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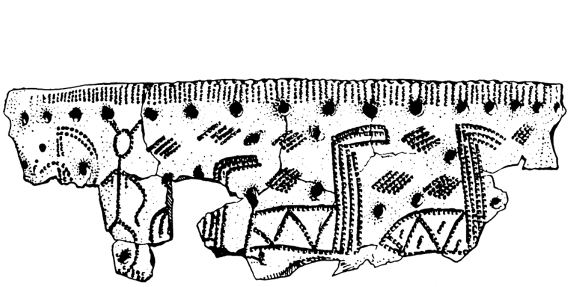

Contents

The origins of pottery in East Asia: updated analysis (the 2015 state-of-the-art)

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ABSTRACT – *Recent developments related to the emergence of pottery in East Asia and neighbouring regions are presented. According to a critical evaluation of the existing evidence, the oldest centres with pottery in East Asia are situated in South China (dated to* c. *18 000 calBP), the Japanese Islands (*c. *16 700 calBP), and the Russian Far East (*c. *15 900 calBP). It is most likely that pottery-making appeared in these regions independently of each other. In Siberia, the earliest pottery now known is from the Transbaikal region (dated to* c. *14 000 calBP). However, it did not influence the more westerly parts of Siberia in terms of the origin and spread of pottery-making.*

IZVLEČEK – *Predstavljamo najnovejši razvoj študij pojava lončarstva v Vzhodni Aziji in sosedstvu. S pomočjo kritične presoje podatkov lahko sklepamo, da so najstarejši centri z lončenino v Vzhodni Aziji umeščeni v južno Kitajsko (ok. 18 000 calBP), Japonsko otočje (ok. 16 700 calBP) in Daljni Vzhod Rusije (ok. 15 900 calBP). Zelo verjetno se je izdelava lončenine v teh regijah pojavila neodvisno druga od druge. V Sibiriji je najstarejše lončarstvo poznano na področju Trans-bajkala (ok. 14 000 calBP). Vendar to ni vplivalo na razvoj in širjenje lončarske tehnologije v zahodne dele Sibirije.*

KEY WORDS – *pottery; East Asia; China; Japan; Russian Far East; Siberia; Transbaikal; radiocarbon dating; Late Glacial*

Introduction

The emergence of pottery is one of the most important phenomena in prehistory (*e.g., Jordan, Zvelebil 2009; Kuzmin 2013a*). Although it is now widely accepted that the oldest vessels made of fired clay appeared first in greater East Asia, encompassing modern China, Japan, and the Russian Far East (*e.g., Kuzmin 2006; Boaretto* et al. *2009*), debates about the exact location and timing of the earliest pottery-making cultural complexes have continued (*Wu* et al. *2012; Kuzmin 2013a; 2013b; Cohen 2013*). Recent attempts to model the spread of pottery technology in the Old World using the radiocarbon (^{14}C) dates of ceramic-bearing sites and the ambiguous results obtained (see *Kuzmin 2013b; 2014; Silva* et al. *2014*) highlight the necessity of a thorough evaluation of the existing records.

The aim of this paper is to give an updated analysis of the data on the earliest pottery from greater East Asia and neighbouring Siberia as of mid-2015 in order to introduce new information and its critical evaluation to the international scholarly community.

Material and methods

Recent overviews on the emergence of pottery among hunter-gatherers in East Asia and the neighbouring regions are used here as background (*Dikshit, Hazarika 2012; Cohen 2013; Kuzmin 2013a; Gibbs, Jordan 2013; Gibbs 2015*). The newly released data on the early pottery from the Transbaikal (southern part of Eastern Siberia) (*Razgildeeva* et al. *2013*) are incorporated into the existing dataset for this region (*Kuzmin 2013a; Kuzmin, Vetrov 2007; McKenzie 2009*) and interpreted. Information on the Gromatukha site in the Russian Far East, published previously by Japanese scholars (see *Kani 1992; Jomon 1996a; 1996a*), is discussed in the

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light of a new study conducted by Shevkomud and Yanshina (*2012*).

The evaluation of ¹⁴C dates for the early pottery complexes is crucial for understanding the origins and spread of ceramics in the Old World, and it is provided here for all the earliest pottery complexes. The calibration of ¹⁴C dates was conducted with the help of the Calib 7.0.2 computer programme (*Reimer* et al. *2013*) at ± 2-sigma, and all possible intervals are combined and rounded to the next ten years (see Tab. 1).

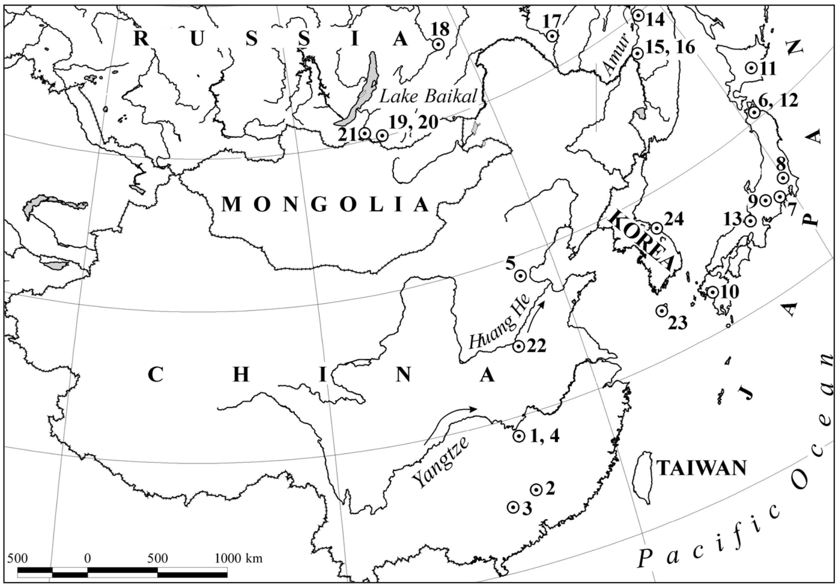

Fig. 1. Location of archaeological sites mentioned in the text. 1 Xianrendong Cave; 2 Yuchanyan Cave; 3 Miaoyan Cave; 4 Wang Dong Cave; 5 Nanzhuangtou; 6 Odai Yamamoto 1; 7 Kitahara; 8 Tokumaru Nakata; 9 Nakamachi; 10 Senpukuji Cave; 11 Taisho 3; 12 Omotedate; 13 Torihama; 14 Khummi; 15 Gasya; 16 Goncharka 1; 17 Gromatukha; 18 Ust-Karenga 12; 19 Studenoe 1; 20 Ust-Menza 1; 21 Ust-Kyakhta; 22 Lijiagou; 23 Kosanni; 24 Osanni.

Results and discussion

China

The results of additional studies at the Xianrendong Cave in southern China (Fig. 1) conducted in 2009 were recently published by Wu *et al.* (*2012*). According to these authors, the ¹⁴C dates of the oldest site's component with pottery are *c.* 16915 BP (western section) and *c.* 17 105 BP (eastern section), correspond to the calibrated age ranges of 19 950–20 880 calBP and 20 440–20 850 calBP, respectively. If true, this would be the earliest pottery in the Old World.

However, several crucial issues allow me to cast doubt on these ¹⁴C dates: (1) there is no direct association between the deer bone samples collected by Xiaohong Wu *et al.* (*2012*) and the potsherds: "*We did not recover any sherds from the reopened sections ... [in 2009]*" (*Wu* et al. *2012.1697*); (2) a ¹⁴C date obtained previously from Stratum 3C1A, the second earliest site component with pottery – 12 530 ± 140 BP (BA95145) (*MacNeish 1999.238; Kuzmin 2013a.544*) – was ignored by Wu *et al.* (*2012*) despite the fact that it is much younger than the rest of the ¹⁴C values from this layer at *c.* 13 885–16 340 BP (*Wu* et al. *2012.1698*); (3) some ¹⁴C dates, which do not fit the age model suggested by Wu *et al.* (*2012*), were declared as 'outliers' without any reasonable explanation (see *Kuzmin 2013a.544*).

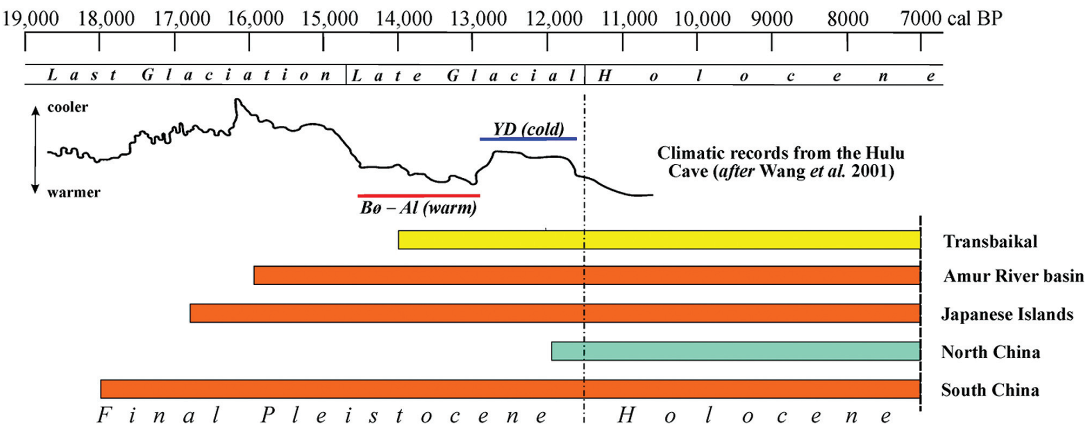

Fig. 2. Chronology of the earliest pottery complexes in greater East Asia and Siberia, on the background of climatic changes. Abbreviations: Bø-Al – Bølling-Allerød; YD – Younger Dryas.

Site	14C date, BP	Lab code and No.	Material dated	Calendar age, cal BP**	Reference
			South China		
Yuchanyan Cave	14 800 ± 55	RTB 5464/BA06864	charcoal	17 830–18 190	*Boaretto* et al. 2009
Miaoyan Cave	13 710 ± 270	BA92034-1	charcoal	15 820–17 380	*Yuan* et al. 1995
Xianrendong Cave	12 430 ± 80	UCR-3561	charcoal	14 160–14 990	*MacNeish* 1999
Wang Dong Cave	11 500 ± 150	BK95138A	charcoal	13 060–13 700	*MacNeish* 1999
			North China		
Nanzhuangtou	10 210 ± 110	BK-87075A	charcoal	11 400–12 390	*Yuan* et al. 1992
			Japanese Islands		
Odai Yamamoto 1	13 780 ± 170	NUTA-6510	adhesion	16 170–17 180	*Nakamura* et al. 2001
Kitahara	13 060 ± 80	Beta-105398	ch. wood	15 320–15 920	*Keally* et al. 2003
Tokumaru Nakata	12 770 ± 225	PAL-383	wood	14 240–15 860	*Keally* et al. 2003
Nakamachi	12 740 ± 380	GaK-9624	charcoal	13 850–16 180	*Keally* et al. 2003
Senpukuji Cave	12 220 ± 80	MTC-11296	adhesion	13 820–14 520	*Sato* et al. 2011
Taisho 3	12 460 ± 40	Beta-194629	adhesion	14 270–14 960	*Yamahara* 2006
			Russian Far East		
Khummi	13 260 ± 100	AA-13392	charcoal	15 640–16 240	*Kuzmin* et al. 1997
Gasya	12 960 ± 120	LE-1781	charcoal	15 150–15 870	*Okladnikov, Medvedev* 1983
Goncharka 1	12 500 ± 60	LLNL-102169	charcoal	14 300–15 070	*Shevkomud* 1997
Gromatukha	12 380 ± 70	MTC-05937	charcoal	14 110–14 850	*Nesterov* et al. 2006
			Transbaikal (Eastern Siberia)		
Ust-Karenga 12	12 180 ± 60	AA-60210	charcoal	13 840–14 240	*Kuzmin, Vetrov* 2007
Ust-Karenga 12	11 240 ± 80	GIN-8066	charcoal	12 930–13 280	*Kuzmin, Vetrov* 2007
Studenoe 1	11 960 ± 80	TKa-15554	adhesion	13 580–14 020	*Razgildeeva* et al. 2013
Studenoe 1	11 995 ± 150	AA-33040	charcoal	13 470–14 210	*Buvit* et al. 2003
Studenoe 1	11 730 ± 60	MTC-16736	adhesion	13 450–13 720	*Razgildeeva* et al. 2013
Ust-Menza 1	11 550 ± 50	MTC-16738	adhesion	13 280–13 470	*Razgildeeva* et al. 2013

* Only the oldest ^{14}C dates for each site are listed here; for more complete information, see the relevant references.
** The IntCal13 dataset (*Reimer* et al. 2013) is used.
a These dates are re-calculated (see *Kuzmin 2013a*).
b Only selected oldest sites (with ^{14}C dates older than *c.* 12 000 BP) are included; see the full list in Keally *et al.* (2003).
c Food remains on the surface of pottery (*e.g.*, *Nakamura* et al. 2001).
d Charred wood.
e Bulk sample collected from Layer 7.
f Sample collected from a hearth in Layer 7.
g Sample collected from Layer 9G.
h Samples collected from Layer 8.

Tab. 1. The earliest East Asian and Siberian sites with pottery and their ^{14}C dates (from* Kuzmin 2013a, *with additions*).

The disturbed nature of the Xianrendong Cave profile can be easily demonstrated by information provided by Wu *et al.* (*2012*). For example, age-depth reversals are common at this site; here, there are ^{14}C dates which contradict the stratigraphic 'integrity' sensu David J. Cohen (*2013*) (layers are listed from top to bottom): (1) Layer 3B1: *c.* 14 610 BP (BA 093181), it is much older than the ^{14}C dates from both underlying and overlapping layers, *c.* 12 240–12 420 BP; (2) Layer 3B2: *c.* 12 420 BP (UCR3561), it is much younger than the ^{14}C date from overlapping Layer 3B1 at *c.* 14 610 BP (see above); and (3) Layer 3C2: *c.* 15 180 BP (UCR3300), it is much younger than the ^{14}C dates from both underlying and overlapping layers at *c.* 17 580–18 510 BP and *c.* 16 165–18 520 BP, respectively (see *Wu* et al. *2012.1698*). As a result, the chronological model created by Wu *et al.* (*2012*) is heavily biased toward the older ^{14}C dates and completely ignores the possibility of post-depositional mixing of the cultural layers and material for ^{14}C dating.

Cohen (*2013.62*) has stated that "*... these dates [by Wu* et al. *(*2012*)] are reliable due to the internal consistency across a large, systematic series of radiocarbon dates done on samples from stable, stratigraphic contexts ...*". Being aware of criticism by Yaroslav V. Kuzmin (*2013a*), Cohen (*2013*) nevertheless accepted the *c.* 20 000–20 900 calBP age for the Xianrendong Cave pottery without addressing the reliability of their 'stratigraphic contexts', which are not secure due to the lack of association between bone samples for ^{14}C dating collected in 2009 and the pottery (see above). Therefore, Cohen's (*2013.62–65*) arguments are not convincing.

