring House 1, whose destruction has been dated to the years 4340–4260 cal BC. They come from two distinct groups of ornaments and raw materials found on the house floor, less than 2m apart from each other. The first group, from which the beads come, contained some 270 items in total, mainly clay, shell and stone beads and a few pieces of unworked shell, whereas the second group containing the awl comprised no less than 1000 beads of stone, a dozen of spondylus bracelets, hundreds of perforated plaques and pieces of boar tusks, graphite cones, and also a few gold ornaments (*Darcque* et al. *2012–2013.753–758; 2014.605–608; 2015; 2020.256–265, Fig. 6–39 to 6–48, 274–275, Fig. 6–64*). One of the two copper beads (actually a sheet of copper folded in the shape of a cylinder) was caught in the hole of a stone bead. Analysis with a portable XRF conducted in 2013 by Sariel Shalev (Haifa University) confirmed that both beads were made from pure copper (the awl was not analysed).

A few more copper artefacts were retrieved from sector 2 at the southern periphery of the tell, but their chronology is not safe as they all come from colluvia with later components (*Darcque* et al. *2020. 86–87, Fig. 3–52.b-d*). The only exception is a small copper bead, which comes from a colluvium securely dated to the 5th millennium BC.

From the same layer of sector 2 also comes a fragmented clay mould (Fig. 7), the first discovered at Dikili Tash (*ibid. 75–76, Fig. 3–39.e*). It is made from well-refined clay and has fine incisions on all sides. The shape of the cavity on its upper surface suggests that it was probably used for the casting of chisels – a type of object common in assemblages of this period in both the Aegean and Balkans (*Chernykh 1978.Pls. 10, 12; Zachos 2010.86, Fig. 6–6*). XRF-analysis detected copper traces in the cavity's walls.

No crucible fragments have been found so far. One vitrified sherd with a copper deposit on its internal surface was found in the area to the southwest of House 3 in sector 6, but very near the surface.

The existence of melting or smelting installations in Dikili Tash is debated. A series of small cavities whose inner surfaces were covered with successive layers of burned clay plaster, alternating with ash layers and bearing traces of intense fire, have been interpreted as possible metallurgical structures. All of them were found in layers of phase Dikili Tash I (three in level XIV of square W30, one in level XIII of square W30 and two in level 11 of square X30) (*Séfériadès 1983.647; Treuil 1992.21–23, Pls. 13.B, 15, 32.A,B; Séfériadès 1992.115*). However, unlike Promachon-Topolnitsa (see above), no trace of slags or other elements related to metallurgical activity have been detected within or nearby these structures.

Paradeisos
The Late Neolithic levels at Paradeisos yielded two copper needles, slightly bent, 7 and 7.2cm in length respectively (Fig. 8) (*Hellström 1987.85, Fig. 48.18, 19*). Some other shapeless copper fragments were collected. No other indications of metallurgical activity were recorded.

Kastri Theologos-Thasos
Two copper pins were retrieved from Late Neolithic levels at Kastri (mid-5th millennium BC). Analysis



Fig. 5. Dikili Tash, sector 6, copper bead found next to a hearth or oven in House 2 (© Dikili Tash Project-EFA).

has demonstrated the existence of arsenical copper, probably of Thasian origin, although this could not be safely attributed to any of the known extraction sites on the island (*Koukouli 1992.677*).

Limenaria-Thasos
Excavations of Neolithic strata at Limenaria brought to light a significant number of finds associated with copper related metallurgical activities. The recovered evidence includes copper artefacts, slags, and numerous fragments of hematite/limonite lumps, some containing secondary cupriferous minerals, mainly malachite and azurite. A malachite bead was recovered from an upper layer in the Konstantinidis plot, dating from the end of the 6th or the beginning of the 5th millennium BC (Fig. 9) (*Papadopoulos 2008.64, Fig. 2, p. 67; Papadopoulos, Malamidou 2012.41*). It is a pierced piece of malachite, made simply by percussion and polishing.

Twenty samples from slags and/or ore lumps, coming from various layers of the excavated areas, were studied with optical microscopy (OM), scanning electron microscopy (SEM- EDX), x-ray diffraction spectroscopy (XRD), and neutron activation analysis (NAA) (*Bassiakos 2012; Bassiakos* et al. *2019*). Analyses showed that copper slag samples derive from reduction smelting to obtain copper. A notable heterogeneity in their texture, either micro-morphological or chemical, seems to have resulted from inefficient reducing conditions, suggesting a certain insuf-



Fig. 6. Dikili Tash, sector 6, copper beads (a-b) and copper awl (c) from House 1 (© Dikili Tash Project-EFA).



Fig. 7. Dikili Tash, sector 2, fragmented clay mould with incised decoration on all sides (© Dikili Tash Project-EFA).

ficient control of furnace operation with some loss in the gaining of metallic copper. Despite that, these slags offer solid proof of a successful metallurgical process for efficient production of metallic copper. Until recently a similar heterogeneity in smelting slags from copper extraction was only noted at Aegean sites dated to the late 4th and 3rd millennia BC, such as Kephala-Petras, Crete (*Catapotis* et al. *2011; Papadatos* et al. *2007*) and Kythnos, Cyclades (*Bassiakos, Philaniotou 2007*), but this is now also reported from the late 5th millennium BC site of Akladi Cheiri in South-East Bulgaria (*Rehren* et al. *2020*).

One sample represents a case of slagged lining deriving from the furnace's internal surface. Slag fragments like this are common within or very close to the smelting furnace from numerous other sites of early copper pyrometallurgy in the Aegean (*Georgakopoulou 2005*). Therefore, locating finds of this kind at Limenaria would suggest that the main smelting site, from which the slags under study derive, was not far from the excavated sectors. The numerous slagged ceramic sherds found in a pit at Akladi Cheiri have also been attributed to the lining of a nearby smelting hearth (*Rehren* et al. *2020; Radivojević, Roberts 2021.221*).

As for the numerous lumps or fragments of iron ores from the same excavated layers, they most probably derive from local sources and could be explained as waste products of a final enrichment stage of a cupriferous iron ore (*cf. Bassiakos, Catapotis 2006*), although they could also have been waste products of a different enrichment process for the extraction of a red or yellow pigment.

Taken altogether, the analytical results strongly suggest that the metalworkers exclusively utilized the local mineral resources for copper production. They demonstrated significant skill and succeeded in extracting metallic copper from the locally available polymetallic (and poor in cupriferous secondary ores) mineral resources.



Fig. 8. Paradeisos, copper needles (© Ephorate of Antiquities of Kavala).

Silver – lead

Limenaria

An unexpectedly early metal find, a small fragment of a silver pin, was discovered in a late Middle/early Late Neolithic horizon (second half of the 6th millennium BC) at the Lioudas plot (Fig. 10) (*Papadopoulos, Malamidou 1997.836–837; Papadopoulos 2008. 65, Fig. 3*). Compositional data and microstructural examination have shown that the pin was shaped by hammering of a lump of silver. Its internal micromorphology reveals that the silver is heterogeneous and consists of pure metal in which semi-translucent, minute pieces of slag are embedded. It is therefore presumed that the silver used to make the pin is not native, but the product of an extraction from argentiferous lead ore (*Bassiakos 2012. 210–211*).

No silver finds are recorded from the 5th millennium, which is altogether less well documented on the site. However, there is firm evidence for silver extraction practice from a context of the early 4th millennium BC ('Final Neolithic'). Three litharge fragments coming from Markoulis plot belong to a piece of the 'shallow bowl' type, which derives from lead-silver extraction process (Fig. 11) (*Papadopoulos 2008.66, Fig. 5.a-b, 68–69; Papadopoulos, Malamidou 2008.431*). Compositional analysis and microstructural examination of these fragments suggest extraction and treatment of local Pb/Zn/Ag ores



Fig. 9. Limenaria, malachite bead (© Ephorate of Antiquities of Kavala).

for the production of silver artefacts (*Bassiakos 2012.208–210; Bassiakos* et al. *2019*). The circular, discoid morphology and the chemical composition of this type of litharge fragments do not relate to the platy or tubular litharge deriving from the well-known cupellation process of historic times (*Bassiakos* et al. *2013*). The process of early silver production that leaves behind as a by-product a shallow bowl of litharge has not been fully clarified yet, but similar examples are known from a number of sites from the end of the Final Neolithic/Early Bronze Age I (second half of the 4th millennium BC) in Mesogeia, Attica (*Kakavogianni* et al. *2006.79; 2008; 2016.446–447, Fig. 15*), or neighbouring Eastern Mediterranean regions (*e.g.*, East Anatolia – *Hess* et al. *1998*; Syria – *Pernicka* et al. *1998*). The dating of the litharge from Limenaria is supported by both the relative and absolute chronology (calibrated date between 3977 and 3789 BC), which makes it one of the earliest, if not the earliest piece, of firm evidence for the process of silver production in the Aegean.

Gold

Dimitra

Three golden artefacts were collected during the excavation in Dimitra, all from Late Neolithic contexts, more or less securely dated to the advanced 5th millennium BC. Two of them are beads: one collected from the upper part of the Neolithic deposits in trench I, disturbed by the LBA wall (*Grammenos 1997.49, Pl. 35.8*), the other from a lower level in the same trench (*ibid. Pl. II*). The third artefact, also from trench I, is described as a fishhook (Fig. 12) (*ibid. 51, Pl. 36.1*). The two beads have been examined with different methods (*Mirtsou* et al. *1997*; see above). Analysis showed that they were made from gold (both contained 10% silver and 0.05% copper), which was cold hammered and annealed to produce ring-pearls with a wall thickness of 0.4mm and an inner diameter of 2 and 5mm (*ibid. 93*). The polished but unetched structure of both gold samples exhibited a number of quartz inclusions, so the artefacts were most probably made from native gold without melting. The etching with *aqua regia* solution revealed a single-phase structure with few twinned crystals, indicating hammering followed by a reheating process.

Sitagroi

One gold bead was retrieved from the sieving of sediments in a small sounding (ZB) adjacent to the main stratigraphic sounding ZA, and it is assigned to phase III, *i.e.* the 5th millennium BC (*Renfrew, Slater 2003.319–320, Fig. 8.1.e, Pl. 8.4*). It belongs to the narrow cylindrical type. Examination under a microscope showed that the bead was made by beating a flat piece of metal around an inner core (which was not preserved). The ends were cut diagonally and had tooling marks near their edges, indicating that an attempt was made to weld them together. No further analysis has been conducted.

Dikili Tash

A small gold bead was found in the sector excavated by Theocharis in 1961 on the east slope of the tell (sector I), but was not included in the relevant preliminary report (*Koukouli, Rhomiopoulou 1992*). Comparison with artefacts from other sites and from the more recent excavations at Dikili Tash itself allows its dating to the late 5th millennium BC (*Tsirtsoni 2018.1276–1279, Fig. 2*). The piece of gold M206 kept at the Philippi Museum is probably the one mentioned by Michel L. Séfériadès (*1992. 113*) as coming from a coeval context from the excavations by Deshayes.

During the 2012–2013 excavations at Dikili Tash, four new gold objects were recovered, but this time from a perfectly secure context: a rich group of finished and half-finished ornaments, tools and raw materials found in the northern part of House 1, in sector 6 (see description and chronology above). Two of the gold ornaments, conventionally described as cylindrical beads, were flat strips of gold rolled around smaller beads from stone, while the third, which was smaller in size, was made with the same technique but contained no beads from a different material. The fourth was a twisted band forming a ring at one end (Fig. 13). The last type had not been attested yet in Northern Greece, but is known from a number of sites (mostly cemeteries) in the Balkans (*e.g.,* at Varna, *Le premier or de l'humanité* 118–119 (grave 4), 136–137 (grave 41), 149 (grave 97); see also *Tsirtsoni 2018.1280*). An SEM Examination by Michael Vavelidis (Department of Geology, Aristotle University of Thessaloniki) showed that all four are

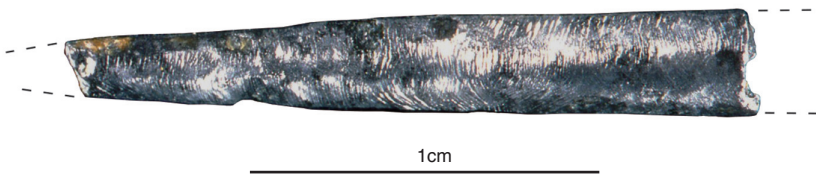

Fig. 10. Limenaria, silver pin (© Ephorate of Antiquities of Kavala).

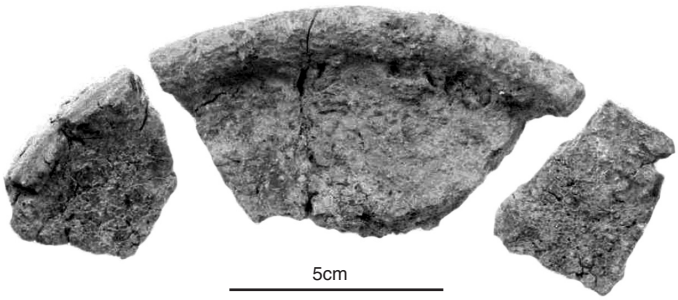

Fig. 11. Limenaria, litharge fragments of the 'shallow bowl' type (© Ephorate of Antiquities of Kavala).

made of gold with a low percentage of silver (4–9%). This points to native gold as a raw material. The surfaces show traces of hammering and rubbing (Fig. 14).