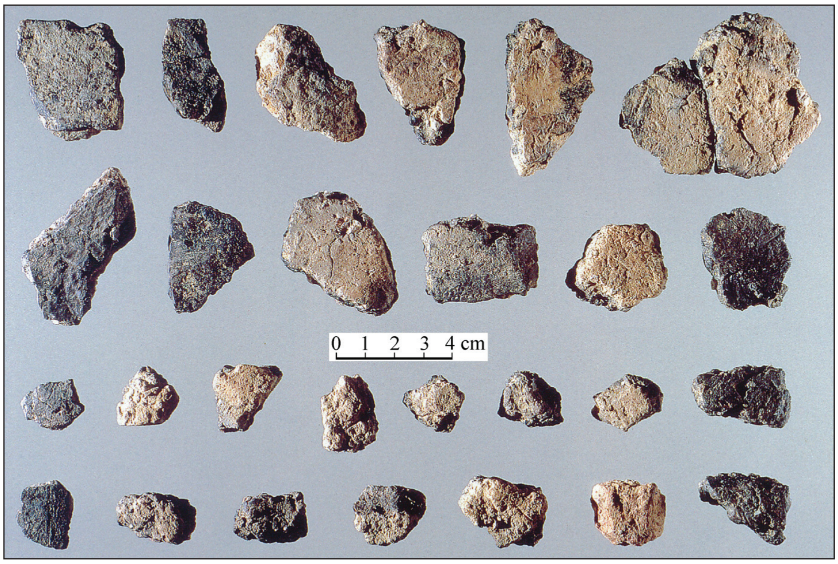

Fig. 3. Potsherds from the Odai Yamamoto 1 site, dated to* c. *13 500–13 800 BP (after* Odai Yamamato 1999*; modified).

Upon critical analysis of the ^{14}C records from the earliest Chinese sites with pottery (*e. g., Kuzmin 2006; 2013a*), it is secure to conclude that the Yuchanyan Cave with ceramics dated to 17 830–18 190 calBP (Tab. 1), centred at 18 010 calBP, represent the oldest case of pottery-making in greater East Asia (Fig. 2). The most reliable age for pottery from the Xianrendong Cave, in my opinion, is *c.* 14 600 calBP. For other sites in South China such as Miaoyan Cave and Wang Dong Cave [Diaotonghuan] (Fig. 1), the age of the earliest potsherd-containing strata is not older than *c.* 16 600 calBP (Tab. 1).

Japanese Islands

Since the publication of summary works in the early 2000s (*Ono* et al. *2002; Keally* et al. *2003; 2004*), supplemented by more recent overviews (*Omoto* et al. *2010; Kuzmin 2013a*), the situation with the earliest pottery corresponding to the Incipient Jomon of Japan has been consistent. The oldest ^{14}C dates, *c.* 13 500–13 800 BP (centred at *c.* 17 000 calBP), come from the northern part of Honshu Island at the Odai Yamamoto 1 site (Fig. 1, Tab. 1). Potsherds found at this site are quite fragmentary (Fig. 3), and it is not possible to reconstruct the vessel's shape. Pottery from other sites is represented mainly by pointed-bottomed vessels (Figs. 4–6), but round-bottomed pots (Fig. 7) and flat-bottomed ones

Fig. 4. Pottery from the Omotedate site, Incipient Jomon (after* Jomon 1996b*; modified).

Fig. 5. Pottery from the Senpukuji Cave (bean-relief design) dated to* c. *12 200 BP (after* Jomon 1996b*; modified).

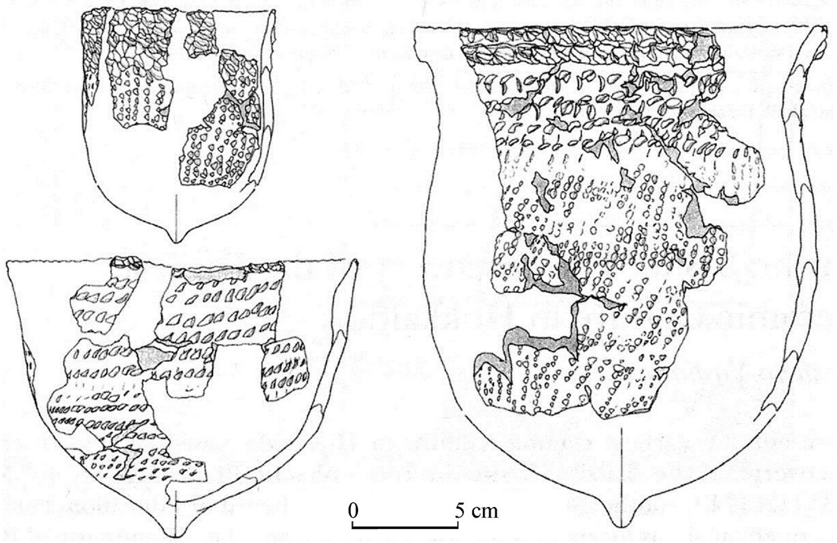

Fig. 6. Pottery from the Taisho 3 site dated to* c. *12 460 BP (after* Yamahara 2006*; modified).

(*e.g., Keally* et al. *2003.4*) are also known. The recent study of lipids in Incipient Jomon pottery indicated that it was used for cooking (*Craig* et al. *2013*); therefore, the function of the earliest ceramics in Japan was utilitarian.

Based on current knowledge, the existence of pottery on the Japanese Islands can be securely established from *c.* 17 000 calBP onwards (Fig. 2, Tab. 1).

The Russian Far East

Since analysis of the main results related to ^{14}C dating of the earliest sites in the Amur River basin (*Kuzmin 2006; 2013a*), the situation has not changed. It is now widely accepted that the first evidence of pottery-making in this region dates to *c.* 12 380–13 260 BP, corresponding to *c.* 14 110–16 240 calBP (Fig. 2, Tab. 1). Flat-bottomed vessels were reconstructed at the Gasya and Goncharka 1 sites (Figs. 8–9). The most probable function of this pottery was utilitarian (*e.g., Medvedev 1995; Kuzmin 2013a*).

The issue of the pottery from the Gromatukha site in the middle course of the Amur River can now be clarified in the light of new research conducted by Igor Y. Shewkomud and Oksana Yanshina (*2012*). Previously, Mikaeil Kani (*1992*) had reconstructed the vessel as round-bottomed (Figs. 10, 11). According to Shewkomud and Yanshina (*2012*), the most common shape of pottery at the lower level of the Gromatukha site, dated to *c.* 12 380 BP (or 14 110–14 850 calBP), is flat-bottomed (Fig. 12).

Why are these reconstructions so different? This question puzzled me for a long time, until I saw the conclusion by Shewkomud and Yanshina (*2012*). After that, I examined the circumstances related to the acquisition of Kani's (*1992*) material. The eyewitness for this is Kumi Kato (*1992*), who participated in the trip when these potsherds were obtained. During the field excursion in 1988 (not in 1991, as Shevkomud and Yanshina (*2012. 220*) assumed), Japanese archaeologists along with Russian colleagues conducted a very brief (four hours only) survey of the Gromatukha site (*Kato 1992.117*). Therefore, it seems less likely that the small Russian–Japanese team was able to dig a proper test pit, as suggested by Shevkomud and Yanshina (*2012.220*). More probably, the potsherds were collected from the talus where the cultural material from all components of the Gromatukha site has accumulated since the large-scale excavations in the 1960s (*Okladnikov, Derevianko 1977*). Because it is now clear that the Gromatukha site contains material of the later Neolithic along with the Initial Neolithic of the Gromatukha complex, it is quite possible that the reconstructed vessel belongs to the Belkachi complex dated to *c.* 3900–6300 BP (*e.g., Mochanov, Fedoseeva 1985; Alekseev, Dyakonov 2009*) with round-bottomed and cord-decorated pottery.

Fig. 7. Pottery from the Torihama site dated to* c. *11 800 BP (after* Jomon 1996b*; modified).

Shevkomud and Yanshina (*2012.221*) noted the single round-bottom fragment recovered from the entire collection of the 1960s excavations at the Gromatukha site, which consists of several hundred potsherds. It might be that this particular piece is not related to the Initial Neolithic complex, because the prevailing paradigm of Aleksei P. Okladnikov and Anatolii P. Derevianko (*1977*) was a gradual development of the Neolithic in the middle course of the Amur River basin, and all the potsherds were described as belonging to the single cultural complex. Therefore, the reconstruction of round-bottomed pottery of the Initial Neolithic at the Gromatukha site (*e.g., Kani 1992; Jomon 1996a; 1996b*) is most probably unreliable. Perhaps, the notion that pottery emerged on the Japanese Islands, which was common in the 1970s and 1980s (*e.g., Aikens 1995*), influenced the reconstruction of the Gromatukha vessel, because Kani (*1992*) assumed that its origin was directly related to the spread of pottery-making from Japan to the neighbouring regions.

Transbaikal

Since the early 2000s, new data on the earliest pottery in the Transbaikal region of Eastern Siberia have been obtained. The Ust-Karenga 12 site is located in the northern part of this territory, on the Vitim Plateau, which is covered by dense forest consisting mainly of Dahurian larch (*Suslov 1961.293–294*), on the border between the middle and southern taiga zones (*Tishkov 2002.219*). Another cluster of sites, Studenoe 1, Ust-Menza 1, and Ust-Kyakhta, is situated in the southern part of the Transbaikal, in the southern taiga zone (*Tishkov 2002.219*). The most important of these are Studenoe 1 and Ust-Menza 1 in the Khilok-Chikoy region (*Suslov 1961. 292–293*) or Dahuria (*Shahgedanova* et al. *2002. 335*), with mountain ranges and river valleys covered by conifer forests (spruce, fir, and Siberian pine) (*Suslov 1961.320*).

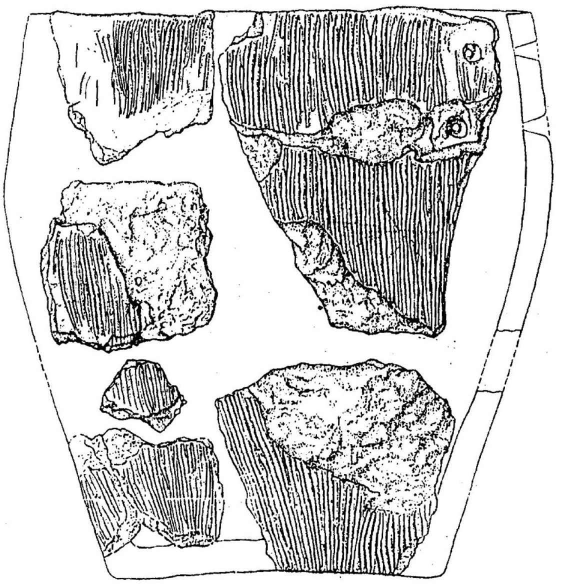

Fig. 8. Pottery from the Gasya site dated to* c. *12 960 BP (after* Derevianko, Medvedev 1995*; modified).

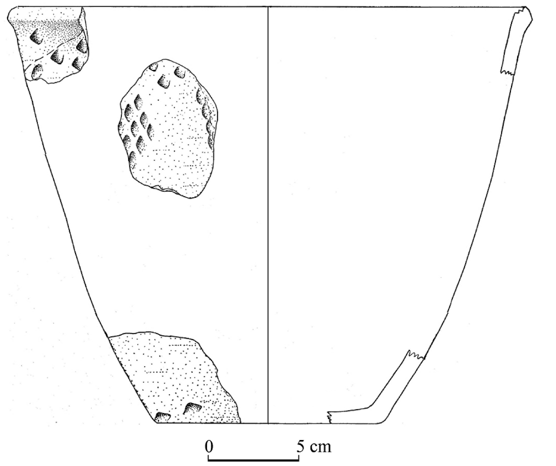

Fig. 9. Pottery from the Goncharka site dated to* c. *12 500 BP (after* Shewkomud, Yanshina 2012*; modified).

In the northern Transbaikal, the age of dispersed charcoal collected from Layer 7 with pottery at the Ust-Karenga 12 site is *c.* 12 180 BP (13 840–14 240 calBP (Tab. 1) (see *Kuzmin, Vetrov 2007*). It was proposed that the most secure estimate is the age of charcoal from a hearth in Layer 7, *c.* 11 240 BP (12 930–13 280 calBP) (see Tab. 1).

As for the southern region, I previously suggested that the earliest pottery from Layer 8 of Studenoe 1 (also known as Studenoe 1/1) site could be as old as *c.* 12 000 BP (13 470–14 210 calBP) (*Kuzmin 2013. 547–548*). Recently, new data were generated by Irina N. Razgildeeva *et al.* (*2013*). Food adhesions attached to the potsherds from Layer 9G (the lowermost stratum with pottery at this site) were ^{14}C dated to *c.* 11 600–11 960 BP; the oldest value corresponds to 13 580–14 020 calBP (see Tab. 1). Several ^{14}C dates of *c.* 11 570–11 730 BP were obtained from food residues on pottery in Layer 8, with the oldest calendar age being 13 450–13 720 calBP (Tab. 1). These new ^{14}C values are in accord with the charcoal date from Layer 8 at *c.* 11 995 BP (13 470–14 210 calBP; see Tab. 1).

Pottery from Layer 9G of the Studenoe 1 site is parabolic in shape (Fig. 13.A), with walls 0.6–0.7cm thick

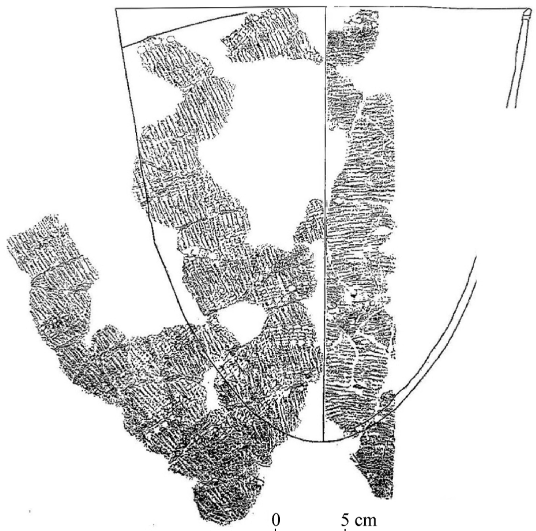

Fig. 10. Reconstruction of pottery from the Gromatukha site (after* Kani 1992*; modified).

at the rim, and 1.0–1.1cm at the bottom. The clay paste contains plant material added at the time of manufacture. The diameter of the vessel at the rim is 23–32cm, and 17cm at the bottom. On the surface, grooves made by a tool with 8–10 protruding 'teeth' and vertical traces made by cord (perhaps, rope on a stick) are visible. The pottery from Layer 8 (Fig. 13.B) is similar to that from Layer 9G; however, no bottom parts were found (*Razgildeeva* et al. *2013.175*).