Although no direct connection has been made yet between the traces observed on the gold ornaments, or the other associated artefacts, and the tools found near them (one copper and one bone awl, one stone hammer/polisher, and several chipped-stone tools), it is clear that we see here an on-going process of manufacturing of jewels and decorative elements. Other craft activities were taking place in House 1 (*e.g.,* decorating of pottery) together with more – and less – ordinary activities, such as storage, cooking and wine-making (*Darcque* et al. *2012–2013. 752–758; 2014.607–610; 2020.298–303*).

The same house yielded another unexpected find connected with gold: a complete clay vessel, a bowl decorated with brown-on-cream painted decoration, which proved to display gold 'stains' at several spots of its exterior surface and in the inner part of the rim (*Tsirtsoni 2018. 1313, Fig. 8*; originally illustrated in *Darcque* et al. *2015.408, Fig. 7; Tsirtsoni 2016.285, Fig. 14*) (Fig. 15). The bowl was standing on the floor a few meters to the south of the group of ornaments discussed above, and at short distance from the other group of ornaments that contained the copped beads (see above). The gold material seems to have been added after the original firing of the vessel, and indeed one wonders if this was done intentionally, as part of a restoration, or accidentally, when someone working with gold paint on another object would have touched the vessel with his/her gold-stained fingers or tools.



Fig. 12. Dimitra, gold 'fish-hook' (© Ephorate of Antiquities of Serres).

However, intentional gold-painting on pottery is also attested at Dikili Tash. Evidence comes from a unique sherd found in sector 2, at the southern periphery of the tell: it is a fragment from the rim and handle of a small amphora, decorated with parallel oblique lines (Fig. 16). Its stratigraphical position is not secure, but according to its typological characteristics (shape, fabric, firing, surface finishing and decorative motifs) it can be dated with certainty to the years between 4800–4200 BC, and most probably after 4500 BC. This vessel type is indeed very common for this period both at Dikili Tash and the wider area, with decoration typically executed with graphite paint. Here, graphite has been replaced by gold, applied before firing (*Tsirtsoni 2018. 1285–1288*). Examples of such substitution of an ordinary colouring material (graphite) for a less ordinary, and presumably precious one (gold) are known so far with certainty only from the Varna necropolis (*Le premier or de l'humanité* 118–125: two vessels from grave 4). Two sherds from the site of Bubanj in Serbia (*Stojić, Jocić 2006.154–155, Pl. 41.b; Bulatović* et al. *2020.46, 53, Pl. 6/1*) and two more from Krivodol and Chirpan in Bulgaria (personal communication of our colleagues Nadezhda Todorova and Petur Leshtakov) could be the only other candidates, if their dating was confirmed.



Fig. 13. Dikili Tash, gold ornament from House 1 (© Dikili Tash Project-EFA).

Discussion

Metal objects, albeit in small numbers, are attested in most sites investigated to some extent (Tab. 1). They are all either small tools (awls, pins, fishhooks, wires) or ornaments (beads, twisted bands, pen-

dants), and no objects with any substantial thickness of metal (like flat axes, shaft-hole axes or axe-adzes) have been found. Few of the metal finds came from a recognisable in situ context of use, with the exception of Dikili Tash, where a copper awl was found in House 1, sector 6, together with golden beads and a group of other finished and semi-finished elements of jewellery.

Although a complete metallurgical chain of production (*chaîne opératoire*), beginning with the raw material and ending with the finished product, was not successfully proven for any of the excavated sites, extraction from ores was attested for copper and silver. Metallurgical installations are not well documented in general either in the Balkans or Aegean. The recovery of a significant number of sherds or crucible fragments and associated copper deposits from phase III levels at Sitagroi is of considerable interest. They offer evidence of, at the least, copper melting on the site. Smelting in small shallow pit-shaped hearths opened in the clay-rich ground is probably also attested at Dikili Tash.

Copper production at Promachon-Topolnitsa is among the earliest in the Balkans, dating from the end of the 6th and the early 5th millennium BC, and is documented both by stratigraphy and absolute dating. There, the production is based on simple smelting of very pure malachite, producing no slag

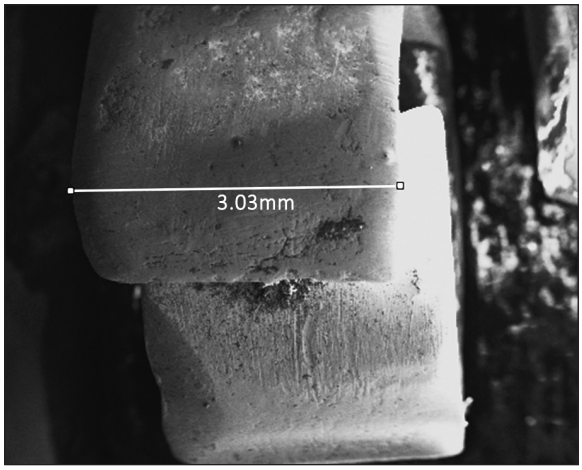

Fig. 14. Dikili Tash, SEM microphotograph of a gold bead from House 1 (© M. Vavelidis-Dikili Tash Project).

(*Koukouli, Bassiakos 2002*), a method consistent with what we know of the main metal-producing techniques of the Balkan hinterland, described as 'slagless' or 'nearly slagless' (*Pernicka* et al. *1997; Radivojević, Rehren 2016; Rehren* et al. *2020; Radivojević, Roberts 2021*).

The finds from Limenaria provide a more diversified picture. Items like the malachite bead show that the properties of the ores, which were collected from sources not far from the settlement, were already understood with regard to their use as pigments and

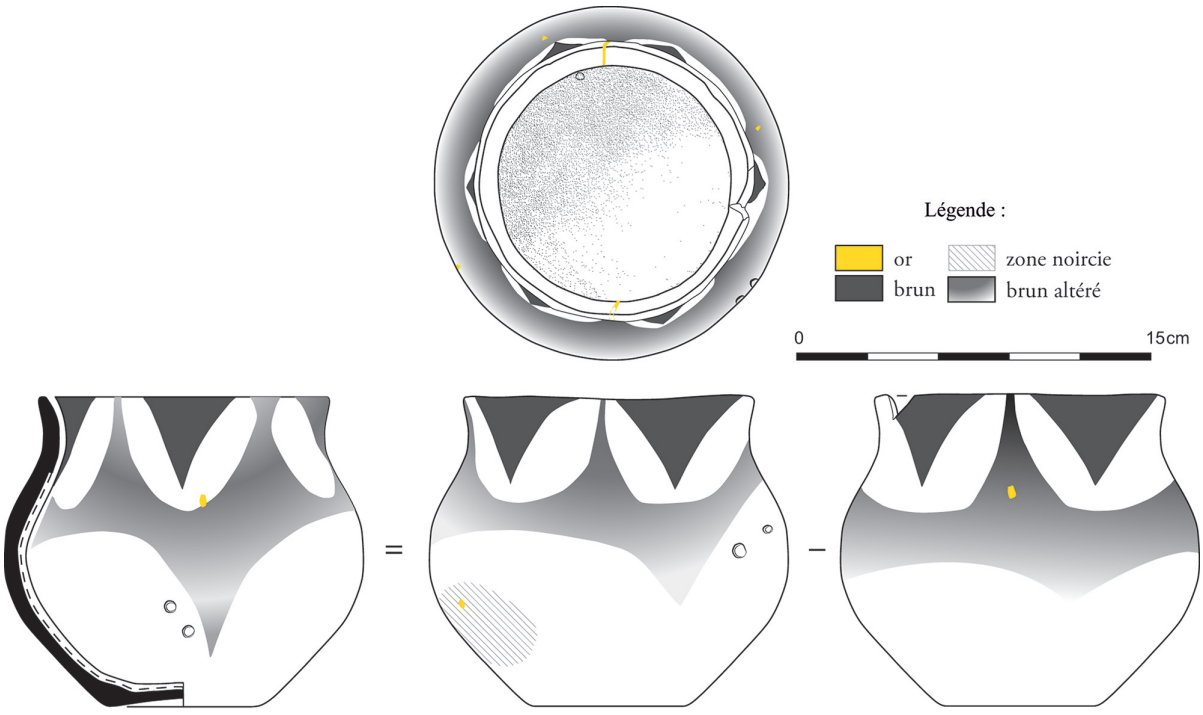

Fig. 15. Dikili Tash, brown-on-cream painted vessel from House 1 with gold 'stains' (drawing A. Ilioglou) (© Dikili Tash Project).

raw materials for other purposes. Given the long tradition among prehistoric communities on Thasos in the exploration of local minerals, it is not surprising that as early as the 5th millennium BC the inhabitants of Limenaria were trying to extract copper from the Thasian polymetallic ores (*Nerantzis, Papadopoulos 2013; Bassiakos* et al. *2019*). The gaining of copper from such polymetallic raw materials required, apart from enriching the ore with copper minerals, a considerable level of skills and experience, which recalls pyro-metallurgical practices that are also attested later in the Aegean (*Bassiakos, Catapotis 2006*). On the basis of this evidence, Thasos seemed to be part of a technological tradition with ties to the Aegean and Asia Minor, rather than to the Balkans (*Bassiakos* et al. *2019.2754*). The recent discovery of similar remains at the late 5th millennium BC Akladi Cheiri, in South-East Bulgaria (*Rehren* et al. *2020*), invites us to reconsider the evolution patterns of early small-scale metallurgy in the wider area.

The fact that Limenaria, Thasos, provided firm evidence for extraction of silver in the early 4th millennium, and possibly earlier, is of great interest. Silver objects are not known in the Balkans before the end of 4th millennium (*Nikolova 1999.303–308; Alexandrov 2009; 2018*), whereas they appear earlier and are more common in the Aegean and southern Greece (*e.g.,* Cyclades, Attica, *Dimakopoulou 1998.64–65; Zachos 2010.89*; see also *Tsirtsoni 2014.295*). Silver is rarely found as a native mineral element. Unlike gold, it is rarely found in significant amounts in placer deposits. The principal sources of silver are the ores of copper, copper-nickel, lead, and lead-zinc. Lead and silver extraction was attested through compositional data and microstructural examination of fragments of litharge and the silver pin found at Limenaria. The availability of resources locally was an important factor for the early exploitation of silver ores by Neolithic people. Nevertheless, given the fact that Thasos is open to southern influences in many regards, sharing of Aegean technological traditions must also have played an important role.

Gold objects are found in mainland sites of Eastern Macedonia only as beads in the form of hammered sheets rolled in a cylindrical shape, while hammered sheets of other shapes and ring-shaped pendants are absent, perhaps because objects of this type are more common in tombs (*e.g.,* Aravissos, central Macedonia, *Zachos 2010.89; 1996b.167, 339–340*; Thessaly, *ibid. 167, 339*). All the above have close typological



Fig. 16. Dikili Tash, fragment of a gold-painted vessel from sector 2 (© Dikili Tash Project-EFA).

similarities with the ones from southeast Europe, which were found in large quantities in tombs, mainly in the extensive cemeteries of Bulgaria.

Gold paints in Dikili Tash show that the Late Neolithic inhabitants of the site were familiar with this metal. They were using it not only as precious material for jewellery making, but also in the *chaîne opératoire* of decorating pottery, in the same way as graphite and other minerals. This fact provides evidence for close relations with the pyrotechnology traditions of the Balkans.

Evidence for the extraction of metals from mining sites is lacking at the moment. Placer gold areas and alluvial gold washeries are difficult to distinguish and locate after centuries of erosional processes. Nevertheless, bearing in mind the abundance of mineralization in the area, one can assume that some prehistoric hard rock mining locations, which survived later mining activities, must exist. Therefore, and despite difficulties, locating traces of prehistoric mining and identifying the origin of the various raw materials and their relationship to the finished objects should be targeted, and ongoing research (*Vaxevanopoulos 2017a; Vaxevanopoulos* et al. *2021*) is in engaged in this.

Conclusion

Despite the relatively modest nature of the individual metal objects retrieved from Eastern Macedonian settlements, their widespread presence and coherent picture add significant data about the development of metal production in the North Aegean and more broadly in the Balkans. The fact that they come from secure stratigraphic contexts allows their dating to be firmly established, whereas their integration in considerably long sequences such as those

Settlement	Copper Artefacts	Silver Artefacts	Gold Artefacts	Ore and Metallurgical Findings	Dating	References
Promachon-Topolnitsa	malachite beads, 1 pendant, fragments			1 crucible, hollows with remains of burnt clay, slags	First half of the 5th mill. BC	*Koukouli-Chrysanthaki* et al. 2007
Dimitra	21 beads, 1 fishhook, 5 parts of pins or wires, 11 undefined fragments		2 beads, 1 fishhook	polymetalic ore fragments	Second half of 6th to 5th mill. BC	*Grammenos 1997; Mirtsou* et al. 1997
Kryoneri	3 pins/awls, 2 fragments of rings			copper ore fragments	Mid-5th mill. BC	*Malamidou 1997; 2007; 2016*
Sitagroi	1 roll-headed pin, 1 awl, five beads		1 bead	oval crucible, copper fragments of lumps, sherds with copper incrustation	Late 6th to 5th mill. BC	*Renfrew, Slater 2003*
Dikili Tash	4 beads, 10 awls or pins, 2 unstratified roll-headed pins, parts of 5 more pins or awls, 1 flat sheet		4 beads, 1 twisted band, 1 unidentified, 1 ceramic vessel with gold stains, 1 gold-painted sherd	copper oxides and copper fragments, 1 burnt sherd with copper traces, 1 sherd with copper incrustation, 1 clay mould, 1 clay-plastered pit	End of 6th to late 5th mill. BC	*Séfériadès 1992; Koukouli, Rhomiopoulou 1992; Darcque* et al. *2015; 2020; Tsirtsoni 2016; 2018*
Paradeisos	2 needles and fragments				Late 5th mill. BC	*Hellström 1987*
Kastri Theologos (Thasos)	2 pins				Mid-5th mill. BC	Koukouli 1992
Limenaria (Thasos)	1 malachite bead	1 pin		20 slags and fragments of hematite/limonite lumps containing malachite and azurite, 3 litharge fragments	End of 6th to early 4th mill. BC	*Papadopoulos, Malamidou 1997; 2008; Papadopoulos 2008; 2012; Bassiakos 2012; Bassiakos* et al. *2019*

Tab. 1. Summary of the evidence of metal use in Greek Eastern Macedonia during the Neolithic period.

of Sitagroi and Dikili Tash enables us to follow their evolution.

The identification of smelting activities in several sites provides documented proof of pyrometallurgical copper extraction at the turn of the 6th to 5th millennium BC, while silver was definitely extracted at Limenaria since the 4th millennium BC. Attested are both the main techniques of production of metal items: 'cold' bead-making using established Neolithic technologies, and 'hot' copper smelting using developed metallurgical skills. Indeed, there is sound evidence for copper smelting being carried out using simple holes in the ground, followed by melting and casting elsewhere in the settlement.

Metal objects have not been found in significant numbers, and most tools and ornaments were still made of stone, bone, shell, or other organic materials. So, even though they might have been significant as prestige objects, metal artefacts do not seem to have been an essential component of the local material culture during the Neolithic. According to the data presented here, metal-working was only supplementary to other more important economic activities like agriculture and pastoralism, and second to other crafts, such as pottery or bone-tool manufacture. Considering the scale and importance of metallurgy during the 5th millennium BC, metal-working should be seen more as part of a bigger techno-complex and less as a main incentive for cultural development.

Nevertheless, new research programs should address the question of the geological origin of the various minerals in use, by identifying ancient mining relics and locations (*cf. Kunze* et al. *2018; Krauss* et al. *2020*; esp. *Kunze, Pernicka 2020b*). New analytical approaches, such as the LA ICP-MS method performed on metal objects, should play a more critical role in gai-

ning additional information about the trace elements included and their relation to ore mineralization. Moreover, coherent and comparable analytical results for Late Neolithic finds could further contribute to our interpretations about the technical and social dynamics of appropriation and early use of metals in the Balkans.

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'Scrap metal hoards' of the Later Urnfield Period in the Carpathian Basin: a case study on a hoard from Dezmir, Romania

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ABSTRACT – *Large 'scrap' metal hoards have so far been seen as a characteristic of the older Urnfield Period in the eastern Carpathian Basin. Using the hoard from Dezmir, Romania, as a starting point, this paper describes a group of hoards with chronologically and spatially diverse components. These hoards were hidden during the younger Urnfield Period and represent smaller variants of the older, large 'scrap' hoards. Earlier research has used them to define a chronological horizon ('Phase 3-Jupalnic-Turia-Ha A2'). Based on archaeological observations, spatial data and a correspondence analysis, we argue that they represent a specific hoarding practice instead, characteristic of Phase 4,* i.e. *the younger Urnfield Period.*

KEY WORDS – *Carpathian Basin; Bronze Age; hoards; chronology*

Depoji 'kovinskih odpadkov' iz pozne kulture žarnih grobišč v Karpatski kotlini: študija depoja iz Dezmirja v Romuniji

IZVLEČEK – *Doslej je veljalo, da so veliki depoji 'kovinskih odpadkov' značilnost starejše kulture žarnih grobišč v Karpatski kotlini. S pomočjo depoja v Dezmirju v Romuniji predstavljamo skupino kronološko in prostorsko različnih depojev. Depoji so bili skriti v mlajši kulturi žarnih grobišč in predstavljajo manjše različice starejših depojev 'odpadkov'. Z njimi so v preteklih raziskavah opredelili kronološki horizont 'faza 3-Jupalnic-Turia-Ha A2'. Na osnovi arheoloških opazovanj, prostorskih podatkov in korespondenčnih analiz trdimo, da predstavljajo depojsko prakso, značilno za 4. fazo, torej mlajše obdobje kulture žarnih grobišč.*

KLJUČNE BESEDE – *Karpatska kotlina; bronasta doba; depoji; kronologija*

The hoard

Dezmir (com. Apahida, jud. Cluj) is situated approx. 2km ESE of Cluj-Napoca at the edge of a valley formed by the Zăpodie, a small tributary of the Someşul Mic. The repertory of archaeological finds from the district of Cluj lists single finds of stone axes, an Eneolithic settlement, another one of the Coţofeni Culture, Scythian and Celtic graves as well as Roman buildings; for the Bronze Age, a single find of pottery and a settlement in a plot called 'Tăuşor' are mentioned (*Crişan* et al. *1992.183–186*). The latter saw some small-scale excavation in the early 1960s (*Popescu 1964.556–557, Nr. 44*). What is entirely missing in this repertory though is information on a hoard (Fig. 1) that was discovered at roughly the same time.

The hoard was first published by Mircea Rusu in the frame of the 'Inventaria Archaeologica' series

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(*Rusu 1977a*). There he mentions that the hoard was accidentally discovered on 29th August 1964, while deep ploughing a plot called 'Bocomaia' some 400m to the west of the Someş depression. A short time after the discovery, Rusu and Viorica Pintea conducted excavations at the findspot, leading to the discovery of several more bronze artefacts and 'Hallstatt pottery'.[1] About 50m to the west of the hoard, a pit house dating to the same period was found. Whether the hoard was originally placed within a pottery vessel remains unclear, as the publication does not indicate the exact findspot of the illustrated pottery fragments. Rusu further mentions that the hoard was discovered next to the wall of a Roman villa rustica, which could indicate that the original context was disturbed to some degree. The finds are kept today in the Muzeul Naţional de Istorie a Transilvaniei (MNIT) Cluj-Napoca.

Given the excavations at the findspot, it seems probable that all preserved items of the find were recovered. The hoard was hidden next to or in a (small?) lowland settlement, within a settlement cluster that also included larger sites in dominant positions. Dezmir-Tăuşor, excavated in 1963, is located on a promontory (*Popescu 1964.556–557, Nr. 44*). A closer examination of this Bronze Age microregional system of different settlement types and hoards is unfortunately not possible at the moment. The finds from Dezmir-Tăuşor have never been published, and the plot 'Bocomaia' cannot be exactly located based on the information provided by Rusu. The Someşul Mic flows to the north of Dezmir. Following Rusus's description ("*400m to the west of the Someş depression*"), this would mean that the findspot was located to the northwest of the village, as the neighbouring village Sânnicoară is located immediately to the northeast. However, within this area no plot of land called 'Bocomaia' could be identified.



Fig. 1. The hoard from Dezmir (photo B. Rezi).

The bronze finds

Thirty-six bronzes and one lead artefact could be documented at the MNIT Cluj-Napoca (Fig. 1).[2] All objects underwent conservation procedures and the ones made of bronze now have a brownish to olive-green surface with patches/remains of light blue patina.

1. Beaked socketed axe with a nearly symmetrical mouth and a loop placed slightly below the rim. Both broadsides are uneven, likely due to gas bubbles trapped in the mould during casting; one has a hole caused by a casting fault. Excess metal was left in the area of the loop and casting seams are visible on the lateral sides. Traces of hammering are visible on the blade; the cutting edge is blunt and has small notches. Registration number MNIT Cluj-Napoca P59.547. Length (l.) 12.5cm, depth of socket (d/s.) 8.7cm, width of blade (w/b.) 5.25cm, weight (w.) 322g (Fig. 2.1).

2. Beaked socketed axe with a loop. Traces of the casting jet are visible on the upper part of the loop. Casting seams are detectable on the upper part of the lateral sides, in the blade area they were levelled through hammering. The cutting edge is blunt and has large nicks. The surface has adhesions of earth. Registration number MNIT Cluj-Napoca P 59.548. L. 11.6cm, d/s. 8.3cm, w/b. 4.6cm, w. 256g (Fig. 2.2).

3. Socketed axe with a sharp-edged mouth, loop and curved body. Below the rim there are two horizontal parallel ribs; one broadside has a casting fault (a large hole), the other one has a hole below the rim. There is unremoved excess metal on the loop, traces of ground casting seams

1 In Romanian terminology, meaning Ha A-B.
2 The artefacts were documented by Botond Rezi.

are detectable on the upper part of the lateral sides, while below they have been removed through hammering and use-wear. The cutting edge has notches and the corners have broken away. The surface is uneven due to gas bubbles trapped in the mould during casting. Registration number MNIT Cluj-Napoca P 59.549. L. 9.4cm, d/s. 5.2cm, w/b. 4.4cm, w. 116g (Fig. 2.3).

4. Beaked socketed axe with a loop and curved body; the trapezoid blade is separated from the body by a low ridge. The raw cast has not been overhauled, the two halves of the moulds have accidentally moved slightly in the vertical direction during casting. One broadside is uneven due to gas bubbles trapped in the mould and has a casting defect (an irregular hole). The casting jet was removed, the casting seams are clearly visible. Registration number MNIT Cluj-Napoca P 59.550. L. 13.2cm, d/s. 7.5cm, w/b. 4.8cm, w. 261g (Fig. 2.4).

5. Beaked socketed axe with a curved body, the loop mostly broken off. The broadsides, particularly in the blade area, have numerous casting defects. The casting jet was carefully removed from the loop, the blade area was intensively hammered, leading to the formation of a ridge between blade and body. The cutting edge is sharp and has small notches. Registration number MNIT Cluj-Napoca P. 59.551. L. 12cm, d/s. 7.2cm, w/b. 4.5cm, w. 230g (Fig. 3.5).



Fig. 2. Socketed axes from Dezmir (photo B. Rezi).

6. Beaked socketed axe with a loop and curved body; a large portion of the socket area, including the beak, has broken off. The casting jet has been removed from the loop and the contact point hammered. The casting seams are visible on the upper two-thirds of the narrow sides; one broadside is uneven due to gas bubbles trapped in the mould. The cutting edge is uneven, with small notches. Registration number MNIT Cluj-Napoca P 59.552. L. 12.8cm, d/s. 8.5cm, w/b. 4.8cm, w. 262g (Fig. 3.6)

7. Beaked socketed axe with a loop and pronouncedly curved body. The contact point of the casting jet is visible on the top of the loop, the casting seams are visible on the upper two-thirds of the narrow sides; below they have been removed. A large part of the cutting edge is missing in the centre. Registration number MNIT Cluj-Napoca P 59.553. L. 13.3cm, d/s. 8.4cm, w/b. 6.1cm, w. 381g (Fig. 3.7)

8. Socketed axe with a thickened rim, without a loop. The parallel narrow sides broaden only in the lower quarter of the body into a narrow blade. On one broadside an ornament composed of four chevrons hanging from the rim is preserved, the other broadside has only faint traces of a similar orna-



Fig. 3. Socketed axes from Dezmir (photo B. Rezi).

ment. No casting seams are detectable on the narrow sides, the cutting edge is rounded and has several notches. The surface is rough. Registration number MNIT Cluj-Napoca P 59.554. L. 12.5cm, d/s. 8.3cm, w/b. 4.6cm, w. 321g (Fig. 3.8)

9. Socketed axe with a thickened facetted rim and loop, the body is slightly curved. Both broadsides have three parallel horizontal ribs, one curved rib and below that a Y-shaped ornament, with a flexed rib on each side. The two halves of the moulds accidentally moved slightly horizontally during casting; the casting seams are visible on the upper two-thirds of the narrow sides; below they have been removed. A ridge divides the socket and blade, the cutting edge is jolted and has a large section with old damage. Registration number MNIT Cluj-Napoca P 59.555. L. 14.8cm, d/s. 9cm, w/b. 5.6cm, w. 518g (Fig. 4.9).

10. Socketed axe, due to a casting defect a part of the socket, including the loop, is missing. The parallel narrow sides evolve into a trapezoid blade. Two horizontal parallel ribs are located below the mouth of the socket, followed by pseudo-wings and a ridge. Traces of the casting seams are visible on the upper two-thirds of the narrow sides; below they have been removed. The surface is smooth, the cutting edge is sharp with only small notches and dents. Registration number MNIT Cluj-Napoca L. 9.2cm, remaining d/s. 5.1cm, w/b. 4.5cm, w. 115g (Fig. 4.10).

11. Socketed axe with a thickened rim, the loop broken off, and the body slightly curved. A remainder of the casting jet is visible on the socket mouth above the remains of the loop. One broadside has a ridge between the socket area and blade. The casting seams are visible on the narrow sides, the cutting edge is blunt with notches, and one edge is missing. The surface is rough; the blade in particular has numerous defects from gas bubbles trapped during casting. Registration number MNIT Cluj-Napoca P 59.567. L. 9.5cm, d/s. 5.1cm, w./b. 3.7cm, w. 96g (Fig. 4.11).