Razgildeeva *et al.* (*2013*) concluded that the ^{14}C age for food adhesions at the Studenoe 1 site is older than the ^{14}C values obtained on charcoal, and the former should be *c.* 12 000–13 000 calBP. Perhaps, they are not aware of the charcoal ^{14}C date of *c.* 11 995 BP (*Buvit* et al. *2003*) corresponding to 13 470–14 210 calBP. This value fits perfectly well with the age of the food remains, and in my opinion, the pottery from the Studenoe 1 site can now be securely dated to *c.* 12 000 BP (centred at *c.* 13 840 calBP).

The earliest pottery from the Ust-Menza 1 site was recently ^{14}C dated for the first time (*Razgildeeva* et al. *2013*). Previously, it was associated with the Early Holocene, *c.* 8715 BP (*e.g., Kuzmin, Orlova 2000*). The age of food adhesion on pottery from Layer 8 is *c.* 11 500 BP (13 280–13 470 calBP; Tab. 1). Potsherds are quite fragmentary, but their overall appearance is similar to the pottery from the Studenoe 1 site (*Razgildeeva* et al. *2013.176*). The ^{14}C date on food residue is considered older than its real age judging from the ^{14}C value of *c.* 10380 BP (11 350–12 710 calBP) in the underlying Layer 11

Fig. 11. Reconstruction of pottery from the Gromatukha site (after* Jomon 1996a*; modified).

(see *Razgildeeva* et al. *2013.172*), and the 'true' age of the pottery from Ust-Menza 1 was suggested as *c.* 12 000–13 000 calBP (*Razgildeeva* et al. *2013*). In my opinion, the ^{14}C dating of adhesions is quite reliable, as in the case of the Studenoe 1 site (see above), and the age of pottery from Layer 8 at the Ust-Menza site can be accepted as *c.* 13 380 calBP.

Based on the general appearance of pottery from the entire Transbaikal region (including the Ust-Karenga 12, Studenoe 1, Ust-Menza 1, and Ust-Kyakhta

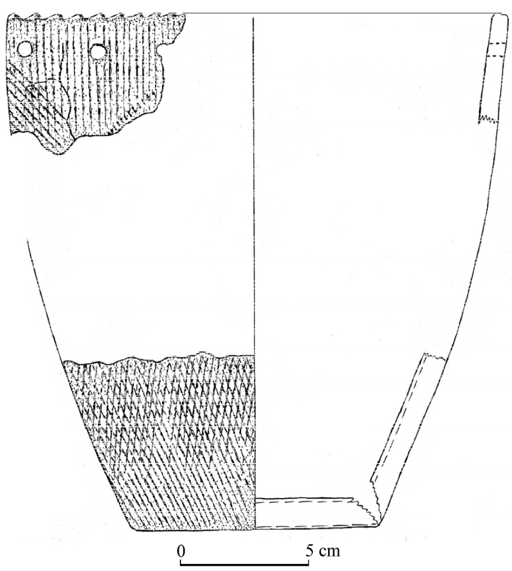

Fig. 12. Pottery from the Gromatukha site dated to c. 12 380 BP (after* Shewkomud, Yanshina 2012*; modified).

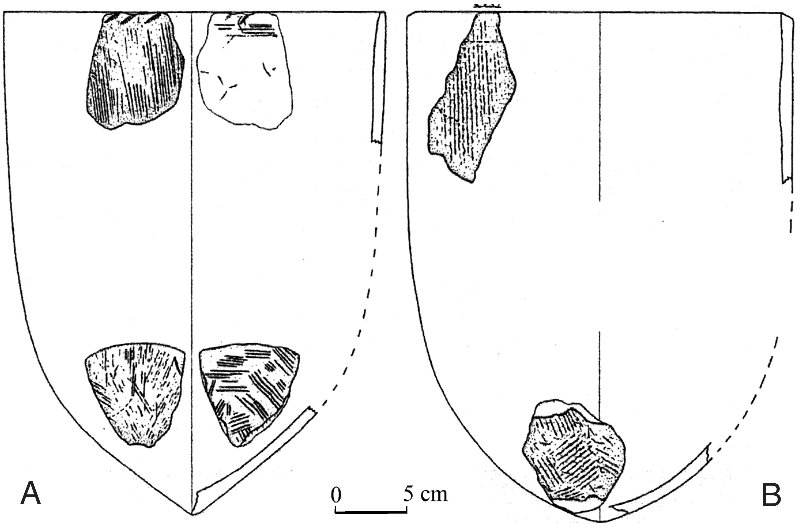

Fig. 13. Pottery from the Studenoe 1 site: A – from Layer 9G (dated to **c.** ***11 960–11 600 BP); B – from Layer 8 (dated to*** **c.** ***11 730–11 570 BP) (after*** **Razgildeeva** ***et al.*** **2013*; modified).***

sites, see Fig. 1), it was concluded that it represents a single cultural tradition of the earliest pottery-making in Eastern Siberia (*Razgildeeva* et al. *2013.177*). Its age can now be established as *c.* 12 000 BP (*c.* 14 000 calBP) (Fig. 2).

Centre(s) of pottery origin(s) in East Asia and neighbouring regions – how many?

Based on previous data, three primary centres of pottery origin in greater East Asia have been suggested: (1) South China; (2) the Japanese Islands; and (3) the Russian Far East (Amur River basin) (*e.g., Kuzmin 2010; 2013a*). This model is still valid, especially in the light of updated information on the age of the earliest pottery complexes outside of these centres (Fig. 14). For example, the oldest pottery in Korea (between the far eastern Russian and Japanese centres) is dated to *c.* 11 780 calBP at the Kosanni site, and *c.* 7960 calBP at the Osanni site (*Bae, Kim 2003; Choe, Bale 2002*). The earliest pottery complexes situated between the southern Chinese centre and the Japanese Islands, the Russian Far East, and the Transbaikal date to *c.* 11 900 calBP in North China at the Nanzhuangtou site (see Tab. 1), *c.* 10 360 BP in Central China at the Lijiagou site (*Wang* et al. *2015*), and *c.* 8480 calBP in Mongolia (*e.g., Kuzmin 2014.720*). Therefore, to the best of my knowledge, no reliable evidence about the diffusion/dispersal of pottery-making from any of these three centres to the neighbouring regions in greater East Asia (including Siberia) is known, contrary to the conclusion that "*Evidence for the dispersal of hunter-gatherer pottery from East Asia and via Siberia, across the continent to Europe suggests that it played an important role in the wider development of Eurasian pottery*" (*Gibbs, Jordan 2013.28*).

As for the Transbaikal, today we have much stronger evidence in favour of a very early appearance of pottery in this region – at *c.* 14 000 calBP, most probably independent of the primary East Asian centres (Fig. 14). However, it did not influence the more western parts of Siberia in terms of the spread of pottery-making. This issue was recently analysed by Kuzmin (*2014*), and no solid evidence was found concerning the diffusion/dispersal of pottery-making from East Asia toward Eastern Europe via Siberia sensu Dolukhanov and Shukurov (*2004*) and Davison *et al.* (*2006*).

Kevin Gibbs (*2015.340*) stated: "*It is possible that in some regions the invention of pottery correspond-*

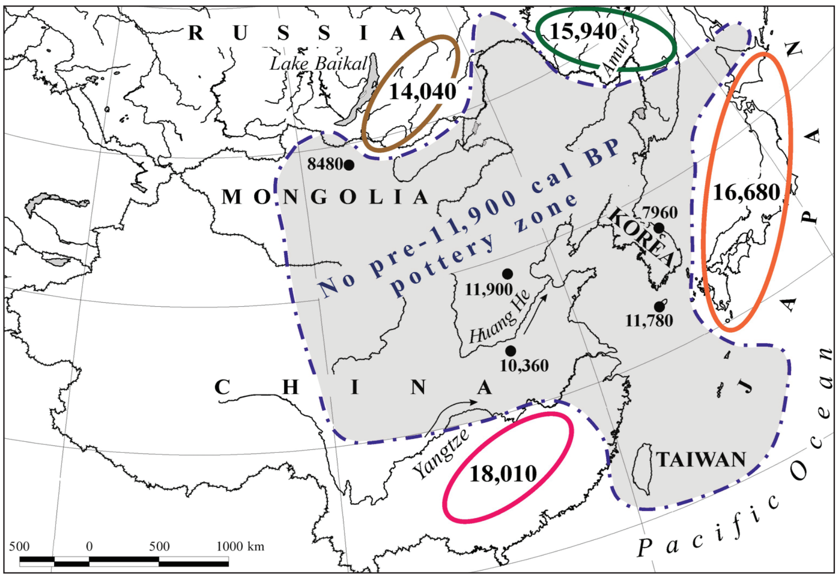

Fig. 14. Primary centres of pottery origin in greater East Asia and neighbouring regions with their calibrated ages (the mid-2015 state-of-the-art).

ed with a newly developed need, perhaps the introduction of a new potential food source that could be better exploited using durable, water-tight containers." I drew the following conclusion some time ago: "*The appearance of pottery was most probably facilitated by the necessity for East Asian populations in the Late Glacial (after* c. *16,000 BP, or* c. *19,000 cal. BP) to have light, easily made containers for the processing and storing of such types of food as wild plants and their nuts and fruit, which are otherwise hard to utilize without vessels for boiling and leaching*" (*Kuzmin 2013a. 551*). A similar view was expressed in the 1970s (*e.g., Ikawa-Smith 1976.515*).

Conclusions

Three regions in greater East Asia, namely South China, the Japanese Islands, and the Russian Far East, are the primary centres of pottery origin in the Old World. It is most likely that pottery-making emerged in these independently of each other, as recent archaeological and chronological data have suggested. It is worthwhile to emphasise that the earliest evidence of pottery preceded the climatic amelioration in the Late Glacial period, the Bølling – Allerød warm interval (*c.* 14 700–12 900 calBP) (Fig. 2). In Siberia, the oldest pottery is now known from the Transbaikal, with a secure age of *c.* 14 000 calBP. It is, however, very unlikely that it is related to the later pottery complexes in both the eastern and western parts of Siberia. It seems that pottery-making in Siberia, as in East Asia in general, emerged in several regions independently and almost simultaneously.

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The oldest pottery in hunter-gatherer communities and models of Neolithisation of Eastern Europe

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ABSTRACT – *The characteristics of the oldest pottery in Eastern Europe, located in three main regions, the Lower Don and Lower and Middle Volga, and a description of different Early Neolithic types of pottery production are described in this article. We present ideas on how and when the oldest pottery traditions were distributed through Eastern Europe according to radiocarbon dates. Also, models of the Neolithisation of Eastern Europe are suggested based on archaeological evidence and absolute chronology.*

IZVLEČEK – *V članku predstavljamo značilnosti najstarejšega lončarstva in zgodnje neolitske keramične tipe v treh vzhodno evropskih regijah: Spodnjem Donu, Srednji in Spodnji Volgi. S pomočjo radiokarbonskih datumov pojasnjujemo, kako in kdaj so se najstarejše lončarske tradicije širile prek Vzhodne Evrope. Predlagamo model neolitizacije Vzhodne Evrope, ki temelji na arheoloških podatkih in absolutni kronologiji.*

KEY WORDS – *Early Neolithic; Neolithisation; pottery technology; radiocarbon chronology*

Introduction

New discoveries about Early Neolithic cultures and sites in Europe, their radiocarbon dates, and information about climatic conditions (*Weninger* et al. *2006; Berger, Guilaine 2009*) led to a new wave of discussion about the components of the 'Neolithic package' (*Özdoğan 2011*), and ways, forms and models of the distribution of Neolithic innovations (*Dolukhanov 2000; Demoule 2007; Cauwe* et al. *2007; Davison* et al. *2009; Fort 2009; Feugier* et al. *2009; Mazurkevich* et al. *2006; Budja 2013*). In addition to a productive economy, pottery and polished tools, it was proposed that prestigious/cultic objects, architecture, settlement organisation, and a new way of life should also be included in the Neolithic package (*Özdoğan 2011.419*). In order to outline the importance of the changes occurring during this time, besides the term 'Neolithic revolution', definitions of other revolutions were proposed: the 'secondary product revolution', introduced by Andrew Sherratt (use of domesticated animals for the purpose of producing 'secondary products', such as milk, wool, and draught power at the end of Neolithic/Bronze Age) (*Greenfield 2010*), and the 'ceramic revolution' (describes how Neolithic innovation was distributed in Eastern Europe) (*Mazurkevich* et al. *2006.20*). However, the 'Neolithic revolution' that occurred in technological and ideological spheres is not now regarded as a rapid process which had an equal influence on all Mesolithic groups that came into contact with Neolithic cultures (*Barnard 2007.17*).

It is supposed that we can trace the integration and coexistence of Mesolithic people with new Neolithic traditions/incomers, rather than an abrupt change in Mesolithic traditions during the earliest stage of Neolithic cultural development in different regions (*Guilane, Manen 2007; Bentley 2007; Hartz* et al. *2007*). Pottery is the only archaeologically visible marker of changes in the cultures of Eastern Europe, unlike in other parts of Europe, where not only pot-

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tery but also other components of the Neolithic package were distributed. This is why Eastern European cultures were excluded from the general Neolithic context in Europe. Various definitions have been proposed to describe the cultures of hunter-gatherers acquainted with ceramic manufacture, such as 'Boreal Neolithic', 'Sub-Neolithic', 'Initial Neolithic' (*Davison* et al. *2007.140; Gronenborn 2010; Dolukhanov, Shukurov 2009.36; Tallavaara* et al. *2010.253; Cohen 2014*). However, it is suggested that the level of social development and complicated social networks that existed should be taken into account in order to estimate the crucial changes that occurred in this transitional period (*Oshibkina 1996*). Radiocarbon dates have recently shown the old age of the first pottery in eastern Europe, attributing it to the first half of the 7th millennium calBC[1] (*Vybornov* et al. *2008; 2012; Mazurkevich* et al. *2013*) (Map 1, Fig. 7). This material is some of the earliest evidence of pottery among communities of hunter-gatherers in Eastern Europe.

The early appearance of pottery that is not related to the distribution of productive economies can also be traced in Southern China at the 20–16th millennium BP, in the Far East and Japan at 17–15th millennium BP, in Southern Siberia at the end of the 14th millennium BP (*Budja 2010.118; Cohen 2014.62*), and in the 10–8th millennium BP in Southern Africa (*Close 1995*). Pottery appeared in these regions independently and has been discovered over a vast area. After pottery making appeared in Southern Africa, it spread over a distance of 3000km (*Close 1995.32*). Recently, a hypothesis suggesting the eastern origin of East European pottery has been discussed (*Gibbs, Jordan 2013.16*). However, there are no intermediate sites with pottery similar and synchronous with the first pottery in the Far East over a huge area from the Far East to the Southern Urals, a distance of over 9000km, which could prove this theory; nor might any similarities be found between the pottery of Eastern Europe and early Eastern or Western Siberian ceramic assemblages.