12. Lower half of a socketed axe. The breaking edges and the broadsides show traces of hammer blows. Faint traces of a decoration comprising of a 'Y' flanked by two flexed ribs on each side (similar to

Nr. 9) are visible. Traces of the casting seams are detectable on the narrow sides; the cutting edge is asymmetrical. The surface is very uneven due to gas bubbles trapped during casting. Registration number MNIT Cluj-Napoca P 59.565. L. 7.6cm, d/s. (preserved) 3.1cm, w/b. 4.95cm, w. 187g (Fig. 4.12).

13. Blade of a socketed axe, traces of hammer blows on the broadside at the break. During casting, the core was out of centre and the two halves of the mould shifted slightly horizontally. The narrow sides preserve the casting seams, the cutting edge is uneven. The surface is slightly uneven due to gas bubbles trapped during casting. Registration number MNIT Cluj-Napoca P 59.568. L. 6.4cm, d/s. (preserved) 2.5cm, w/b. 4.8cm, w. 148g (Fig. 4.13).

14. Fragment of an axe, lead. The shape and proportions indicate a socketed axe. However, as only the lower two-thirds are preserved and there is no indication of a socket, the object likely was massive. Traces of the casting seams are detectable on the narrow sides; the dark grey surface is uneven and shows white deposits. Registration number P 59.569. L. 8.4cm, body diameter 4x1.4cm, w/b. 5cm, w. 358g (Fig. 4.14).

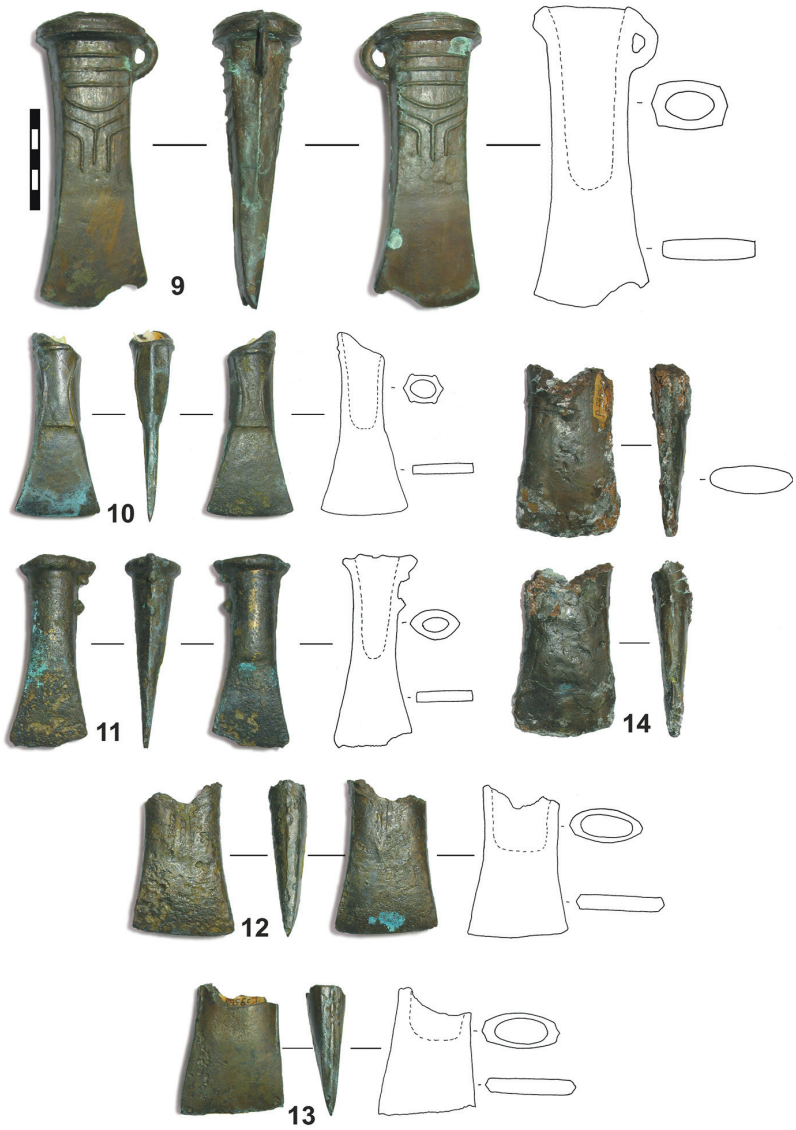

Fig. 4. Socketed axes from Dezmir (photo B. Rezi).

15. Fragment of a knob sickle ("Knopfsichel"). The hafting area and a large portion of the sharply curved blade are preserved. The base of the hafting area is slightly bent inwards and features a conical knob with a round cross section. Two oblique ribs followed by an antithetic rib pair are only faintly visible. The thickened rim of the blade is followed by a rib. The cutting edge has deep notches and nicks. Registration number P 59.556. L. 10.9cm, width 2.8cm (Fig. 5.15).

16. Fragment of a hook sickle ("Hakensichel") with a thickened rim. A casting defect (hole) did not prevent use, as the damage on the cutting edge shows. Registration number P 59.557 (MNIT), 59.558 (Rusu). L.7.4cm, width 2.4cm (Fig. 5.16).

17. Knob sickle, the point is missing. The base of the hafting area is slightly bent inwards and features a conical knob with a round cross section. The thickened rim of the blade is followed by two ribs. The cutting edge is heavily notched. Registration number P 59.560 (MNIT) 59.563 (Rusu). L. 14.1cm, width 2.2cm (Fig. 5.17).

18. Blade of a knob sickle with heavily thickened rim, which is followed by two ribs. The casting jet is still preserved, the cutting edge has several large notches. Registration number P 59.558 (MNIT), 59.557 (Rusu). L.12.6cm, width 2.5cm (Fig. 5.18).

19–20. Two fitting blade fragments of a hook sickle with a thickened rim. Registration number P 59.559.

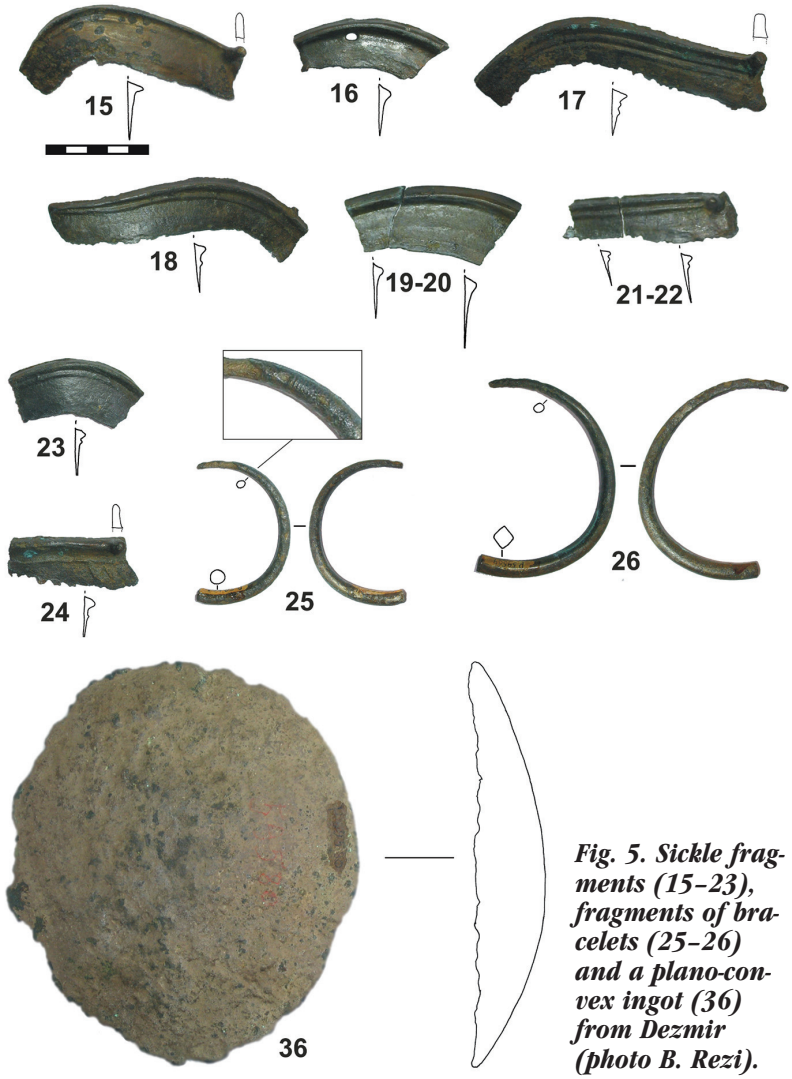

Fig. 5. Sickle fragments (15–23), fragments of bracelets (25–26) and a plano-convex ingot (36) from Dezmir (photo B. Rezi).

L. 5.5cm, width 3.4cm. Registration number P 59. 562b. L. 3.2cm, width 3.8cm (Fig. 5.19–20).

21–22. Two fitting fragments of a knob sickle. The base of the hafting area is rounded and features a conical knob. The rib runs along the edge, followed by a smaller, parallel one. The preserved part of the blade is straight, traces of several hammer blows are visible on the cutting edge. Registration number P 59.561, P 59.562a. L. 6.2cm, width 2.5cm. L. 3.3cm, width 2.1cm (Fig. 5.21–22).

23. Fragment of a knob sickle, the curved middle part is preserved. Registration number P 59.562c. L. 6.5cm, width 2.4cm (Fig. 5.23).

24. Hafting area of a knob sickle with an inwards bent base and small knob. Below the thickened rim runs a small rib; at the base, three parallel inclined ribs are added. The cutting edge shows several and quite regular notches. Registration number P 59.562 (MNIT), P. 59.560 (Rusu). L. 6.3cm, width 2.2cm (Fig. 5.24).

25. Fragment (approximately half) of a bracelet with a round cross section and pointed ends. Towards the end the surface is damaged and shows traces of ornamentation with regularly disposed vertical lines. Registration number P 59.563. Max. diameter 7cm, w. 29g (Fig. 5.25).

26. Fragment (approximately half) of a bracelet with rhomboid cross section and pointed ends. Towards the end the surface is damaged. Registration number P 59.564. Max. diameter 9.7cm, w. 58g (Fig. 5.26).

27. Irregular fragment of a plano-convex ingot (PCI),[3] bronze. Registration number P 59.570. L. 2.7cm, thickness 1.6cm, w. 106g (Fig. 6.27).

28. Fragment of a flat/flat PCI, bronze. Registration number P 59.571. L. 4.7cm, width 2.8cm, w. 447g (Fig. 6.28).

29. Irregular flat/flat PCI. Registration number P 59.573. L. 7.1cm, thickness 0.9cm, w. 130g (Fig. 6.29).

30. Irregular fragment of a flat/flat PCI, bronze. Registration number P 59.574. L. 5.8cm, thickness 3.3cm, w. 813g (Fig. 7.30).

31. Fragment of a presumably sub-rectangular, flat/convex PCI with a very large cavity. Registration number P 59.575. L. 6.4cm, width 2.8cm, w. 348g (Fig. 7.31).

32. Fragment of a likely drop-shaped convex/convex PCI, bronze. Registration number P 59.576. L. 5.8cm, width 3.9cm, w. 628g (Fig. 7.32).

3 The description of the PCIs follows the terminology proposed by Modl (*2019.380–381, Figs. 6–7*).

33. Complete round flat/convex PCI. Determined as copper after the colour of the metal. Registration number P. 59.577 (MNIT) 59.580 (Rusu). Diameter 8.9cm, thickness 2.5cm, w. 3950g (Fig. 6.33).

34. Fragment of a concave/convex PCI, bronze. Registration number P 59.578. L. 5.3cm, thickness 5.9cm, w. 866g (Fig. 7.34).

35. Fragment of a presumably irregular convex/convex PCI with a very large cavity, determined as copper after the colour of the metal. Rusu published a concave cross section drawing, the re-documentation shows clearly that the object is hollow and roughly half of it is preserved. Registration number P 59.579. L. 10.7cm, thickness 5.8cm, w. 1008g (Fig. 7.35).

36. Complete slightly ovoid flat/convex ingot. Registration number P 59.580 (MNIT), P 59.577 (Rusu). Diameter 19.6cm, thickness 3.4cm, w. 740g (Fig. 5.36).

37. Bronze ingot, bar/rod-shaped with a triangular cross section. Excess bronze on both narrow sides hints at casting in an open mould. Registration number P 59.572. L. 11.6cm, cross section 2.6x1.5cm, w. 133g (Fig. 6.37).

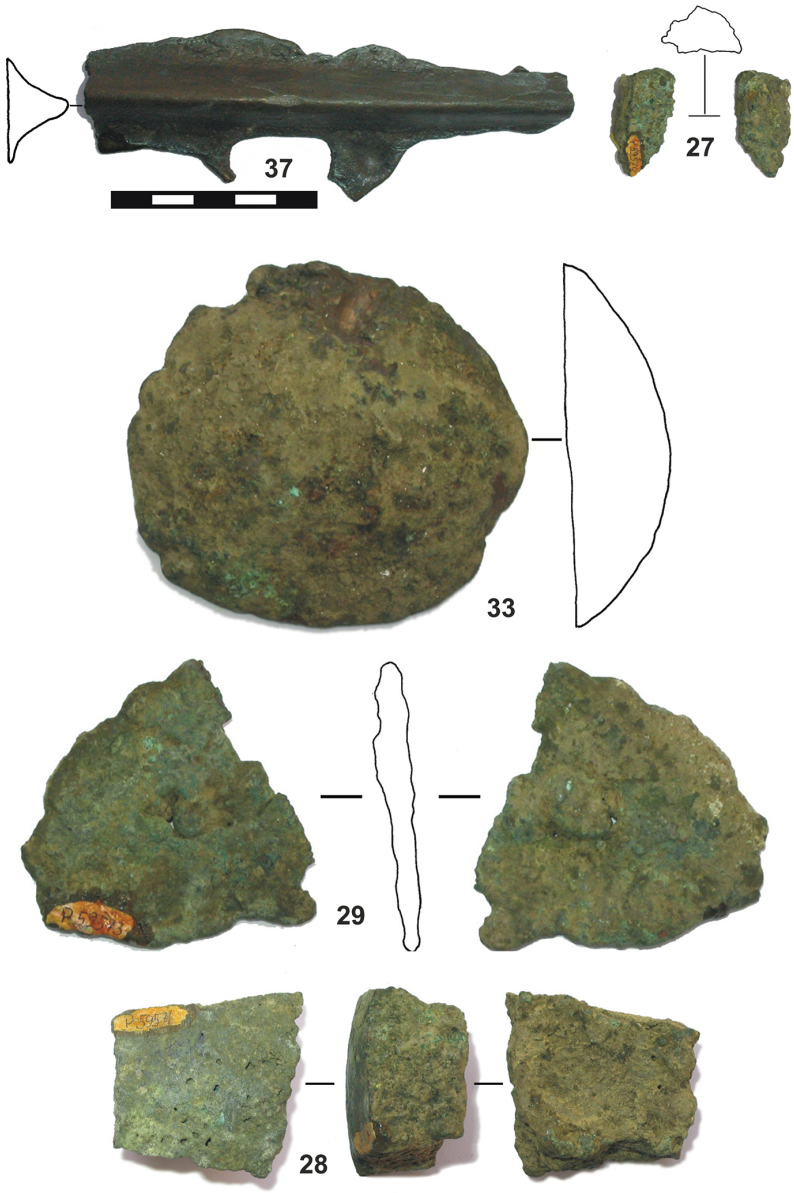

Fig. 6. Plano-convex ingots (27–28, 33), an irregular piece of bronze (29), and a rod-shaped ingot (37) from Dezmir (photo B. Rezi).

A total of 14 socketed axes, 10 sickle fragments, two fragments of bracelets, 10 plano-convex ingots and one bar-shaped ingot can be recorded for the hoard from Dezmir. These numbers differ slightly from earlier publications. Rusu published 14 socketed axes, nine sickle fragments (seven illustrated), two bracelets, one bar-shaped and ten plano-convex ingots (*Rusu 1977a*).[4] Mircea Petrescu-Dîmboviţa (*1977.122–123*) lists, without explanation, 14 socketed axes, nine sickle fragments, two bracelets, a 'casting residue' ("*un rest de turnat/Gussrest*": the

4 The find was first discussed in Rusu's (*1972.553–554, Nr. 84*) doctoral thesis, which remained unpublished. The illustrations are the same while some of the information differs. Rusu states that the findspot was a slight slope and that the plough would have reached a depth of 70–80cm. The find was discovered in a depth of 60cm and two pit houses were discovered at a distance of 50m from the findspot. The content of the hoard is also listed differently: "*6 celturi cu plisc, un celt masiv cu decor, un celt fără toartă şi decor, 2 celturi zvelte, decorate cu cîte două linii paralele reliefate, un celt zvelt cu aripioare false, 2 fragmente de celturi, dintre care unul cu decor; un fragment de celt din plumb; 10 fragmente de seceri dintre care 4 cu butoni şi 6 de tipuri neprecizate, 2 fragmente de brăţări nedecorate cu secţiunea rotundă sau ovală, o brăţară cu secţiunea plan-convexă, 14 turte de bronz şi mai multe fragmente de vase de lut hallstattiene.*" As the thesis clearly has the character of a manuscript, it seems likely that Rusu corrected this account for publication. However, some discrepancies remain, and are hard to explain as the published account states that Rusu personally knew the findspot.



Fig. 7. Fragments of plano-convex ingots from Dezmir (photo B. Rezi).

term is open to interpretation) and 13 ingots.[5] He illustrates five of the sickles already published by Rusu; the ingots and the 'casting residue' are not illustrated (*O.c.122–123, Pl. 288.11–17, 289.1–7*). In the German variant of his monograph, the number of ingots is corrected to ten, and all nine sickle fragments are illustrated (*Petrescu-Dîmboviţa 1978.137–138, Nr. 198, Pl. 217E, 218; sickles Pl. 218.15–23*).

The identification of the bar-shaped object nr. 37 as an ingot or a casting residue is a matter of interpretation, although we share Rusu's opinion and see it as a bar-shaped ingot. The discrepancies regarding the number of sickles are harder to explain. In Rusu's first publication of the hoard, several captions for sickles and bracelets on page R65b got mixed up. Rusu states that four fragments of one sickle (inventory numbers 59.561–59.562 a,b,c) were part of the hoard, but only one fragment (P. 59.561) is illustrated. Research on the originals showed that only the fragments P 59561 (Nr. 21) and P 59562a (Nr. 22) are from the same sickle, while P 59562c (Nr. 23) is at least not a directly fitting piece, and P59562b (Nr. 20) fits with P 59559 (Nr. 19). In his 1978 monograph, Petrescu-Dîmboviţa illustrated nine sickle fragments. Research at the MNIT Cluj-Napoca produced one more fragment, making a total of 10 fragments from at least seven, possibly eight sickles (if Nr. 23 is not from the same artefact as Nr. 21–22).

There is also a contradiction in the total number of hoarded objects. In 1977, Rusu mentioned a total of 43 artefacts with a weight of 13.114kg and published 34 bronzes with illustrations. A simple explanation in the sense of transposed digits is doubtful, as he further lists the mentioned sickle fragments without illustrations. Additionally, there is an unexplained gap in the inventory numbers between Nr. 59.564 and 59.571. Of course, this is not proof that there are missing objects. The 37 objects listed above are all that are stored at the MNIT. If the sickle fragments are assembled, the total number of artefacts would be 34.

On the level of particular objects, the renewed analyses of the artefacts reveals a few differences compared to the published record. The socketed axe Nr. 8 has to date been described as plain (*Rusu 1977a.*

5 Why Petrescu-Dîmboviţa mentions 13 ingots remains unclear. However, in his doctoral thesis Rusu mentions 14 ingots, illustrating 10. If Petrescu-Dîmboviţa used that source (which he does not cite) or other information from Rusu, the number could be explained by subtracting the 'casting rest' from the number of ingots.

Pl. R65a.8; Petrescu-Dîmboviţa 1977.Pl. 288/16). However, it has traces of chevron-shaped ornaments on one broadside. Socketed axe Nr. 2 has a clear ridge between the blade and socket area in the published drawings (*Rusu 1977a.Pl. R 65a.2; Petrescu-Dîmboviţa 1977.Pl. 288.12*), which does not exist on the original object. The bracelet Nr. 25 has been published as undecorated (*Rusu 1977a.R65b.12; Petrescu-Dîmboviţa 1998.62, Nr. 487, Pl. 48.487*), but there are indeed traces of ornaments. The plano-convex ingot Nr. 35 has been drawn and described as 'massive' (*cf. Rusu 1977a.Pl. R65c.34; Petrescu-Dîmboviţa 1978.Pl. 218/36*), although it is clearly hollow.

In summary, most of the artefacts are fragmentary or damaged. The socketed axes have a striking number of casting defects. However, as notches, breakages and deformations of the cutting edges show, all of them have been used except for the unfinished cast Nr. 4. The degree of use (ABN), a measure for the intensity of the use of socketed axes (*Dietrich 2021a.155–156, 162–164, Fig. 7/14*), points in the same direction. Five degrees of use can be determined using the ratio between blade and socket length between ABN 0 (raw casts) and ABN 4, meaning an artefact whose cutting edge has been moved nearly up to the socket by continuous use, rendering the axe unusable.[6] Applying this scheme to the axes from Dezmir, it becomes clear that most of them could still have been used.[7] This is different for the sickles, which are heavily damaged or in fragments. Several fragments have heavily damaged cutting edges, and for Nr. 24 in particular the uniformity of the notches could hint at intentional damaging. In addition to two complete ingots, the hoard contains eight fragments. Using the terminology established by Bianka Nessel (*2014.404–405*) for ingot segments, they are mostly amorphous, some nearly square. All can be characterized as small segments of large plano-convex ingots, none of the fragments fit together. Of particular interest are the two hollow fragments Nr. 31 and 35. Following Daniel Modl (*2019.381*), these cavities are too big to be caused by gas distention during casting of the ingots. One plano-convex ingot from the hoard of Miljana, opć. Klanjec, Croatia (*Dörfler* et al. *1969.69–72, Pl. I.1-2*) has a lead core instead of the cavity. Modl assumes that this could also have been the case for the quite rare 'hollow' plano-convex ingots (the same idea already in *Hansen 1994.231*). The reason for these poly-metallic ingots remains unclear. However, this practice could be interpreted as an attempted fraud within the trade for raw bronze, or as a way to manufacture less valuable votive items (*Hansen 1994.230–231*). In any case the fraud would have been easily detectable when the ingots were partitioned.

The fragment of a lead axe

The socketed axe made of lead (Nr. 14, Fig. 4.14), preserved fragmentarily, cannot have been intended for use, judging from the soft material and the missing socket. While lead is known from several finds in the Carpathian Basin (*Boroffka* et al. *2016*), the lead axe is unique so far. The only distant comparison is a socketed axe from the first hoard from Várvölgy, Zala/Veszprém megye, Hungary, with a lead content of 60.53% (*Müller 2006.15, Fig. 7*). The axe from Dezmir has been described as an axe-shaped ingot (*Boroffka* et al. *2016.409*). The shapes of ingots in the Carpathian area are quite standardized, though (*Modl 2019; Nessel 2019.185–204*), and axes are not among them.

Lead socketed axes are however known in larger numbers from Western Europe, and their find contexts offer another possible interpretation. A bronze casting mould from Cambridge-New Street contained a fragment of a lead socketed axe (*Lawson 1979.178; Needham, Hook 1988.274, App. 2.1*); another find is known from Southall-Brickfield (*Gowland 1901.368, Nr. 2; Britton 1960.Pl. GB51.1a-b*). A casting mould from a hoard discovered on the Isle of Harty, Kent, had lead adhesions (*Evans 1881.441–442*), and Needham and Hook have published a total of seven finds of lead in casting moulds, including the above mentioned axes (*Needham, Hook 1988.App. 2*). There are further instances of lead axes appearing without associated casting moulds (see list in *Dietrich 2011*), but this association was the basis for their interpretation.

Ronald F. Tylecote (*1962.125–128*) saw the lead axes as cores that took the role of wax cores in a procedure similar to lost wax casting. Ernst Foltz (*1980*) has argued against the feasibility of this tech-

6 Degree of use ("*Grad der Abnutzung*", ABN). 0-raw cast, unused. 1-light: Blade socket ratio only slightly reduced; blade is more than 1/3 of the whole axe. 2-medium: the blade is reduced to nearly 1/3 of the whole axe. 3-heavy: the blade is reduced to 1/4 or less of the whole axe. 4-extremely heavy: the blade is reduced up to the socket area. The axe is unusable.

7 As far as determinable: Nr. 1: ABN 3; Nr. 2: ABN 2; Nr. 3: ABN 1; Nr. 4: ABN 0; Nr. 5 ABN 2; Nr. 6: ABN 2–3; Nr. 7: ABN 1; Nr. 8: ABN 2; Nr. 9: ABN 1; Nr. 10: ABN 1; Nr. 11: ABN 1.

nological process, pointing out that lead lumps would remain in the mould when the molten bronze was poured in. Additionally, socketed axes were not produced by lost wax casting, as the casting seams on all axes known from Eastern and Western Europe demonstrate. Although they accept these arguments, Needham and Hook still do not completely exclude the possibility of lead cores (*Needham, Hook 1988. 265–268*).

An alternative interpretation has been proposed though, starting from numerous lead artefacts of the first millennium AD (for a summary see *Bergen 2005.26–37*): a multiphase technological process to produce clay or sand casting moulds from lead models (*Drescher 1978.97–98; Foltz 1980*). Klaus Goldmann (*1981*) has argued that casting in sand moulds may have been the most important technique of Bronze Age casters, as there are only very few stone or bronze moulds preserved. Although this seems debatable, there is good evidence for the use of bronze models in mould production for southeastern Europe (*Dietrich 2011*). Therefore, a similar role seems possible for the lead axe from Dezmir.