We suggest that the oldest pottery in Eastern Europe had special characteristics which could make it part of a near-eastern Neolithic package that arrived here in different ways and from different places, whereas the further development and appearance of other cultural traditions in Eastern Europe can be connected with the regional development and interaction of hunter-gatherer communities (Map 2).

Different groups can be distinguished in the pottery assemblages of Eastern Europe ascribed to the Early Neolithic that differ in their technological, morphological and decorative features. Some are very similar, although separated by hundreds of kilometres. At the same time, the deposit of Early Neolithic pottery together in one stratigraphic layer suggests the simultaneity of these events, which can in reality be separated by long periods. This is why a technological and typological analysis of pottery, together with radiocarbon dates and stratigraphy, is necessary in order to distinguish the oldest groups within pottery assemblages.

An overview of the oldest pottery traditions of Eastern Europe is presented in this article, along with a discussion of their chronological position, distribution and origin.

Absolute chronology of Early Neolithic pottery in Eastern Europe

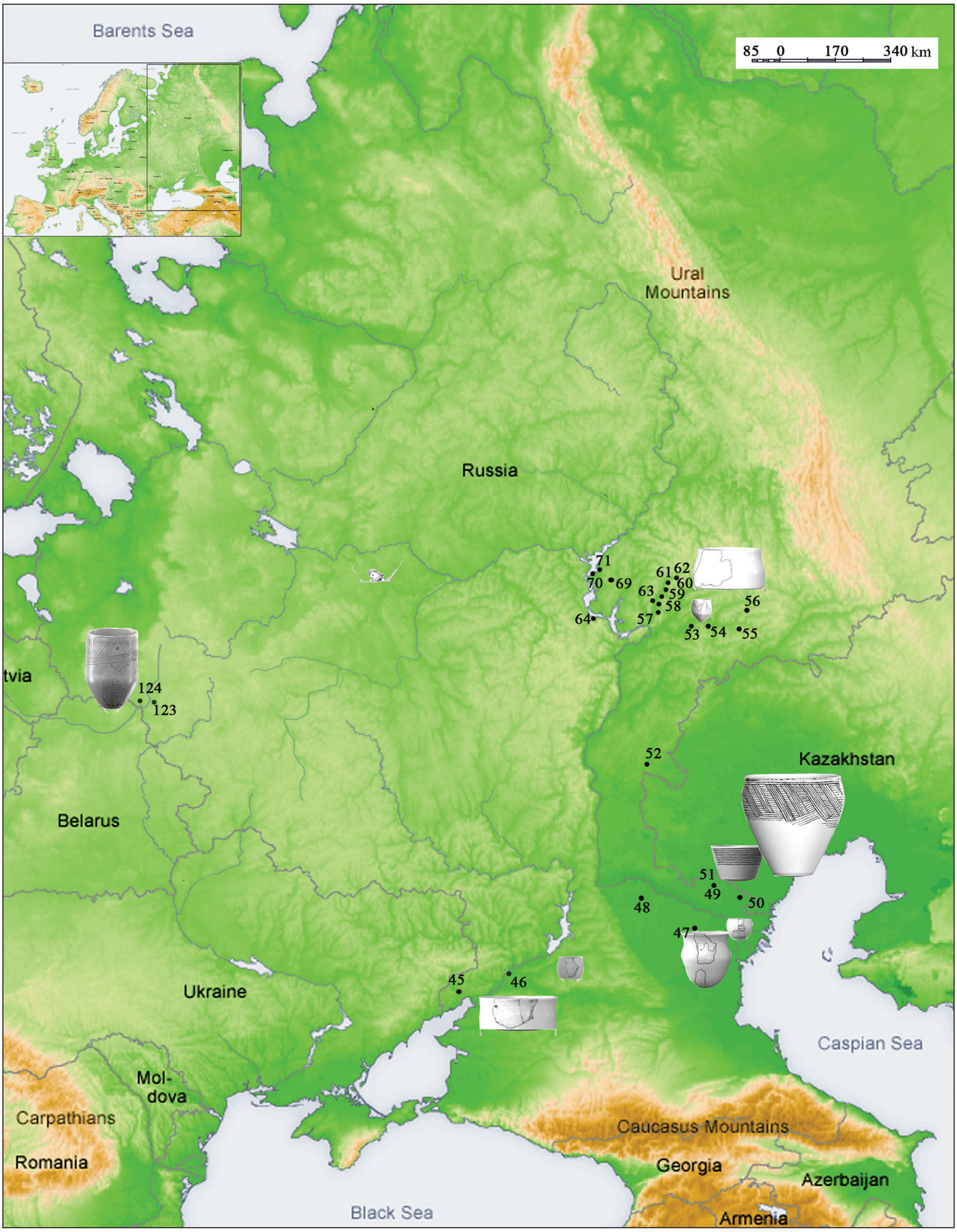
The analysis of the radiocarbon dates attributed to the Early Neolithic pottery of Eastern Europe (according to *Vybornov 2008; Vybornov* et al. *2008; 2012; 2013; Ivanischeva 2009; Hartz* et al. *2012; Smol'yaninov, Surkov 2014; Tovkailo 2010; Gaskevich 2010; Karmanov 2008; Zaiceva* et al. *2014*) makes it possible to divide dates into groups (Figs. 4–6). These groups relate to different types of the earliest pottery, represented by undecorated vessels, pottery decorated with impressions (triangular and/or dots) and with incised lines, as well as vessels of later stages with different technological and typological characteristics.

The dates of these types of pottery are believed to be distributed non-uniformly in the time span, but concentrated in certain periods. This might be explained by the increase in the number of sites, materials and, perhaps, population during these periods. These dates make it possible to synchronise different events reflected in the appearance of various types of pottery, and also show that bearers of different traditions could coexist during the same periods in the same area. Several explanations may be proposed: the appearance of various types of pottery at the same sites could have been separated by short periods which cannot be detected from radiocarbon dating, and also the coexistence of societies with different pottery or 'Mesolithic' and 'ceramic' communities might be supposed.

1 calBC – calibrated dates according to OxCal 3.10 (*Bronk Ramsey 2005*).

The oldest pottery assemblages from Eastern Europe date to the first quarter of the 7th millennium calBC. One of the oldest complexes with pottery can be found at Rakushechny Yar in the Lower Don basin (Map 1).

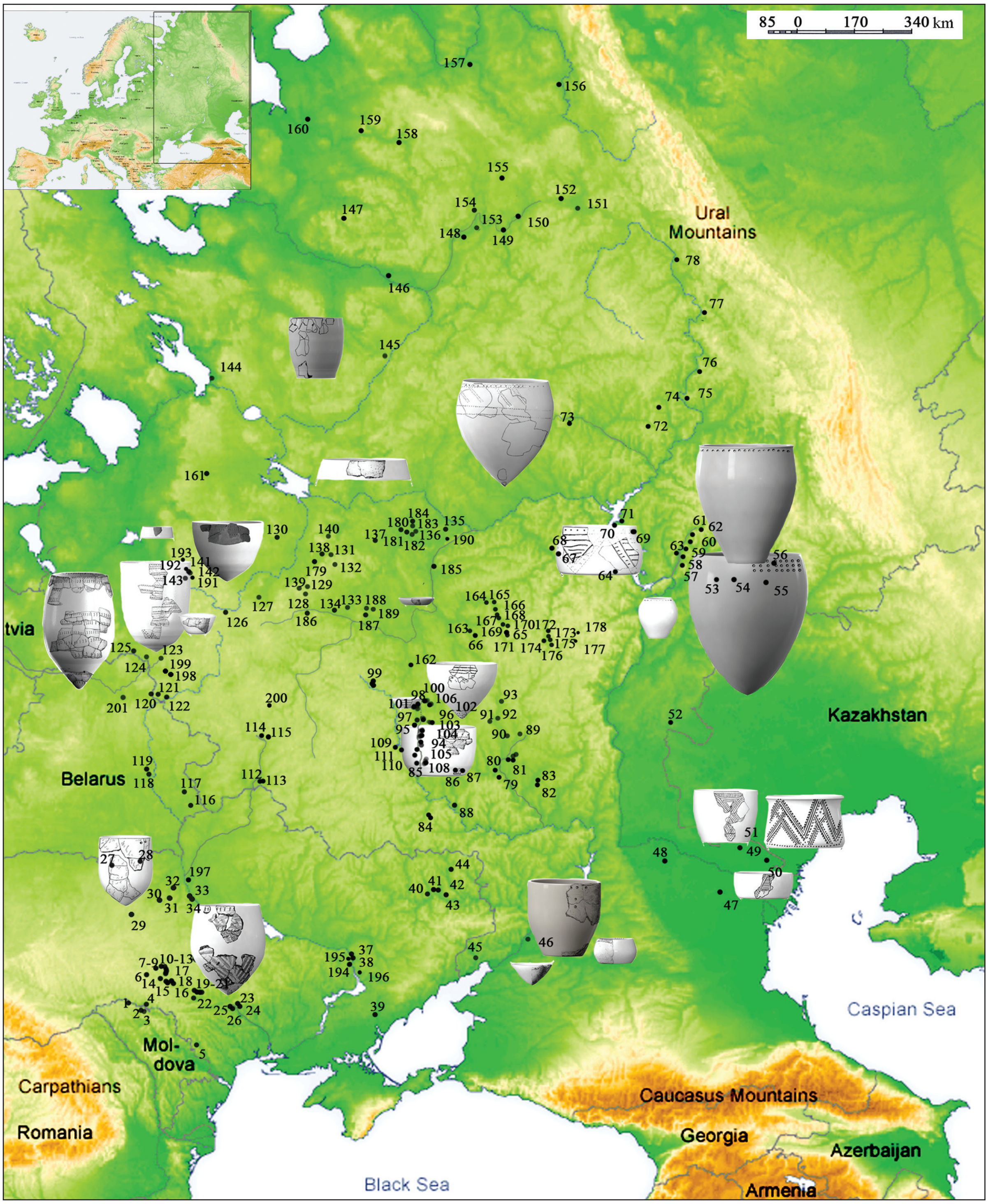
The next period with a concentration of dates is attributed to the beginning of the second quarter of the 7th millennium calBC, connected to the Elshanskaya culture pottery in the Middle Volga region. According to the radiocarbon chronology, the Elshan-



Map 1. Distribution of sites with the oldest pottery during the first half of the 7th millennium calBC in Eastern Europe (according to radiocarbon dates).

skaya culture existed here for a long period (*Vybornov 2008*).

The concentration of dates around the middle-second half of the 7th millennium calBC is connected with pottery decorated with triangular impressions and dots from the Lower Volga and the Caspian basin. It might date to an even older time, evidenced by the appearance of this type of vessel in the first ceramic assemblages of Elshanskaya culture (*Viska-*



Map 2. Sites with Early Neolithic pottery in Eastern Europe dated to the middle of the 7th–6th millennium calBC (site positions according to **Gaskevich 2010; Vybornov 2008; Krainov 1996; Smol'yaninov 2009; Surkov 2007; Smirnov 1991; Sinyuk 1986; Karmanov 2008; Tyurina 1970; Stavickii, Hrekov 2003; Lychagina, Cygvinceva 2013; Urban 1996; Gurina 1997; Telegin 1996; Cvetkova 2011; Cetlin 2008; Kotova 2002*). For the list of Neolithic sites 1–195 see Appendix.***

lin 2014). The distribution to the north of populations in the northern Caspian and Lower Volga region can be dated to the second half of the 7th millennium calBC, which led to the formation of a new culture in the Middle Volga basin (*Andreev 2014. 14*).

Radiocarbon dates between 8000–7500 BP yield a large spread of possible calendar age ranges because of a plateau in the calibration curve (*Alekseev* et al. *2005.42*). This makes it difficult to obtain narrow calibrated spans for different ceramic traditions and to date more precisely their distribution in various areas (Fig. 4a).

It is interesting that the increase in the quantity of radiocarbon dates at sites with decorated pottery in the Caspian region happened at the end of the 7th millennium calBC and beginning of the 6th millennium calBC, but this was absent at sites with undecorated pottery. Elshanskaya culture stage II appears at the end of the first/second quarter of the 6th millennium calBC. This stage also includes ceramic complexes from other areas dated to the second half of the 6th millennium calBC. Pottery assemblages of sites located in the north Caspian Region, such as Jangar (layer 2), Kachkarstau, Tenteksor I, date to the middle of the 6th millennium calBC. Another concentration of dates for pottery decorated with triangular impressions can be traced in the second half of the same millennium.

The increasing quantity of dates from the forest and forest-steppe zone achieved recently fall in the interval of the middle/second half of the 7th millennium calBC, which can hardly be explained solely by an age offset due to the reservoir effect. According to recent research, the hard-water effect, which could have influenced these dates, could be absent or minimal in some regions (*Kulkova* et al. *2014*). Moreover, the dating of modern materials does not allow us to determine the real age offset which must be taken into account in date calculation (*Kulkova* et al. *2014; Philippsen 2014*). Also, the analysis of early Neolithic vessels from Eastern Europe reveals that some were used to cook non-aquatic products, which excludes the possibility of any reservoir effect (*Meadows 2014*).

It seems that these dates reflect some cultural processes occurring since the second half of the 7th and middle of the 6th millennium calBC. This is a period when local, regional traditions in the Upper Volga, Middle and Upper Don, Dnepr-Dvina regions and other territories formed and developed and spread to neighbouring areas (Map 2, Fig. 5).

Besides the oldest dates from the Lower Don, Lower Volga and Middle Volga regions, there are also dates falling in the interval of the first half/middle of the 7th millennium calBC obtained from organic crust on vessels or synchronous materials from northern territories, which shows the very old age of this pottery, almost synchronous with the appearance of the oldest pottery in the southern areas (*Mazurkevich* et al. *2013*).

It is important to understand how this almost simultaneous appearance of ancient pottery occurred in various regions of Eastern Europe that are separated by hundreds and even up to 2000 kilometres; can we trace these processes in archaeological material, not only in radiocarbon dates, and what cultural model could best explain this type of evidence?

Description of different regional cultures with the most ancient ceramic traditions

Lower Don Region: the ceramic assemblage from the Rakushechny Yar site

Rakushechny Yar is located at the north-western end of the modern island of Porechny on the Don River (Fig. 1). An area of approx. 1000m^2 was excavated by an expedition from Leningrad State University under the direction of Tatyana D. Belanovskaya in 1961–1966, 1968, 1971, 1976–1977, 1979 (*Belanovskaya 1995.9–12*); new excavations of the oldest layers were conducted by Pavel Dolukhanov, and later by Andrey Tsybriy and Andrey Mazurkevich (*Tsybriy* et al. *2014*). The cultural layer at Rakushechny Yar consists of several isolated outcrops of different sizes, often at a distance from each other, where excavations II – V were made. Excavation I was in the central part of the site. Belanovskaya divided the site into six horizons, with several layers forming the sixth horizon (Fig. 2); all were identified as cultural layers separated by sterile interlayers. Layers 9–23 were attributed to the Early Neolithic.

The first researchers to investigate the site outlined its unique character and traced analogues with Near Eastern materials (*Belanovskaya, Timofeev 2003*). However, only a small part of the excavated lower layers, uncovered in 1965 when the level of the Don was very low, yielded a very restricted complex of finds, which appeared to be very small in the lowest layers (23–21). This should be considered when investigating this Early Neolithic complex, which reveals a small fragment of the ancient history of this region.

Fig. 1. View of the Rakushechny Yar site.

In this research, ceramic materials from layers 23–11 from excavation I (housed in the Department of Archaeology of Eastern Europe and Siberia of the State Hermitage Museum) were studied. The assemblage consists of 2421 wall and rim fragments of vessels and 272 fragments of bottoms and low vessel parts attributed to approx. 490–500 vessels.

The petrographic studies by Marianna Kulkova determined the mineral composition of the paste, identified tempering materials, and determined their quantity (*Mazurkevich* et al. *2013*). Several raw materials were distinguished which could be located at different hypsometrical levels and which have different origins. The use of these different types of clay and silty raw materials probably depended on variations in the level of the river. The characteristics of the raw materials of these vessels point to an origin near the site, which allows us to suppose that the pottery was made locally. Thus, Neolithic potters used various raw materials to produce pottery, depending mostly on its accessibility at different times.

The following pastes used in pottery making were identified by visual analysis:

- Plastic clay with natural inclusions of shells, with or without a small amount of temper. The clay was well kneaded at the pre-treatment stage, which is typical of pottery from the lowest layers. Also, there are vessels made from the same type of paste, which was poorly kneaded, and with a great quantity of natural organic matter. This type of vessel increases in quantity in the upper layers.
- Clay mixed with organic temper was also found at the site.
- Also, there is a type of a paste with grog or crushed pottery temper added to the paste, which was confirmed by the petrographic analysis (*Mazurkevich* et al. *2013*).

That the technology of pottery making was stable is proved by the existence of definite *chaînes opératoires* in all layers. Several types of coil modelling were identified: N, U (Tab. 1.1), and S-type of coils junction (Tab 2.4), and the slab technique (Tab. 3.2). The thickness of vessel walls is 0.6cm, 0.7–0.9cm, and 1.2cm. Coils were stretched in most cases when N-junctions of coils were applied (Tab. 3.3). N-junctions of coils with stretching predominated in vessels from the lowest layers 23–11 (Tabs. 1.2, 2.3). Additional pieces of clay were often used (Tab. 3.1), which is clearly seen in radiographic photographs of the fragments.

Vessels from layers 13–11 were made with long coils stretched vertically, and consisted of two to three layers (Tab. 1.3). In addition, the 'paddle and anvil' technique appeared in layers 13–11; the diameter of anvils might not have exceeded 3–4cm. Vessels made with the slab technique appeared here, as well as with blocks of coils which were attached with a U-shaped junction. These were made by long coils stretched vertically. This type of modelling could have been used for large vessels with diameters of about 40cm.

The forming of the rim was the same on all the vessels from layers 23–11. Rims have almost perfectly flat and symmetrical edges, which shows that a technique was used that allowed the vessel rims to appear almost uniform. Usually, the flat edge of the rim was formed either by a coil that was bent out or by the addition of a small coil to thicken the edge of the final coil. The rim was then pressed with fingers, which is evident from the traces of finger pressure, and treated with some tool with a flat edge. In several cases, we observed traces of pebble use.

The surface treatment included the redistribution of excess clay and levelling of the surface with a comb-like tool and further smoothing and polishing. The vessel surfaces are eroded due to post-depositional conditions and further cleaning of finds. This is why some traces of surface treatment did not survive. The surface was usually smoothed; there are traces of smoothing made with 'wet hands', pebbles, and also traces of bone tools (see *Martineau 2001.Figs. 17–18*). Traces of a comb-like tool left in the process of roughening can often be observed on the inner surface, which was especially important while making vessels with thick walls to remove or redistribute surplus clay. Traces of working with comb tools are often smoothed. In rare cases, they can also be traced on the outer surface of the vessels that is well smoothed. Elaborate polishing is rarely observed and is usually present on surfaces of thin-walled vessels decorated with dots or undecorated. Smoothing and polishing was often made after decoration, which is proved by the indistinct form of the impressions. Fragments of thick walls (to 1.2cm) with traces left by a thin comb tool on both surfaces which were not smoothed later were found in layer 20 and the layers above. This type of technique corresponds with a new clay paste with organic temper. Traces left by comb tools are very rare on vessels from layers 15–11, which can be explained either by very careful smoothing of the surfaces of these vessels or because comb tools were no longer used. A new tool for surface smoothing, probably a wooden tool or a shell, was used in this period, leaving thin linear traces on the surface of vessels (see examples of traces in *Glushkov 1996*).

Vessel bases were made with slabs pressed together or from coils formed in a spiral from the centre of the base (Tab. 1.6.1). The vessel was then shaped by stretched coils. This is clearly seen due to the 'groove' along the perimeter of the flat base (Tab. 1.7a) which appeared as the result of finger pressure while attaching the first coil of the body to the base.

Some 13 vessel forms were identified in total (Pls. 1, 2) in layers 23–11 (Tabs. 4–10) (*Mazurkevich, Dolbunova 2012*). Vessel rims are predominantly flat and roundish, while pointed rims are rare.

In most cases, only the upper parts of vessels can be reconstructed, but due to the parts near the base and the profile features, it can be supposed that most had flat bases. Flat bases have varying diameters (4–6cm, 7–9cm, 10–11cm, 12cm, 16cm). Bases with a diameter of 7–9cm are the most widespread. The analysis of divergence angles of the low parts of the vessels allowed us to trace several features (Pl. 3). Divergence angles of 65–70° were typical of bases in the lowest layers; in the upper layers, bases of different types appeared (from 46° to 80°). Four different divergence angles existed in layer 20 (50°, 60°, 65° and 70°). In layer 13, bases had different angles (from 48° to 78°). Some definite standardisation of the divergence angles of bases were found in layer 12 (55°, 65°, rarely 70° and 75°). The maximum standardisation is seen in layer 11. In this layer, bases were made with three main standards (65°, 70°, 75°); bases with other angles were rare in this layer (46–48°; 55–62°). This strict standard may testify to the use of some forms for making the bases of vessels or the use of tools bevelled at a definite angle for pottery moulding.

Pointed bases from layers 13 and 11 can be found in the collection of the State Hermitage Museum (Tabs. 9.15, 10.11). Belanovskaya (*1995. 104*) noted the existence of a pointed base in layer 20, but the method of production and the forming suggest it is more probably a fragment of a flat base. Pointed bases have two standards of divergence angles (90° and about 110°). Also, round bases probably existed in layers 21, 20, and 13–11.

We can observe from reconstructed vessels that the height/diameter ratio is 1 to 1.3. Vessel forms can be divided into four volume groups according to their diameter (which are 7–9cm, 12–16cm, 18–24cm and 30–40cm). Vessels have estimated volumes of 0.25–0.4, 1–2, 5–6 and 14.5–

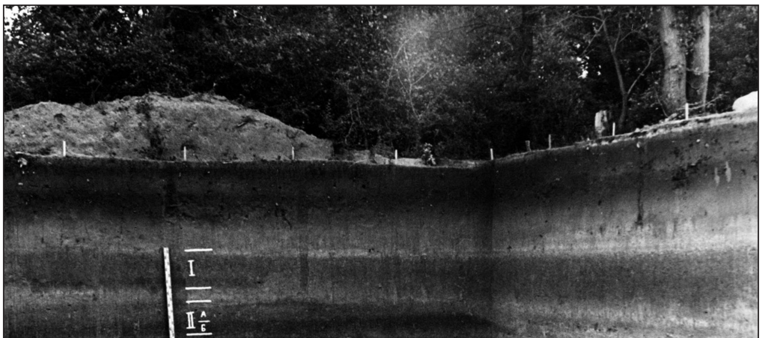


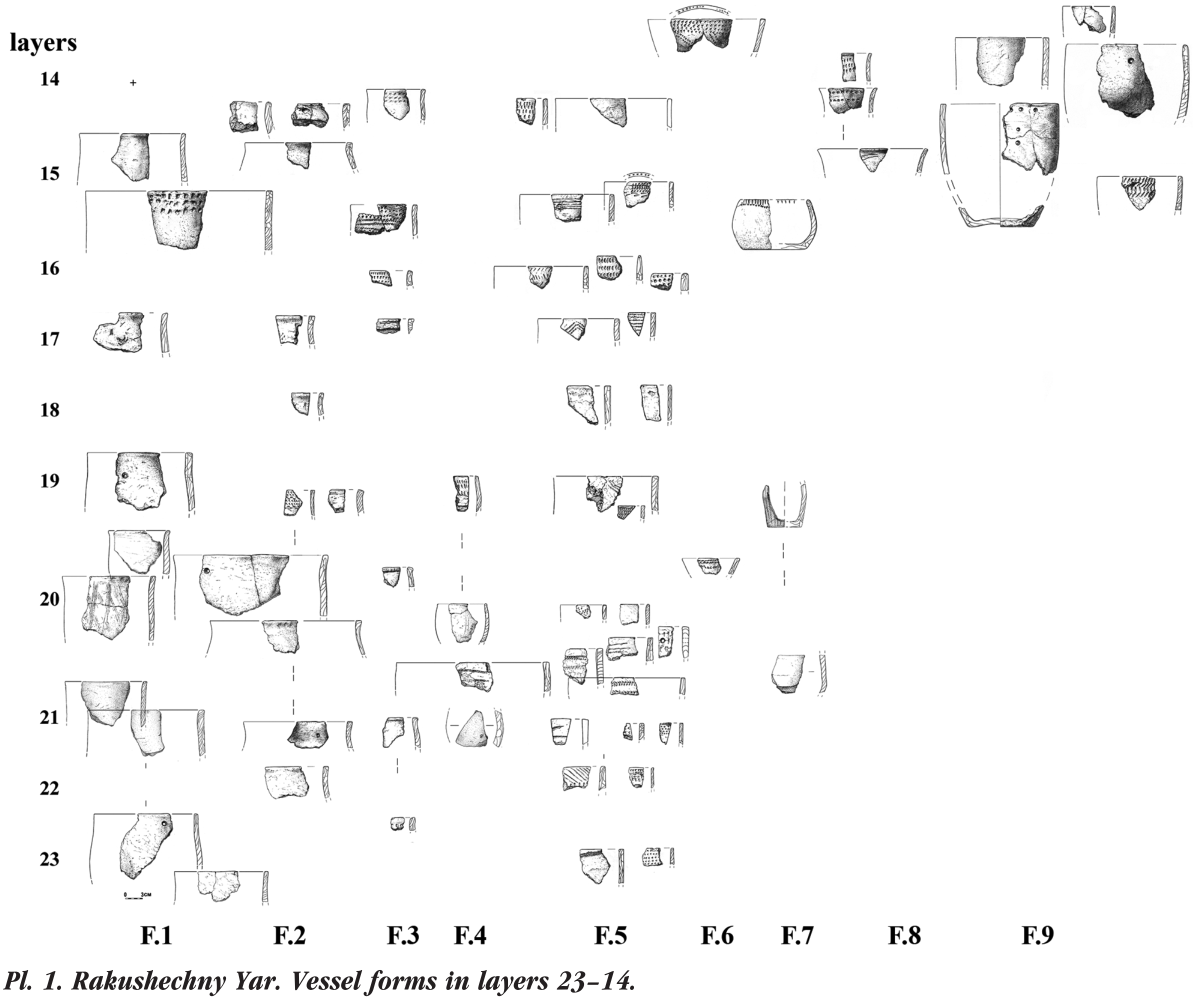
Fig. 2. Rakushechny Yar. View of excavation I (1964) and layers (after* Belanovskaya 1964.Tab. 2*).

20 litres, correspondingly. A particular group consists of 'bowls' and 'plates' (forms 6 and 12) where the height/diameter ratio is 0.3 to 0.4, and the volume is about 0.15 to 0.3 litres (form 12).

Most of this pottery is undecorated, and decorated vessels comprise only 9% of the assemblage; in individual layers this percentage is even lower (*Mazurkevich, Dolbunova 2012.Tab. 1*). Vessels covered with red and yellow ochre on the outer and/or inner surfaces are also present at the site. A layer of red ochre can clearly be seen on some of the vessels, but usually only small parts of ochre survived on the surfaces. Also, an Unio shell with a layer of ochre inside was found in layer 20. The analyses (microscopic, microchemical, X-ray fluorescence spectroscopy, infra-red spectroscopy) made in the State Hermitage Museum by L. Gavrilenko of these fragments in order to identify the material on the surface lead us to believe that more than 10% of the whole ceramic assemblage was covered with red and/or yellow ochre consisting of iron oxide (II, III) and iron hydroxides with traces of titanium and manganese compounds.

The pottery is decorated with different impressions and incisions: small and large triangular, roundish (in layer 20), rectangular and large denticulated impressions, double toothed, impressions of belemnite (in layer 14), large pinches (in layer 15), drop-like dots, vertical and horizontal incisions, and also impressions made by a comb-tool creating several motifs. The design techniques vary: pin action, 'rocking-chair', drawn, individual marks linked through a single continuous stepped back drawn movement. A variety of techniques is seen in pottery from the lowest layer, where material decorated with triangular and rectangular impressions was found, drawn traces of 'comb', lines and denticulated impressions made with the 'rocking-chair' technique (in layers 23–22).

The decoration is very simple, consisting of horizontal and parallel lines of impressions (*e.g.*, Tab. 4.1–3) usually covering only the upper part of the vessel. Vessels decorated with a net of impressions left by a comb-tool were also found (Tab. 6.4). Pottery decorated with a figure made with triangular impressions was found in layers 20 and 19. Pottery



Pl. 1. Rakushechny Yar. Vessel forms in layers 23–14.

with geometrical motifs consisting of diagonal parallel lines appeared in layer 21, and pottery with other diagonal compositions in layer 16 (Tab. 8.3). It was in this layer that not only new compositions appeared, but also new impressions for decorating vessels in this style (for example, Tab. 9.9,14).

Chronology, genesis and characteristics of Early Neolithic complexes at Rakushechny Yar

The pottery assemblage from Rakushechny Yar consisted of flat-bottomed vessels of different forms, with standardised rims and bases of vessels, the existence of several *chaînes opératoires*, characteristic types of technology used to make definite forms of vessels, the rare use of decoration and traditions of surface treatment with red or yellow ochre.