The pottery

As (preserved/recovered) ceramic vessels associated with hoards are relatively scarce in the Carpathian Basin, a closer look at the fragments published by Rusu[8] is of interest (*Rusu 1977a.Pl. R65d, Nr. 35–46*). The following 12 fragments were published (the numbers correspond with Fig. 8):

1. Rim sherd, undiagnostic;
2. Rim sherd of a coarse, bellied vessel with flaring rim, decorated with a (damaged?) knob;
3. Rim sherd of a fluted shallow bowl with fluted rim. The sherd is positioned incorrectly in Rusu's drawing, suggesting a large vessel;
4. Body sherd with handle, decorated with a ridge with finger imprints;
5. Body sherd, undecorated, likely part of a large vessel with cylindrical neck;
6. Undiagnostic bottom sherd;
7. Rim fragment of a globular fluted bowl with slightly incurved rim ("Einzugsschale": *Pankau 2004. 62, Typentafel IV, kalottenförmige Schalen Variante 3*);
8. Globular body of a large bowl, the flaring neck is lost, undecorated;
9. Fragment of a broad handle ("Bandhenkel");
10. Fragment of a fluted bowl (?);
11. Undiagnostic bottom sherd;
12. Neck and globular body of a vessel with conical neck ("Kegelhalsgefäß"). The neck has horizontal, parallel fluting, the body arcuate fluting ("*konzentrisch übereinandergelegte Halbkreise, die sich an spitz nach oben gerichteten Umbruchstellen zu einer Bogenreihe schließen*": *Pankau 2004.71, Pl. 5.A2a*).

Three of the twelve pottery fragments are diagnostic for typo-chronological questions (Nr. 3, 7 and 12). The remaining nine are too heavily fragmented (Nr. 1, 4, 6, 9, 10, 11) or are part of types wide-

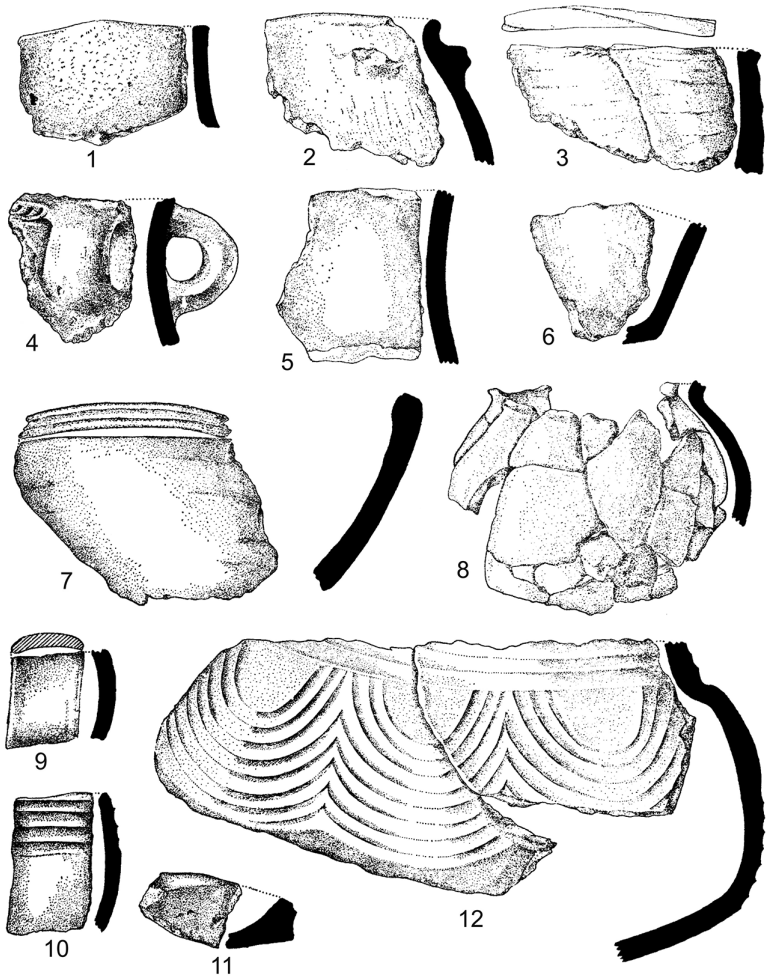

Fig. 8. Pottery found with or near the hoard after Rusu (1977a).

8 The pottery was not available for study at the MNIT Cluj-Napoca at the moment the bronzes were documented.

ly distributed in time and space (Nr. 2, 5, 8). The vessel with a conical neck Nr. 12 has analogies in the so-called Mediaş-Reci Group of the Gáva Culture, for example in the settlements of Mediaş-Cetate, jud. Sibiu (Layers I and II: *Zaharia 1965.Fig. 9.2, 6, Fig. 10.1, 6; Pankau 2004.Pls. 2.1, 12.6, 15.2*) and Reci, jud. Covasna (*Zaharia 1965.Fig. 11.10, 12*). There are further analogies from the so-called Grăniceşti Group of the Gáva Culture, for example from Grăniceşti, jud. Suceava (*László 1994.Fig. 25. 1–4, Fig. 26, Pl. II.3A and Pl. XII.16*, with 'closed' bows). Layer II of the multi-stratified settlement of Teleac, jud. Alba, has more developed variants of the same type (*Vasiliev* et al. *1991.Fig. 32.1, 9, Fig. 41/ 3, 5*). The vessels Nr. 3 and particularly Nr. 7 also have good comparisons in Teleac (Layers II and III; *Vasiliev* et al. *1991.Figs. 31.4, 34.3,6,10,13, 35.6,8,11*).

The dates for Layers I and II at Mediaş and Reci lie between Ha B1-B3 (*Zaharia 1965.102; Vasiliev* et al. *1991.128*) A. László has proposed a start date for Grăniceşti already in Ha A (*László 1994.93–94*); layer II of Teleac was dated to Ha B2-C, layer III to Ha D by Vasiliev (*Vasiliev* et al. *1991.118–129*; but see also the modifications by *Ciugudean 2012*). In short, the best chronological indicator for the pottery is provided by vessel Nr. 12, which has good analogies in Mediaş and dates broadly to Ha B. The importance of this chronological hint for the hoard is lessened by the fact that Rusu did not clearly state which fragments were found directly associated with the hoard, or in the house at a distance of about 50m.

A framework for the spatial-chronological analysis of the hoard from Dezmir

Rusu placed the hoard of Dezmir at the border of the hoarding horizons Jupalnic-Turia (Ha A2) and Moigrad-Tăuteu (Ha B1), while Petrescu-Dîmboviţa dated the find clearly into the Jupalnic-Turia horizon (*Rusu 1977a, Pl. R65d.7; Petrescu-Dîmboviţa 1977. 122–123*). Meanwhile, doubts have been raised about the existence of an equivalent of the central European phase Ha A2 within the Carpathian Basin (*Hansen 1996; Tarbay 2015; Dietrich 2021a*). Additionally, general methodological issues regarding the fine dating of hoard finds have been highlighted. Many hoards represent collections of metalwork accumulated over a longer period of time (*e.g., Vachta 2016; Hansen 2019*), and thus the depth of time represented by the artefacts can be extensive. There are, for instance, Middle Bronze Age shaft hole axes from hoards like Dipşa (*Ciugudean* et al. *2006.37. 22, Nr. 185, Pl. XXXVIII.2, XLVII.2*), Guşteriţa II (*Reissenberger 1872.14–15, Pl. II.11*[9]) and Şpălnaca II (*Petrescu-Dîmboviţa 1978.Pl. 140B.3*[10]), hoards that have conventionally been dated to Ha A1 (hoard horizon Cincu-Suseni). Şpălnaca II has additionally produced Middle Bronze Age flanged axes (*Petrescu-Dîmboviţa 1978.Pl. 140B.1–2*). Moreover, hoards like Guşteriţa II, Şpălnaca II, or Uioara de Sus include artefacts dating to the younger Urnfield Period, *i.e.* to a time after their conventional dating (*Dietrich 2021b*).

Svend Hansen (*2019*) has recently argued that these new insights into the formation processes of hoards should lead to a rethinking of the 'closed find' as a core concept of archaeology. These long-term collections of metalwork are closed finds, but they are not useful for the construction of chronologies, as they may span several hundred years. Hansen used the hoard from Moosbruckschrofen/Piller as a case study, whose artefacts were collected over roughly 300 years. For Romania, Soroceanu *et al.* (*2017*) have described this phenomenon for the first time for the hoard from Band. Whether the long-term accumulation of hoards reflects holy places continually used for depositions or sanctuaries where accumulated votive offerings were buried after being on display for some time, remains open at the moment and would be a topic for a proper study. With regard to the present paper, the chronological implications are of importance.

The only chronological system developed for hoard finds of the Carpathian Basin that takes their chronological fuzziness into account (although not identifying the formation processes as its reason) was developed by Wilhelm A. v. Brunn (*1968*). He differentiated four combination groups of bronze artefacts, which he equated with the phases defined by Herman Müller-Karpe (*1959; v. Brunn 1968.29*) for central Europe: Phase 1 – Bz D – Uriu-Domăneşti; Phase 2 – Ha A1 – Kisapáti-Lengyeltóti; Phase 3 – Ha A2 – Jaszkarajenö-Uszavölgy; Phase 4 – Ha B1 – Rohod-Szentes. However, v. Brunn explicitly stressed the problems of defining clear phases (*v. Brunn 1968.29*). Combinations of types from different pha-

9 Two axe fragments belong to the hoard, but not the one illustrated by Petrescu-Dîmboviţa (*1978.Pl. 106/68*), which has been identified as a single find from the same location already by Alexandru Vulpe (*1970.45, Nr. 148*).

10 Vulpe (*1970.65, Nr. 284*) interprets the artefact as a fragment of a hammer axe.

ses were common, and many finds were not clearly attributable to one phase. Only the contents of the earliest and latest phases were mutually exclusive, which led him to his well-known scheme of an older and younger group of types ("*ältere und jüngere Typengesellschaft*"). He particularly pointed out that the third phase (Jaszkarajenö-Uszavölgy) was detectable only by the gradual appearance of new types and the slow disappearance of older ones, *i.e.* a mixture of older and younger artefacts in closed finds (*v. Brunn 1968.46*). The hoard of Dezmir should be analysed within this theoretical framework, first establishing the chronological position of each of its components.

Chronological analysis

The fragments Nr. 19–20 and 16 belong to hook sickles judging from their strong lateral ribs and plain blades, but cannot be determined typologically beyond this point. Hook sickles are characteristic of the older Urnfield Period/ältere Typengesellschaft, they are rare in younger hoards (*Petrescu-Dîmboviţa 1978.69–70*). Most of the sickles from Dezmir are knob sickles. The well-preserved Nrs. 15 and 17 were classified as belonging to his type Panticeu by Petrescu-Dîmboviţa, which is mostly characteristic of the same older phase (*Petrescu-Dîmboviţa 1978. 14, Nr. 59–60, 24*). Fragment Nr. 18 was listed under the type Cenadu Mare-Şpălnaca I, which is dated to Jupalnic-Turia und Moigrad-Tăuteu (*Petrescu-Dîmboviţa 1978.24.18, Nr. 169*). The remaining fragments are too small for classification. Bracelets with pointed ends like Nr. 25 appear throughout the later Bronze Age (*Petrescu-Dîmboviţa 1998.71*). For bracelets with pointed ends and a rhomboid section (Nr. 26), one Bz D grave context from Cruceni, jud. Timiş, Romania, has been published (*Petrescu-Dîmboviţa 1998.124, Nr. 1374*). Plano-convex ingots have been discussed repeatedly in recent decades, but so far no chronological relevance of certain types has been detected (*Mozsolics 1984; Czajlik 1996; Nessel 2014; 2019.185–204, 272–274; Modl 2019*). The chronological position of Dezmir is thus largely dependent on the socketed axes.

The Romanian socketed axes have been analysed and published recently (*Dietrich 2021a*), and brief remarks on the types present at Dezmir may suffice here. Two large groups of socketed axes are present in the hoard: beaked axes and axes decorated with ribs. The beaked axe Nr. 1, with a nearly symmetrical mouth and rounded cross section of the body, represents a type characteristic of Phase 4 in northwestern Romania and eastern Hungary (*Dietrich 2021a.290, Nr. 0399, 291–292; type A11*). Nr. 2, a socketed axe with a short, vertical beak and nearly straight rim belongs to a chronologically indifferent variant, which is attested in the older and younger Urnfield period over a large area within the Carpathian Basin (*Dietrich 2021a.277, Nr. 0356, 282; variant A8h*). The long and slender axe Nr. 4 with a rounded cross section and a long vertical beak is one of the most common variants of Phase 4 in Romania, where 57 finds concentrate along the middle Mureş and the Someş-region; further finds are known from Slovakia, northeastern Hungary, and from the Transcarpathian regions of Ukraine (*Dietrich 2021a. 264, Nr. 0279, 280, variant A8a*). Axe Nr. 5, a rather squat and massive axe with a short, steep beak and a rounded cross section, belongs again to a variant mostly characteristic of Phase 4 (*Dietrich 2021a.249, Nr. 0211, 254; variant A6e*). Socketed axes like Nr. 7, with curved mouths, short beaks and rounded cross sections, are mainly known from Phase 4 contexts but also appear earlier (*Dietrich 2021a.233, Nr. 0130, 236, variant A5b*). A round cross section, a feature determined as being in general characteristic of beaked socketed axes of the younger Urnfield period (*Petrescu-Dîmboviţa 1944–1948*) is the only indication for the age of fragment Nr. 6 (*Dietrich 2021a, 297, Nr. 0453*).

The remaining socketed axes belong to variants with rib decoration. Axe Nr. 3, with a massive, curved body and broadening blade area has two horizontal ribs running below the mouth area. There are a few axes of this variant from contexts of the older Urnfield period, while most finds belong in Phase 4 (*Dietrich 2021a.672, Nr. 2731, 682–683; variant D5w*). On the other hand, long and slender axes without loops decorated with chevrons like Nr. 8 are mostly known from Phase 2 contexts (*Dietrich 2021a.542, Nr. 1927, 548–549; variant D1g*). The long and slender trapezoid axe Nr. 9 has a Y-shaped ornament below horizontal ribs; the rounded upper part of the Y is repeated above it by a bow – this variant is almost always associated with Phase 4 hoards (*Dietrich 2021a.596, Nr. 2264, 614; variant D3m*). The massive, curved axe Nr. 10, which is further characterized by an abruptly and significantly broadening blade and an hourglass-shaped decoration, belongs to a variant of the so-called Passau Type (*Blajer 2018*), dated securely in Phase 4 (*Dietrich 2021a.666, Nr. 2688, 681; variant D5m*). The same is true for the undecorated slender and trapezoidal axe Nr. 11 (*Dietrich 2021a.604, Nr. 2323, 618; variant D3y*). Fragment Nr. 14 has a Y-

shaped motif, which substantiates a Phase 4-date (*Dietrich 2021.606, Nr. 2343*). Finally, fragments 13–14 cannot be classified (*Dietrich 2021a.688, Nr. 2796–2797*).

Summing up the dating of all hoard components (Fig. 9), the general impression is of a chronologically diverse assemblage. Some types are clearly or partly characteristic of the older Urnfield Period, while others have a tendency towards or a clear date in the younger Urnfield Period. The youngest artefacts define the moment the hoard was hidden, Phase 4. There is no reason to date the hoard of Dezmir to Phase 3 – Ha A2 – Jupalnic-Turia.

Spatial analysis

The hoard is not only chronologically, but also geographically diverse. Knob sickles of the Panticeu type concentrate between the middle Mureş and the Someş region, in the upper Tisza area and again in Central Germany (*Petrescu-Dîmboviţa 1978.Pl. 291A*).[11] The Cenadu Mare type of knob sickles concentrates in the Upper Tisza region and the Someş area (*Petrescu-Dîmboviţa 1978.Pl. 291B*). As there still is no general overview on knob sickles except for central Germany (*Sommerfeld 1994*), these observations are not much more than tendencies though. Again, the socketed axes can provide a clearer image.

Between the types and variants present in the hoard, beaked axes of variant A8a (Fig. 10) and the axes with chevron motifs of variant D1g (Fig. 11) are the most frequent types in the Carpathian Basin and adjacent areas. Variant A8a has a very dense distribution in the Upper Tisza region, and a less dense one to the east of the Apuseni mountains in the Someş region. Socketed axes of variant D1g on the other hand concentrate in Transdanubia and in the Drava-Sava region; the eastern Carpathian Basin represents the periphery of their distribution, where larger numbers of these axes appear only in exceptionally large hoards like Uioara de Sus or Guşteriţa II (*Dietrich 2021b*). They are, indeed, foreign to this region. These two geographical areas – the Upper Tisza region on one hand and Transdanubia/the Drava-Sava region on the other – represent the main geographical components within the hoard of Dezmir. The remaining types/variants of beaked axes in the hoard follow the same trend, with the notable exception of variant A5b, which is clearly indigenous to the Someş area and the Crişana, with few finds further to the west (Fig. 12). Between the axes with plastic ribs, variant D5w is characteristic of the eastern Carpathian Basin, variant D5m concentrates in the Someş region and the Crişana (Fig. 13), while variant D3y is found throughout the Carpathian Basin north of the Mureş River and variant D3m again is mostly known from the Drava-Sava region, with a few finds reaching the Crişana and even the middle Mureş (Fig. 13).

The best approach to better determine the interaction zone the hoard from Dezmir is part of is map-

	Phase 1	Phase 2	Phase 3?	Phase 4	Phase 5
Rings with pointy ends and trapezoid square section					
Hook sickles					
Knob sickles type Panticeu (Petrescu-Dîmboviţa 1978)					
Socketed axes variant A8h					
Socketed axes variant A6e					
Knob sickles type Cenadu Mare-Şpălnaca I (Petrescu-Dîmboviţa 1978)					
Socketed axes variant A5b					
Socketed axes variant D1g					
Socketed axes variant D5w					
Socketed axes variant A8a					
Socketed axes type A11					
Socketed axes variant D3m					
Socketed axes variant D3y					
Socketed axes variant D5m					

Fig. 9. Chronological overview of the components of the hoard from Dezmir (white: absent; light grey: sporadic appearance; dark grey: main time of use).

11 Petrescu-Dîmboviţa's map partly reflects the degree to which the archaeological material in certain regions had been analysed and published at the time he finished his monograph. The high concentration of Central German finds is partly due to an in-depth study published on the sickle hoards of this area (*v. Brunn 1958*).

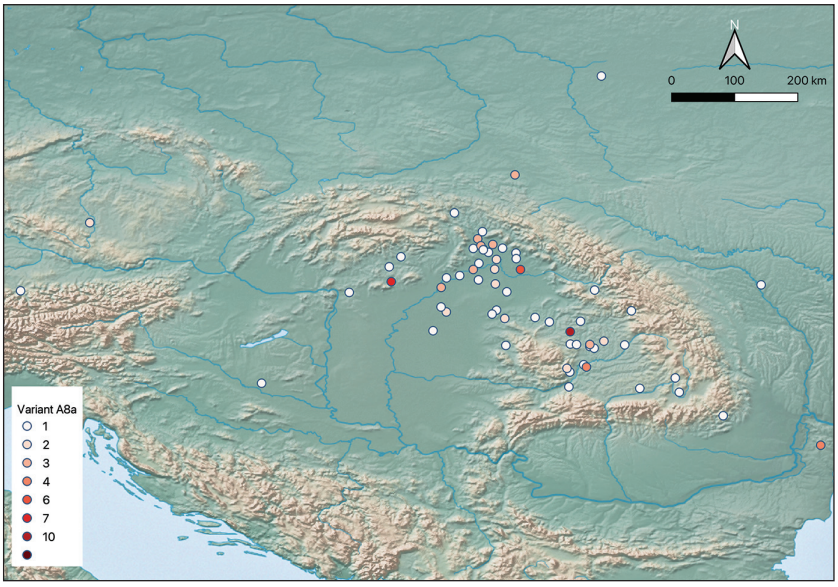

***Fig. 10. Distribution of socketed axes of variant A8a by quantity. Map: Natural Earth Data (Public Domain: https://www.naturalearthdata.com/); QGIS 3.16. Data from* Dietrich 2021a.**

ping hoards with a similar combination of socketed axe types (Fig. 14). It comes as no surprise that hoards which have three or more types of socketed axes in common with Dezmir concentrate in the Someş region. The closest match is a hoard discovered at Dârja, a few kilometres to the north of Dezmir (*Rusu 1977b*). Another concentration of hoards with similar assemblages of socketed axes is located in the Upper Tisza region. In Transdanubia or in the Drava-Sava area, however, similar combinations are nearly completely missing.

Discussion: Dezmir and the 'scrap hoards' of the younger Urnfield Period

Based on the analysis carried out above, it is possible to determine the characteristics of the hoard from Dezmir as follows:

1. A high frequency of damaged artefacts or fragments;
2. Different metals (bronze, copper, lead);
3. Raw material/ingots;
4. Chronologically diverse artefacts, the youngest, however, belong in Phase 4 after v. Brunn;
5. A relatively large catchment area from which the artefacts derive.

These characteristics are highly reminiscent of the large 'scrap metal hoards', which usually represent long-term collections but have a major accumulation phase in the older Urnfield Period (*Dietrich 2014; 2021b*). For Dezmir, a date in a horizon Jupalnic-Turia or Phase 3 after v. Brunn does not hold, as shown above. This raises the question as to whether the mixture of older and younger artefacts is a general characteristic of the hoards once used to define this chronological phase. What was once believed to be a chronological grouping could in reality be a certain hoarding pattern. To test this hypothesis, all hoards once attributed to the Phases Jupalnic-Turia/Moigrad-Tăuteu were tested by a correspondence analysis (CA).

Hoards are multivariate datasets, differentiated by the presence or absence of chronologically relevant types ("Leittypen"). The appearance, main time of use, and slow disappearance of these types should follow a unimodal model for hoards dating to a short, clearly determined period. The CA has been used successfully for similarly structured datasets in archaeology (*Müller, Zimmermann 1997; Müller-Scheeßel 2008; Siegmund 2015; Greenacre 2017*).

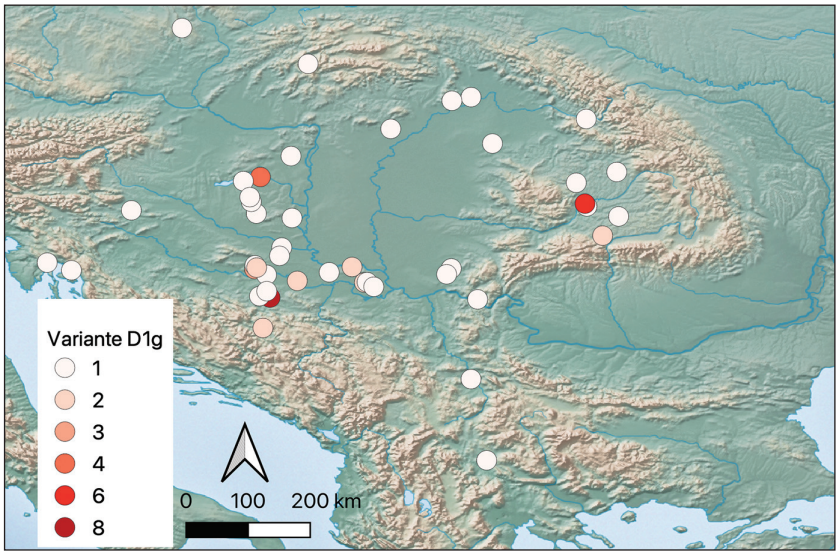

***Fig. 11. Distribution of socketed axes of variant D1g by quantity. Map: Natural Earth Data (Public Domain: https://www.naturalearthdata.com/); QGIS 3.16. Data from* Dietrich 2021a.**

A CA calculates the similarity of multivariate datasets based on a contingency table that lists the presence/absence or abundancy of attributes (in this case the types of artefacts in the hoards). First, scores are calculated for the columns and rows of the table, whose similarity is then checked by chi-squared distances. Then, the inertia of the columns and rows is calculated (*i.e.* their deviation from the mean values of the columns/rows). This results in the overall inertia of the analysis. If the inertia is very low, the data are too similar for a statistically valid result.

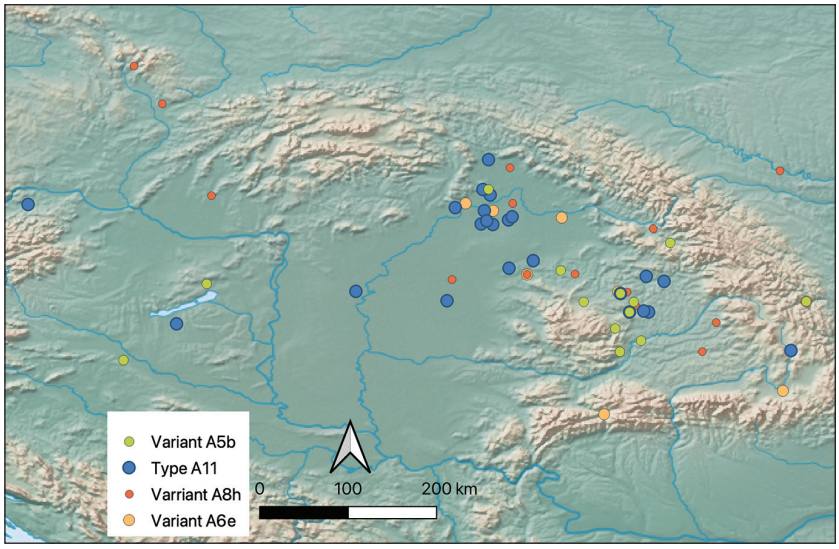

***Fig. 12. Distribution of socketed axes of variants A5b, A6e, A8h and type A11. Map: Natural Earth Data (Public Domain: https://www.naturalearthdata.com/); QGIS 3.16. Data from* Dietrich 2021a.**

The results of a CA are multidimensional. Thus, there are several solutions for every CA, which in the reduced visualization of the results take the form of different axes. The first one (axis 1) is the dominant result. The other solutions are independent of the first axis, and all represent a ratio of the inertia. This ratio is expressed through the eigenvalue of each axis and through its percentage of the total inertia. In archaeology, the first three solutions are usually checked for statistical meaning. An ideal solution would have a high eigenvalue and the datapoints would be distributed in a parabolic or u-shaped plot in the diagram. Deviations from this distribution hint at problems within the dataset, *e.g.*, types used for a long time distorting the solution.