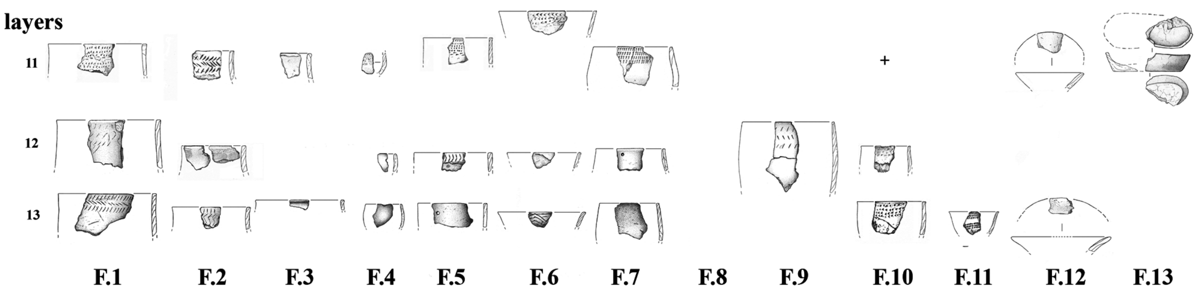
The great variety of raw materials and clay pastes used for pottery shows the ability of potters to adapt to different types of materials which were available at different periods, which might be an indicator of developed skills and experience in pottery making (*Mazurkevich* et al. *2013*). The ability to adapt different types of raw material and their use in the framework of different *chaînes opératoires* could be interpreted as a developed cultural tradition. This was not typical of pottery making in northern areas, such as the Dnepr-Dvina Region, where the process was rather conservative and where definite pottery recipes were used in various 'ceramic phases'. The range of similar technological operations typical of vessels of the lowest layers (*e.g.*, surface smoothing and vessel treatment with a comb-like tool, modelling of symmetrical flat rims, predominance of the coil technique with N-junction, use of well-kneaded clay and additional pieces of clay for modelling, typical vessel forms) allow us to characterise this pottery assemblage as one made according to established cultural standards. Standardisation of pottery making could reflect the level of specialisation and quantity of pottery made (*Roux 2003.768*). This observation is of special interest in the context of this material that was excavated outside the central settlement at Rakushechny Yar, which was probably a seasonal area connected with fishing (*Girja, Lozovsky 2014*).

The variety of pottery found at Rakushechny Yar might testify to its functional diversity: a variety of forms and volumes, as well as the use of different pottery operational sequences can be traced here. The most widespread vessel form (Form 1, made from coils with an N-junction, slightly stretched, with a smoothed surface) could be interpreted as kitchen ware. Alongside this, there were several other categories of vessels, some of which could also have served some utilitarian purpose, while some could have played a particular role (vessels covered with ochre on the inner and outer sides; vessels for ochre storage).

The chronology of the material culture from Rakushechny Yar can be reconstructed from the ^{14}C dates of different materials: charcoal, soil, organic crust on pottery from excavation I (*Belanovskaya, Timofeev 2003.Tab. 1*). In addition, several dates are known for the different materials (bone, pottery, soil with charcoal and soil) from the test pit excavated in 2008, which was dug 25m from excavation I (Fig. 7).

The dates from excavation I correlate well with each other (Fig. 3), except for the dates on shell and some of the dates on charcoal and soil samples. These dates show the existence of different sites over a long period in this area. The oldest date, of an elk bone, comes from below layer 23 of the new excavation and may date the first stages of this occupation to 7970±110 BP (SPb-729).

Dates from layers 20–17 show that the early Neolithic complex can be placed at the turn of the 7th millennium calBC (Figs. 3, 7), which indicates that Rakushechny Yar was occupied over a period of approx. 800 years without any great changes. Later, many changes in pottery decoration, morphology



Pl. 2. Rakushechny Yar. Vessel forms in layers 13–11.

and technology can be seen to occur over approx. 500 years (layers 16–9). The end of the Early Neolithic at Rakushechny Yar can be dated to the end of the 6th millennium calBC (Fig. 3).

The buried soil X (*Aleksandrovsky* et al. *2009.Fig. 4*) deposited at the base of the cultural layers of the test pit is dated to 7380±100 BP (Ki-15181), *i.e.* a period later than the lowest layers of Belanovskaya's excavation I (Fig. 4). This suggests that this area was inhabited approx. 600 years later. It was located on ground higher than the area of excavation I, and the soil was formed here when the occupation of the excavation I area started. The beginning of occupation of this area correlates with the period when cultural layer 20 of excavation I was formed. The differences in ^{14}C dates and the number of cultural layers (their thickness and characteristics) supports Belanovskaya's hypothesis that the cultural layers identified at the shore, in test-pits and in the numerous excavations at Rakushechny Yar in different parts of the island cannot be simply correlated. Synchronous layers might also occupy different hypsometric positions. This 'diversity' is evidence of asynchronic and repeated occupation of this area.

The origin of the Rakushechny Yar complex raises many questions and discussions. The appearance of this complex can be dated to the first quarter of the 7th millennium calBC (*Timofeev* et al. *2004; Davison* et al. *2009; Aleksandrovsky* et al. *2009; Tsybriy* et al. *2014*), *i.e.* contemporaneous with Early Neolithic (ceramic) complexes in the Near East (*Belanovskaya, Timofeev 2003*). During this time, the oldest pottery centres were formed in the steppe areas of Eastern Europe, which could have occurred under the influence of Neolithic cultures in the Caucasus (*Belanovskaya 1995.181–182*), whereas the Southern Caucasus area was within the zone of influence of early Anatolian Neolithic cultures during the Pre-Pottery Neolithic B period (PPNB) (*Kiguradze, Menabde 2004.353*). However, no such ancient sites with pottery have survived in the Caucasus, where Early Neolithic complexes have been dated to the end of the 7th and to the 6th millennium calBC (*Arimura* et al. *2010; Hansen* et al. *2007; Hamon 2008*).

However, based on a range of similar features, *i.e.* similar forms of pottery and similar ceramic techniques (the use of coils or slabs, the simplicity of pottery, rare use of decoration) (*Vandiver 1987.9–23; M. le Mière, Picon 1999.5–16; Nishiaki, M. le Mière 2005.59–63; Voigt 1983*), the existence of specific types of tools with a longitudinal groove, similar to tools distributed in the Levant and Western Mesopotamia (*Arimura* et al. *2010.80*), adobe architecture and the proximity of radiocarbon dates, we might also suppose direct infiltrations from the Near East to the Lower Don Region. Relations be-

Layers	Organic crust	Charcoal	Soil with charcoal	Bone	Shell
			5290±260 (Le-5327)		
layer 2		4830±90 (Le-5383)	6300±300 (Le-5343)	4180±100 (Le-5428)	
layer 3		4360±100 (Bln704)			
				5060±230 (Le-5140)	
layer 4				6300±90 (Le-5482)	
			6320±40 (Le-5582a)	5920±90 (Le-5479)	
layer 5			6440±35 (Le-5582b)		7840±105 (Ki-955)
layer 8		6070±100 (Bln1177)			
layer 9					7180±250 (Le-5344)
	6930±100 (Ki-6478)				
	6950±100 (Ki-6479)				
layer 15	7040±100 (Ki-6480)				
	6841±40 (Ua-41365)				
layer 18	($\delta^{13}C$ - 28,0**)				
	7156±41 (Ua-41364)				
layer 19	($\delta^{13}C$ -28,0**)				
	7290±50 (Ua-37097)				
	($\delta^{13}C$ – 28,6)				
	7690±110 (Ki-6475)				
	7860±130 (Ki-6477)				
layer 20	7930±40 (Ki-6476)			7970±110BP (SPb-729)*	

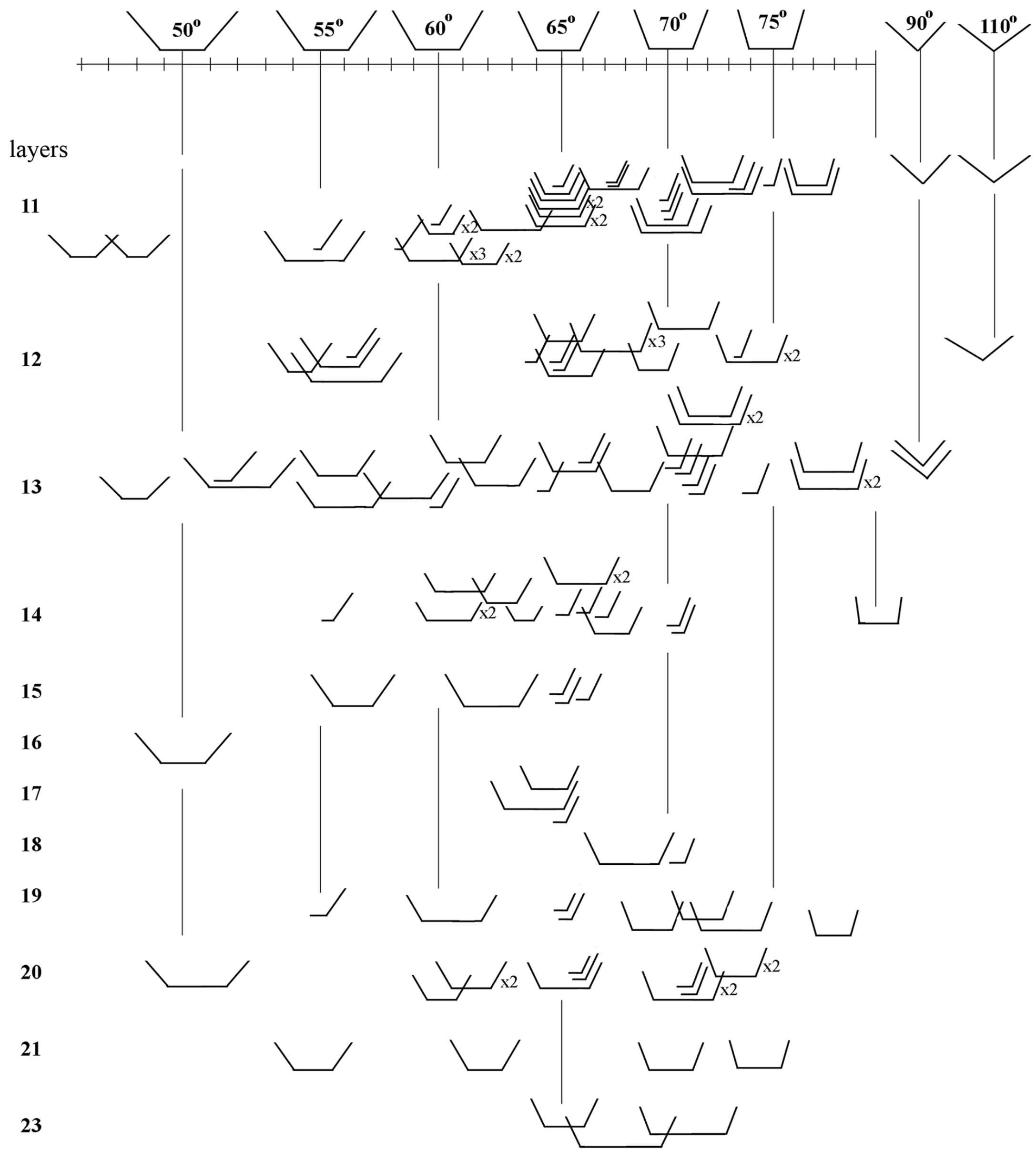
Fig. 3. ^{14}C dates made on different materials found at excavation I of Rakushechny Yar (* dates obtained on material found during recent excavations; ** estimated value).

tween the steppe areas of Eastern Europe from the Black Sea to the Azov Sea with Armenia and Central Anatolia could also be evidenced by finds of obsidian that originated from deposits located in the latter regions (*Biagi* et al. *2014*). Recent research has revealed traces of the penetration of Near Eastern cultural traditions dating to an even earlier period into these areas (*Gorelik* et al. *2014*). This might testify to multiple cases of penetration by bearers of Near Eastern cultural traditions with different components of the 'Neolithic package' in the Lower Don region.

Sites in the Lower Volga River basin

A detailed description of early Lower Volga Neolithic sites can be found in publications by Aleksander A. Vybornov (*Vybornov 2008; Vybornov* et al. *2012; 2013*). We present here a description of pottery of this region based on these publications and also on the results of pottery analyses from different sites. The pottery assemblages are presented here in the chronological order proposed by Vybornov (*2008*) based on an analysis of pottery, the stone industry and the radiocarbon dates of organic crusts on pottery, and other materials attributed to different periods.

Sites in the Lower Volga River basin are divided into two groups, one on the left bank and another on the right bank of the river (Map 1) (*Vybornov 2008*). Almost all the pottery from the North Caspian area was made from silts with organic solutions (definitions



Pl. 3. Rakushechny Yar. Divergence angles and base' diameters in layers 23–11.

of raw materials by *Vasilieva 1999; 2010*); later, shells were incorporated into the paste (*Vasilieva, Vybornov 2012*). According to Irina N. Vasilieva, the Early Neolithic pottery of the North Caspian was made from slabs put together in spirals (*Vasilieva 1999.84–85*). Large vessels could have been made from slabs organised into blocks or with the moulding of vessels (*Vasilieva 1999.86–91*).

The early chronological stage of the Volga left-bank group (termed Kairshak-Tenteksor) includes the Kugat IV and Kulagaisi sites (Tab. 12.1–3). Vessels were made from paste with crushed shells and organic remains; they have straight walls and round bases. Decoration did not cover the whole surface, and was made by incised lines or oval-form impressions (*Vybornov 2008*). The dates of the first and second stages overlap and have aroused some controversy, which needed to be explained (Tab. 12). The conservation of Mesolithic traditions in the stone industry can be traced during this stage (*Vybornov 2008*). These sites could reflect the first wave of distribution of pottery-making traditions in this region.

The second chronological stage is represented by Kairshak I–IV (Tab. 12.6–30) and Burovaya 42. Vessels were made from sandy silts with a natural admixture of shells and organic material; they usually have bowl-like forms, with flat, somewhat concave bases. Decoration consists of various motifs (*Vybornov 2008*), while some fragments of undecorated pottery, similar to the undecorated pottery from the lower layers at Rakushechny Yar, were found at Kairshak III.

The third chronological stage includes Tenteksor I, Je-kolgan, Kachkarstau, Kyzyl-hak II. Vessels were made from sandy silts with a natural admixture of shell and organic material; they have flat bases with a simple or complex profile and flat or roundish rims. Most of the vessels are decorated with oval or quadrangular-form impressions, while geometrical curvilinear decoration is typical of this material (*Vybornov 2008*).

The Jangar-Varfolomeevskaya group was located on both banks of the Lower Volga. Tu-buzgu-huduk represents the earliest stage; pottery was made from clay paste with a mixture of sand and organic remains. Vessels have straight walls and closed forms; bases are flat and roundish. Decoration is rather simple, consisting of triangular and oval impressions in the upper part of the vessels forming horizontal rows of impressions and zigzags (*Vybornov 2008*).

The second chronological stage includes the second and third layers at the Jangar site (Tab. 13.11, 23–26) and layer 3 at Varfolomeevka (Tab. 13.1–10, 12–23). Vessels from Varfolomeevka were made from silt, similar to those from the North Caspian area. The pottery in layer 3 was made with shell temper. Most of the vessels from layers 2 and 2a were made from silty clay (*Vasilieva 2010*). This pottery was constructed from coils; the outer surface was polished, and the inner surface smoothed by a comb tool or grass (*Yudin 2004*). The coils could have been stretched and attained up to 2.5–3cm. Most vessels have straight walls; bases are predominantly flat, but slightly concave compared to the flat bases at Rakushechny Yar, and they rarely have a clear angle between the base and the wall. Pottery was decorated with triangular impressions, usually covering the upper part of the vessels or the whole pot; a technique with dot impressions was applied. Complex motifs consisting of zigzags and geometrical figures, as well as simple compositions of horizontal lines, are typical. Rims are slightly cut, straight and roundish (*Yudin 2004*).

The vessels from Jangar were made from silts, although some pots were made from silty clay. Bases are usually flat, although some vessels have round bases, with straight walls, and a closed or complex profile. Decoration on the upper part is in the form of triangular, oval and quadrangular impressions. The decorative compositions vary (*Vybornov 2008; Koltsov 1988*).

Several major ceramic forms were identified (Pls. 4–5), which include open vessels (form 1, form 8), vessels with a complex profile (form 2.1, form 4.1, form 7) and small bowls (form 10). The volumes of vessels from the earliest sites (Kugat IV, Kulagai-si) are 0.3, 1.5 and 3 litres. Vessels from Varfolomeevka (layer 3) have volumes of 0.15, 0.3, 0.8, 1.5–2.2 and 5 litres. Later, large closed vessels were more common (form 4.2, form 12), open big vessels (form 8), and small bowls (form 11). The volumes of vessels increased in this period: for examples, at Kairshak III, vessels of 0.7, 1.2–1.5, 3, 5–6 and 13–14 litres were found. We might also suppose, due to the diameter of the upper parts, that there were larger vessels in the assemblage. The volumes of examples from Varfolomeevka (layer 2B) are 4, 6 and 18.5 litres, and from Jangar (layer 2) 0.5 and 10 litres.

Sites in the Middle Volga basin

The description of the ceramic collection from this region is based on an analysis of published materials and observations made when analysing some of the ceramic finds from various sites.

Elshanskaya pottery appeared in the second quarter of the 7th millennium calBC in the Middle Volga basin. Its origin may have been connected to the penetration of the conical ware ceramic tradition, poorly decorated, from south-western areas, from the Eastern Caspian area and Aral region, bypassing the Caspian plain (*Vasilliev, Vybornov 1988.24*). It has also been proposed that this ceramic tradition originated in this region, which was only slightly influenced by southern groups (*Kuz'mina, Lastovskii 1995.43*). Early Neolithic complexes in the southern forest-steppe of the Volga-Ural region can be found at sites located on the banks of the Samara, Sok and Tok rivers (*Morgunova 1995.14*).

Three chronological complexes can be identified in the Elshanskaya materials (Tabs. 14–15): early, middle and late (*Vasilieva, Vybornov 2012*). Vessels were predominantly made from silty clay with an admixture of organic solutions and grog (crushed pottery) (*Vasilieva 2011; Vybornov 2008.241*). Vessels were made from slabs on different moulds or arranged by sections (*Vasilieva 2011*). The 'paddle and anvil technique' was also applied. Wall thickness is 3–4mm. The coil technique with N-junction appears on some vessels from Staroelshanskaya II and Chekalino IV. Smoothing and polishing were the main types of surface treatment. Pottery was fired at low temperatures (*Vasilieva 2011*).

The early Elshanskaya complex includes undecorated pottery with thin walls, with predominantly S-profile or straight walls and conical bases. Although it might be supposed that flat bases would have been among the most ancient types (*Andreev 2012*).

The middle Elshanskaya complex includes pottery with decoration (short incisions on the rim, incised lines organised in a net, bands of impressed dots, combined with incised decoration and triangular impressions). This pottery was rarely made from silt. Vessels have round and flattened bases (*Vasilieva, Vybornov 2012*).

The late Elshanskaya complex includes vessels with thick straight walls, with a row of impressions below the rim, and predominantly flat bases (found at Krasny Gorodok, Vilovatovskoe and other sites in the northern Middle Volga basin). Pottery surface treatment included smoothing with a comb (*Vasilieva, Vybornov 2012a*).

A separate group that includes undecorated vessels with round and flat bases found at Vilovatovskoe was also attributed to Elshanskaya culture (*Vasilieva, Vybornov 2012a*).

According to the analysis of reconstructed vessel forms published in the literature, Elshanskaya pottery had estimated volumes of 0.16, 1.5–2 and 5–6 litres in the early stage. The forms of the vessels are open with an out-turned rim (Pls. 4–5), made from combined cones (form 2.1, 2.2), cylinder and ellipse (form 3), closed forms (form 5), and cylindrical ware (form 9). The pottery of the middle complex had volumes of 1, 2.5, 5–6, 10 and 40 litres. As well as bowls (form 11), the pottery forms of this stage are 3, 5, 4.1, 6, and 12. The forms of flat-bottomed ware of the final stage have the same form as the conical ware (forms 3, 5). The vessel volumes are 0.25, 0.44, 5.7, 7 and 20–23 litres. Also, small bowls with volumes of 0.11, 0.15, 0.22 and 0.45 litres (form 11) were found at Ozimenki 2, Imerka 8, Lebyazhinka IV, and Ivanovskoe.

Early Neolithic sites of the Dnepr-Dvina region

The basin of the Upper Western Dvina River is one of the first regions in the forest zone of Eastern Europe where pottery appeared at the beginning of the 7th millennium calBC. This was probably the result of migrations of small groups and/or 'migrations of ideas' (*Mazurkevich* et al. *2006*), firstly from the territory of the Lower Don and later from the Lower Volga region (*Mazurkevich 1995*). During the early Neolithic, various types of pottery appeared here, which have been defined as 'ceramic phases' which mark changes in pottery technology, morphology, and design (*Miklyaev 1995*) (Pl. 6). The analysis of pottery assemblages allows us to trace several technological, morphological and decorative traditions, the formation of which was influenced by a variety of factors. The appearance of bearers of other cultural traditions here can be traced primarily in the changes in morphology and decoration; in most cases, the technology changed little. We also deduce from our analysis that specific ceramic recipes were used for specific *chaînes opératoires*, which is typical of the pottery of this region.

Phase 'a-1' is represented by fourteen vessels from eight sites situated in the Serteysky (Serteya X (Fig. 8), XXII, XIV, XXXVI, 3–3) and Usviatsky (Romanovskoe, Cyganovy Nivy, Uzmen') micro-regions (Tab. 16). Vessels were made from lean kaolinite clay with a high content of clastic material, and sand and grog temper (dry clay). Vessels were constructed with the coiling technique, with coils set at an obtuse angle in vertical and horizontal section 0.9–2cm high (Tab. 17). Wall thickness is from 0.7–0.8cm to 1–1.1cm. Traces of a comb-like tool left in the course of surface roughening after covering the vessel with a layer of liquid clay are visible on both surfaces; they show through a thin layer of surface covering that had been polished or smoothed. The vessels are not decorated. They have a straight form, with a slightly out-turned flat edge, which is characteristic only of the pottery of this phase, and there is one example of a pointed rim.

Phase 'a'. Thirteen vessels from four sites in the Serteysky (Serteya X, 3-3; Rudnya Serteyskaya) and Usvyatsky micro-regions (Poloneika) have been discovered. They were made from clay of hydromica composition, with an admixture of sand and grog or aleurite sediments without temper, and constructed with the coiling technique (Tab. 19). Coils are at an obtuse angle in the vertical and horizontal sections, which are 0.9–2cm high. The wall thickness varies from 0.7–0.8cm to 1–1.1cm; some fragments have 0.4–0.6cm thick walls. The vessels have traces of comb on both surfaces showing through a thin layer of polished covering. The vessels were decorated with incised short lines, put in horizontal and diagonal rows. The pottery forms from this phase have pointed to round and straight rims.

Phase 'b'. Ninety-nine vessels (Tab. 20) were discovered at 22 sites located in the Serteysky (Serteya X, XII, XIX, XX, XXI, XXII, XXIV, XIV, XXVII, XXXV 3–1, 3–3, 3–4, 3–5, 3–6; Rudnya Serteyskaya), Usviatsky (Usviaty II, Uzmen', Romanovskoe, Cyganovy Nivy) and Sennitsky (Froly I, Dubokrai I) micro-regions. Several vessels were made from aleurite sediments without temper. However, most were made from two types of clay paste: aleurite and hydromica sediments (lean clay) with an admixture of sand, and grog, as well as more plastic clay with a greater percentage of grog and sand. A change in raw material sources can be noted in the pottery of phase 'b': gyttja sediments from lakes and aleurite from riverside areas were used most frequently as raw material. Furthermore, this trend was associated with the occurred river transgression and, consequently, the appearance of new sources of raw materials.

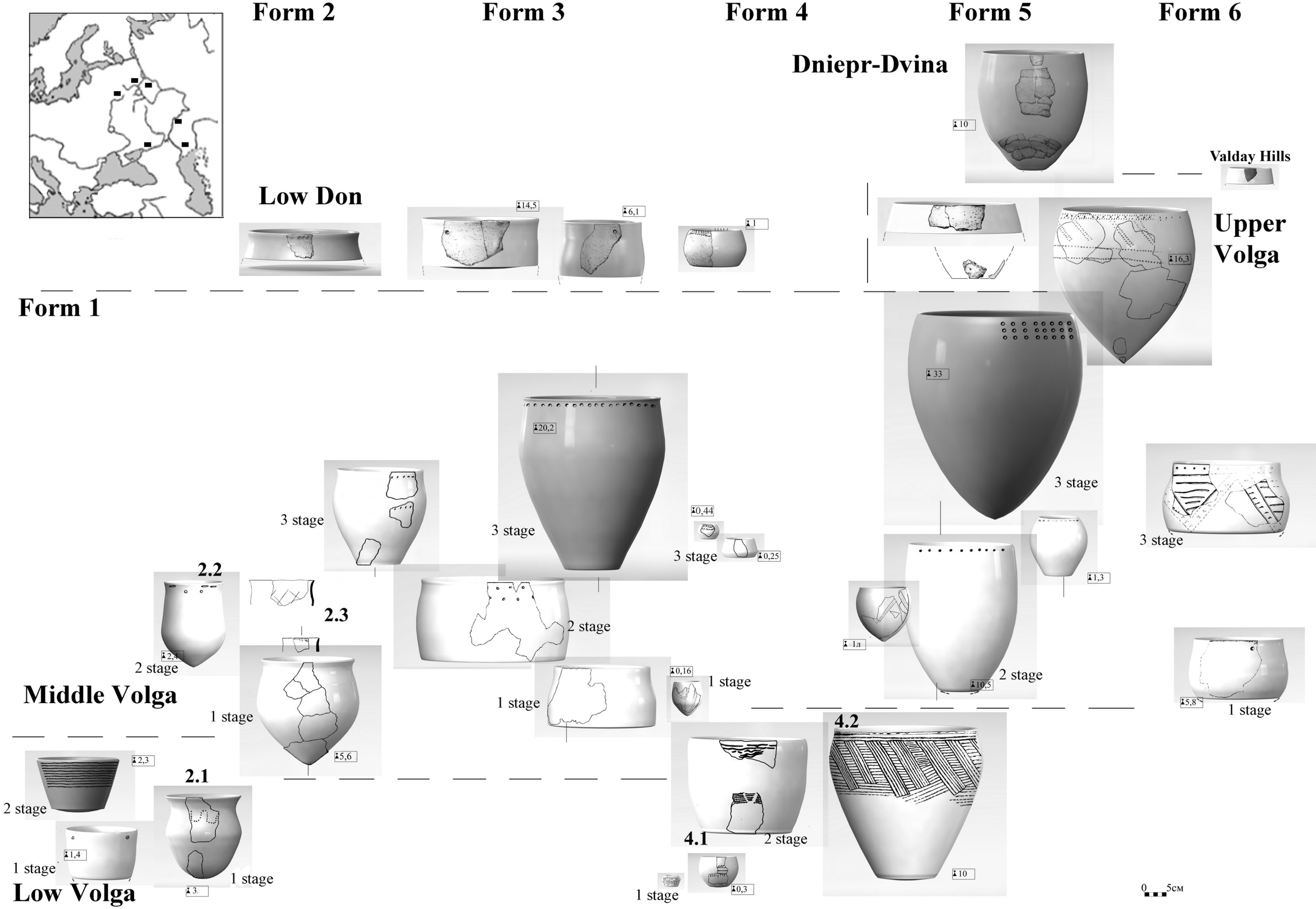
The pottery technology of phase 'b' differs little from phase 'a'. The coil technique was used, and slabs could also have been added. Surfaces were polished or smoothed. It is possible that they were coated with a thin layer of liquid clay and then roughened, as in the case of the other phases. Vessels are decorated with drop-like impressions, triangular impressions and incisions. Compositions consisting of motifs in horizontal rows predominate. There are also compositions with a rhomboid and rectangular grid system similar to nets. Vessels take different forms: open with straight, out-turned rims, as well as some with parallel walls and round-edged rims, with either conical or rounded bases.

The cultural and chronological position of the early Neolithic ceramic complex in the Dnepr-Dvina region

In 1964, and later in 1985, when this pottery was discovered, it was almost impossible to define its Early Neolithic age based on similarities. These similarities came from different, rather distant territories (as far as the north Caspian region), and the materials were from mixed artefact assemblages (*Miklyaev* et al. *1987*). In addition, radiocarbon dates were not available for most of these complexes. In recent years, with the appearance of new materials and radiocarbon dates of Early Neolithic pottery from Eastern Europe, these proposed similarities have come to be accepted by a wide scientific community.

At the beginning of the Atlantic Period, two waves of pottery traditions penetrated this region. This happened during a period of significant climatic change. This is also supported by greater anthropogenic influence on the ecosystem and palaeo-lakes in comparison with the preceding Boreal period (Mesolithic). However, the traditions of phase 'a-1' pottery did not become very widespread, whereas the traditions of phase 'a' demonstrate their further development in this region, as does the appearance of phase 'b' pottery decorated with triangular impressions.

Ceramic phases 'a' and 'a-1', which constitute the oldest pottery traditions, appeared in this region, each with their own origin. Phase 'a-1' seems to be the oldest in this region, given the typological-technological analysis and ^{14}C dates, and could have originated in the pottery of the Rakushechny Yar site. It was dated to 8380 ± 55 BP (Ua-37099) based on organic crust from a vessel fragment. A very low percentage of $\delta^{13}C$ (–33.8‰) in the charred food crusts is evidence of a hard-water reservoir effect, so the date could be older (*Fischer, Heinemeier 2003*). This pottery fragment was found in the lowest sandy layer at Serteya XIV. The sand was probably formed at the same time as that on the site at Rudnya Serteyskaya. Based on these assumptions and also analogues in Neolithic cultures in southern part of East-



*Pl. 4. Distribution of forms 1–6 in the Lower and Middle Volga, Lower Don, Dnepr-Dvina regions, Upper Volga with indication of vessel volumes. *1 Kovyliay I (after* Arheologiya Mordovskogo kraya 2008.Fig. 32*).*

ern Europe, the appearance of these materials might date to the first half of the 7th millennium BC.