All hoards defined by Petrescu-Dîmboviţa (*1978*) as characteristic of the phases Jupalnic-Turia and Moigrad-Tăuteu were used for the CA, with some additions of more recent finds (Fig. 15). The list was reduced to secure find contexts with at least two relevant types ("Leittypen") that appear in at least two hoards. The types were chosen based on the list provided by v. Brunn (*1968.Fig. 1–4, Tab. 1*), with some additions regarding the socketed axes based on Dietrich (*2021a*).[12] The software package PAST 5.0 (*Hammer* et al. *2005*) was used for the analyses. If the resulting axes 1 and 2 are mapped in a coordinate plane, the distribution takes on the form of a parabola, although the area to the left of the y-axis has fewer finds and types (Fig. 16). The axes represent 11.6 and 10.1% of the total inertia, respectively. The hoards to the left of the Y-axis are characterized by types 12 ('Transylvanian' socketed axes), 20 (richly decorated belts), 43 (hook sickles), and 45 (saw blades). A combination of all these types causes the single outlier, the hoard of Zimandu Nou. They are also the key to an explanation of this result. All are characteristic for the older Urnfield Period. The result of the CA therefore reflects chronology – some of the finds have older artefacts in their composition, and therefore move away from the main cluster of finds. Dezmir is within the group of chronologically diverse finds, as are most of the hoards proposed earlier as characteristic of Phase 3-Jupalnic-Turia-Ha A2. This becomes clearer if the finds are arranged in a combinatory table according to their position in the CA (Fig. 16). The table lists their main components: tools, weapons, ornaments, raw material, bronze vessels, wagon parts, and horse gear. The general tendency is that the chronologically diverse finds are also heterogenous in their com-

12 The following types characteristic to Phases 2–4 are present in the hoards and were chosen for analysis (numbering after v. Brunn (*1968*), with additions): 12 socketed axes of the 'Transylvanian' type; 16 early winged axes with wings in the upper part of the axe; 20 richly decorated belts; 30 socketed axes with flexed rib decoration; tongue sickles, variant 2; 32 massive winged axes, the wings are located in the upper part and there is no ridge between blade and body; 33 socketed axes of the 'Passau Type'; 34 socketed axes decorated with vertical curved bundles of ribs; 35 socketed axes decorated with chevrons and a pronounced ridge between blade and body; 36: bracelets/legrings decorated with hatched chevrons; 37 tongue sickles of type 3; passementerie fibulas with small spirals at the bow and large terminal ones; 43 hook sickles; 44 flange hilted swords of the Reutlingen type; 45 saw blades; 49 beaked socketed axes with round diameter and steep beak; 51 kettles of type B1; 53 cups of the Kirkendrup type.

position, while the finds clearly datable to Phase 4 have fewer components and are generally smaller.

Result

A close analysis of the hoard from Dezmir and comparable finds reveals good evidence against the formerly proposed chronological hoarding horizon 'Phase 3-Jupalnic-Turia-Ha A2'. In the Eastern Carpathian Basin, this group comprises of hoards with chronologically diverse artefacts hidden in Phase 4. Their structure, here described and analysed using Dezmir as a case study, is highly reminiscent of the large so-called scrap metal hoards like Uioara de Sus, which were accumulated mostly during the older Urnfield Period. These hoards comprise a large number of chronologically diverse, often damaged or fragmented artefacts and a high percentage of raw material, while some of the objects are foreign to the region they were deposited in (*Dietrich 2014; 2021b*). Contrary to earlier beliefs, this hoarding scheme does not disappear in the younger Urnfield Period, but survives in a quantitatively reduced form. The hoard from Dezmir is a characteristic example of this group of hoards.

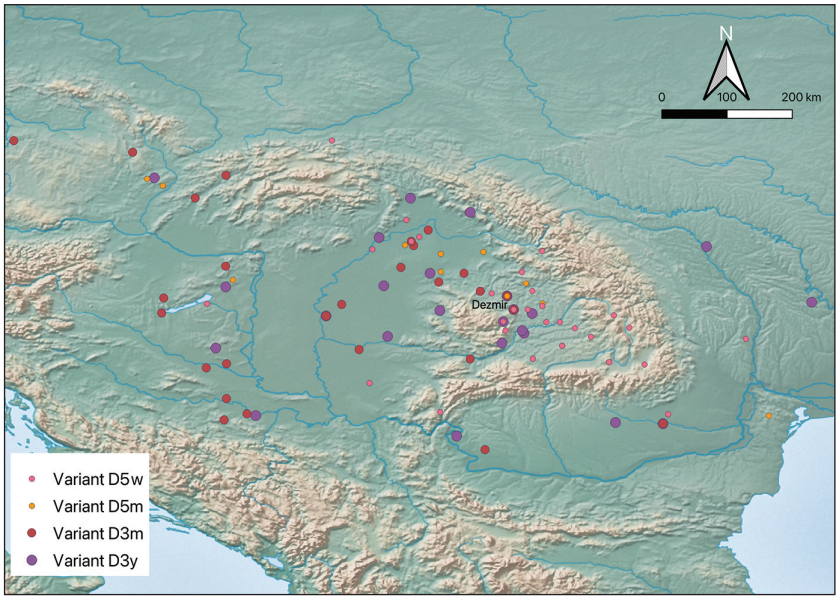

***Fig. 13. Distribution of socketed axes of variants D3m, D3y, D5m, D5w. Map: Natural Earth Data (Public Domain: https://www.naturalearthdata.com/); QGIS 3.16. Data from* Dietrich 2021a.**

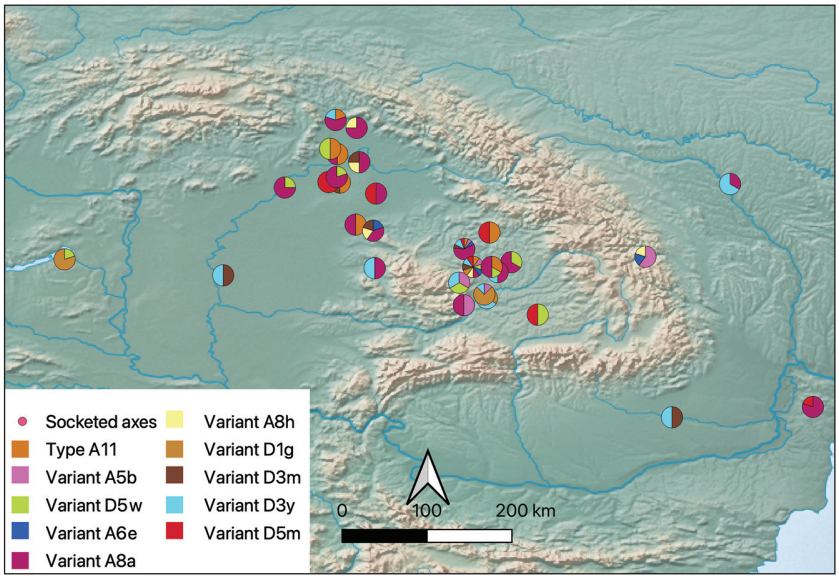

***Fig. 14. Distribution of hoards with socketed axe combinations similar to Dezmir. Map: Natural Earth Data (Public Domain: https://www.naturalearthdata.com/); QGIS 3.16. Data from* Dietrich 2021a.**

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Hoard	*Number of objects*	tools	weapons	ornament	ingots	vessel	wagon	horse
Zimandu Nou	16	x		x	x			
Cetea	24+	x	x	x	x	x		
Vărd	34	x		x	x			
Dridu	341	x	x	x	x	x		x
Zagon II	32?	x	x	x				
Nou Săsesc	23+?	x		x	x			
Cluj-Napoca III	12	x	x	x				
Dezmir	34	x		x	x			
Brăduţ	48+	x		x	x	x		
Moigrad I	32	x	x	x		x		
Variaş	7	x	x					
Budeşti-Fânaţe	10	x	x	x	x			
Visuia	54	x		x	x	x		
Dârja	40	x	x		x			
Târgu Secuiesc I	6	x						
Fizeşu Gherlii I	13	x		x			x	
Brad	4	x	x	x				
Cenad	23+	x	?	?	x			
Sâg	39	x	x	x		x		
Săcuieni	29+	x	x	x				
Sărvăzel	12	x	x		x			
Blăjenii de Jos	9	x						
Şpălnaca I	136+	x	x	x	x	x		
Cluj-Napoca II	11+	x	x					
Ciceu Corabia	43+	x	x	x				x
Sâmbăta Nouă I	33	x			x			
Seleuşu	36	x	x	x	x			
Şoarş	36+	x	x					
Văleni	2+	x						
Tăuteu	47	x	x	x	x			

Hoard	*Number of objects*	tools	weapons	ornament	ingots	vessel	wagon	horse
Căpuşu de Câmpie	40+	x	x	x	x			
Suatu	31	x	x	x				
Pir	35	x	x	x				
Corneşti	114	x	x	x	x	x		
Câţcău	5	x	x					
Jupalnic	22	x	x					
Ghirişu Român	31	x	x	x				
Sălard	56?	x		x	x		x	
Josani	48	x			x			
Giorocuta	6	x		x				
Porumbenii Mari	7?	x	x					
Henig	3	x		x				
Sărăţeni	4+?	x						
Boldeşti	9?	x						
Zagon I	45?	x	x	x		x		
Pănade	8+	x		x	x			
Hida	25	x	x					
Ţelna	9?	x						
Dacia	10	x	x					
Plăieşti	7?	x						
Bancu I	29	x	x					
Şieu II	14	x	x					
Arad	51	x	x	x	x			
Mileni	16	x	x					
Glod	11	x	x					
Groşii Ţibleşului	13+	x						
Oradea-Umgebung	2+	x						
Cămin	12+	x	x					
Zlatna II	11?	x	x					
Bârlad	5	x		x				

Fig. 15. Result of the correspondence analysis of hoards of the 'Jupalnic-Turia' an 'Moigrad-Tăuteu' phases (PAST 5.0).

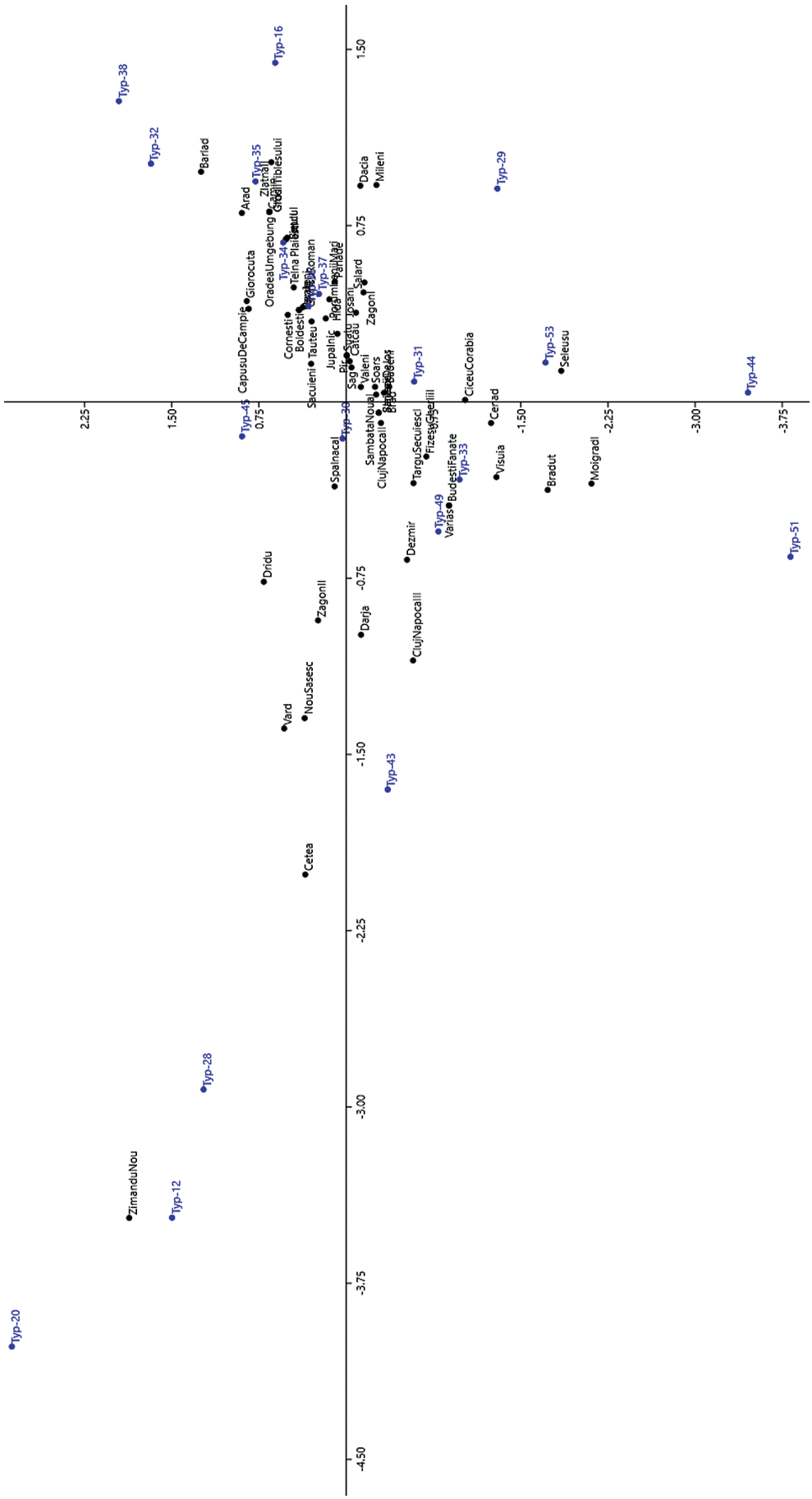

Fig. 16. Combination table of hoards of the 'Jupalnic-Turia' an 'Moigrad-Tăuteu' phases in the order established by the correspondence analysis, highlighting the main components of the finds.

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