The pottery of phase 'a' is similar to the early Neolithic pottery of the Northern Caspian region and to the range of cultures in the Middle and Upper Don region (*Smol'aninov 2005.Fig. 2.8*), the Middle and Upper Volga (*Vybornov* et al. *2000.186, Fig. 1; Krainov-Khotinsky 1977.Fig. 4.3, 14, 15*) and the Sura-Moksha basin. The traditions with triangular impressions first found in materials of phase 'a' continued into phase 'b'. It was probably during this time that the influence of this decoration of steppe cultures first spread in different directions along the basins of the Middle Volga, Middle Don, Upper Volga, Sursko-Moksha basin, Desna, Upper Dvina, Upper Dnepr and Valdai valley.

At the Rudnya Serteyskaya site, phase 'a' pottery was found in a layer of sand, and some of the fragments attributed to this phase were found in a layer of bluish, sandy, shell-rich gyttja (Fig. 9). The formation of the sandy layer occurred in the Boreal period, when regression occurred, and the interruption in sedimentation can be traced in the pollen diagram (*Dolukhanov* et al. *1989*).

At Serteya X, fragments of phase 'a' pottery were also found in a layer of bluish, sandy, shell-rich gyttja. There were three horizons of cultural layers divided by sterile inter-layers of bluish-grey sandy gyttja. This gyttja deposit at the bottom of the lake basin is dated to 7800+120 BP (Lu-4255) – 7510 ± 140 BP (Lu-4256), which is when sites with phase 'a' pottery existed on the lake shore. This can be proved by dates obtained from organic crust on phase 'a' pottery. The accumulation of gyttja, which covered the sand at Rudnya Serteyskaya, and on which phase 'b' artefacts from the Serteya X site were found, can be dated to 7380 ± 130 BP (Lu-4258) – 6680 ± 150 BP (Lu-4277) due to the investigation of bore-hole 63 (*Arslanov* et al. *2009*). Some of the vessels from this phase were found in layer A-2 at Serteya X, which correlates with the date obtained on wood from the same layer, 7300 ± 80 BP (Le-5260).

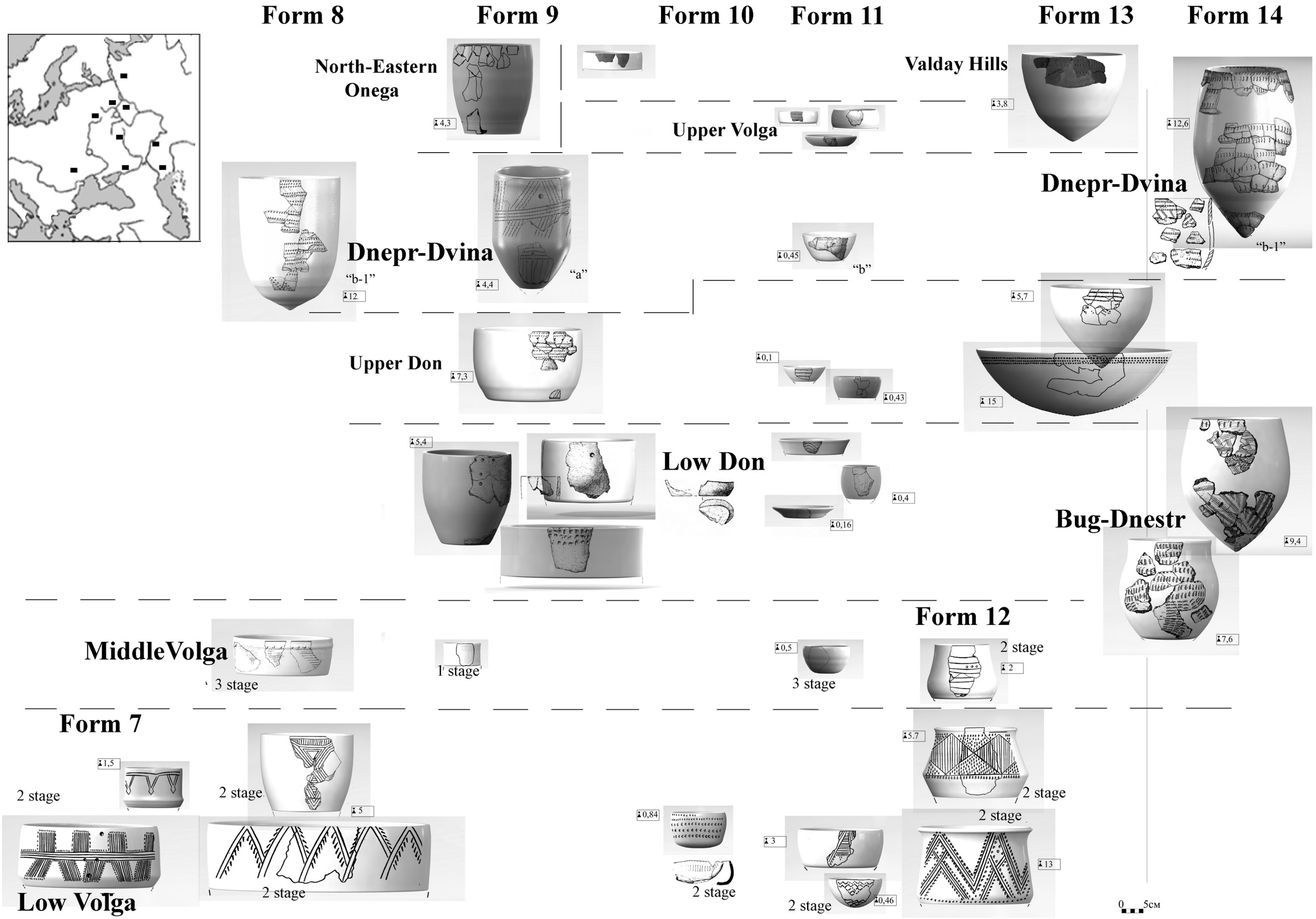
The dating of organic crust from phase 'a' pottery corresponds to 7870 ± 100 BP (Ua-37100) ($\delta^{13}C$ = –31.7‰) (Rudnya Serteyskaya site) and 7150 ± 50 BP (Ua-37098) ($\delta^{13}C$ = –31.2‰) at Serteya X, layer b. Thus, we may suppose that phase 'a' pottery may be dated to 6800–6100 calBC. Despite rather high negative values of $\delta^{13}C$, the determination of $\delta^{13}C$ alone cannot be a definite marker, which shows the older age of the sample, as some plant materials also have high negative $\delta^{13}C$ values (*Boudin* et al. *2010*).

Discussion

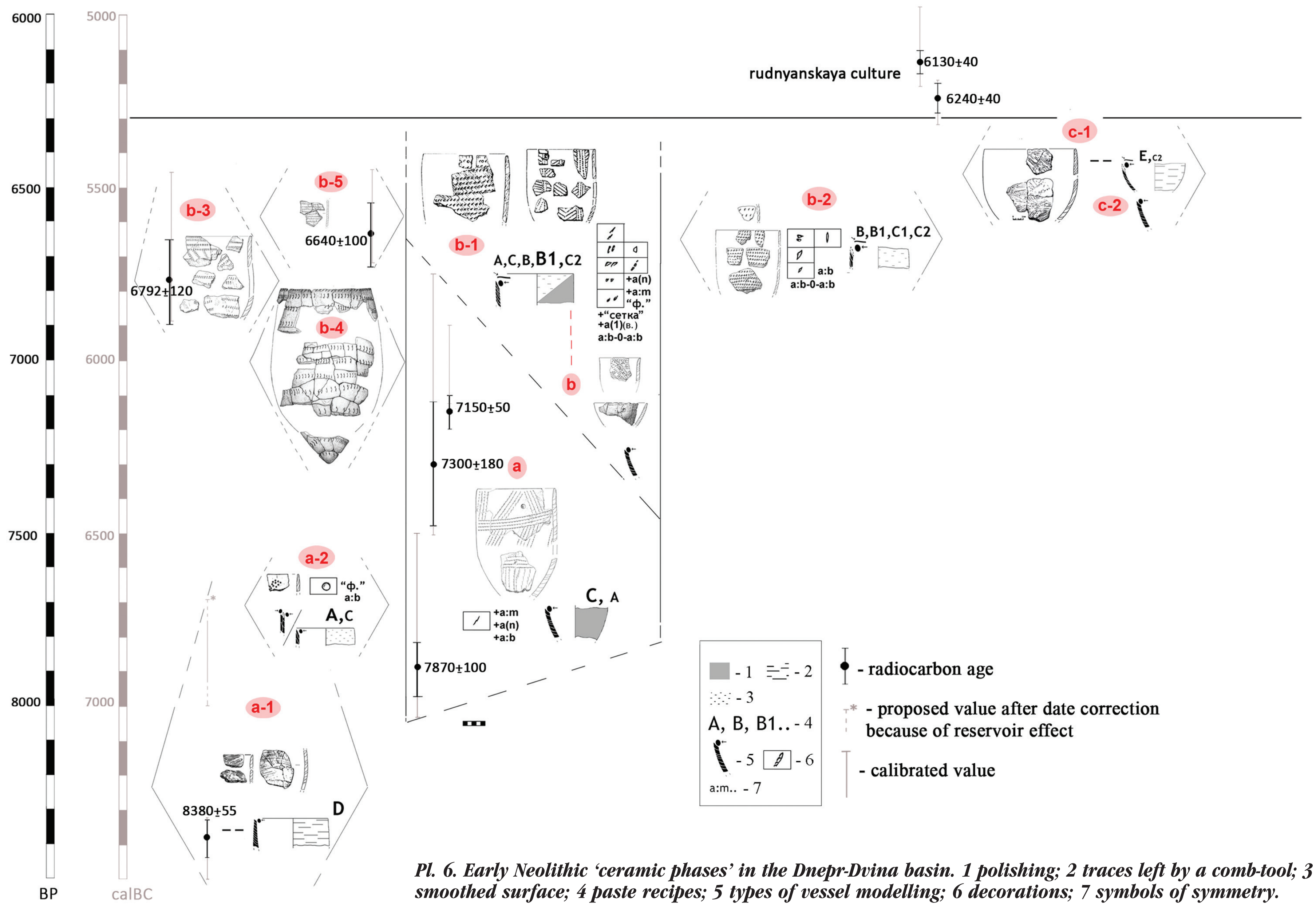
The oldest pottery traditions in Eastern Europe were distinguished on the basis of specific technological-typological characteristics and radiocarbon dates. We might also suppose the existence of intermediate sites located between the southern and northern areas with the oldest pottery assemblages, which is also evidenced by the analysis of Early Neolithic materials found in mixed complexes with pottery dating to different periods. For example, undecorated pottery similar to the Rakushechny Yar ceramic tradition was identified at sites located in the Middle Don and Upper Volga regions.

We propose two different models of Neolithisation for the territory of Eastern Europe. The first relates to the 'standard' spread of the 'package of innovations' that marked the beginning of the Neolithic period (pottery, a productive economy, architecture, stone vessels that can be found, for example, at Rakushechny Yar), and to the formation of 'primary' centres of Neolithisation in the Lower Don, Northern Caspian and Middle Volga Regions (which could have been influenced by other early Neolithic ceramic cultures with origins beyond Eastern Europe). The advantages of components of the 'Neolithic package' were not evident to tribes of hunter-gatherers, who could estimate the value of these components and choose those that suited them, namely pottery, which seemed not to be the most important part of the package. The competitive character of different economic strategies can be seen at this stage and the 'readiness' of local populations to admit definite innovations would be important. The absence of a productive economy could be explained by specific characteristics of the local natural environment: low fertility of soils, long winters and rich water and forest resources (*Dolukhanov 1996*), as well as the low population numbers in ecological niches. Later on, cultural impulses began to diffuse from those centres that have been archaeologically fixed through pottery – 'ceramic waves' – throughout Eastern Europe (*Mazurkevich* et al. *2013*).

The second model is 'septentrional' – the appearance of only one component of the 'Neolithic package' – pottery, and the formation of 'secondary' ceramic centres. It is important to note that the appearance of pottery-making skills, their dispersed distribution, and further expansion and development in



*Pl. 5. Distribution of forms 7–14 in the Lower and Middle Volga, Lower Don, Dnepr-Dvina regions, Valday Hills, Upper Don, Upper Don, North-Eastern Lake Onega, the Bug-Dnestr basin with indication of vessel volumes. *1 Berezovaya slobodka II–III (after* Ivanisheva, Ivanishev 2006.Fig. 4*);*2 Plautino 2 (after* Surkov 2007.Fig. 37*); *3 Karamyshevo 9 (after* Smolijaninov 2005.Fig. 1–2, 4*); *4 Shurivici-Porig (after* Gaskevich 2010.Fig. 3,4*).*



Pl. 6. Early Neolithic 'ceramic phases' in the Dnepr-Dvina basin. 1 polishing; 2 traces left by a comb-tool; 3 smoothed surface; 4 paste recipes; 5 types of vessel modelling; 6 decorations; 7 symbols of symmetry.

Eastern Europe are *two different processes*. We suggest that it is necessary to divide the process of 'Neolithic package' diffusion and formation of the oldest ceramic assemblages (related to the first model) and further distribution of pottery traditions in the Mesolithic milieu from other, *secondary*, centres situated in forest and steppe-forest zone. The end of the development of the first Early Neolithic traditions can be regarded as the end of the early Neolithic that happened in different regions at different times.

The appearance of pottery should not be regarded as merely a simple feature. The fact that similar pottery traditions were distributed over a great area in a short period probably had definite reasons. Some techniques, artefacts, materials and designs appear to be trans-cultural and distributed in other regions, whereas the zone of distribution of other items is limited to their place of origin (see *Martineau 2000. 226*). The preciseness in copying pottery technology, choice of raw materials, design and forms of vessels suggest the conservation of initial traditions in the milieu of local populations over a long period, which indicates that pottery became a trans-cultural phenomenon. One of the reasons for this could be the idea of prestige and/or sacred significance of this first ceramic ware. There might be other reasons why pottery could become an object of distribution/exchange, along with a utilitarian function: the use of pottery in feasts (*Heron, Craig 2008*), the high aesthetic and function of certain vessels, their content (*Moore 1995.47*) and prestigious character (*Hayden 1998*) *etc*.

Several facts could support the hypothesis that pottery and/or the idea of pottery making was distributed over great distances in various regions, and thus be additional evidence of the existence of 'primary' and 'secondary' centres:

❶ the existence of vessels made from raw materials that come from deposits in other parts of a microregion or from other regions, which may be evidence that they were transported over various distances (*Mazurkevich* et al. *2013*);
❷ the similarity of decorative, technological and morphological pottery traditions found in different areas;
❸ the existence of particular vessels that differed in technological, morphological and decorative features from the pottery assemblage of a site. Such 'imports' can be found in materials from the Northern Caspian (Kairshak III), the Upper Volga (Sakhtysh IIa) and the Dnepr-Dvina regions (Uzmen').

'Primary' centres became areas from where pottery-making traditions spread to other territories. One of these centres was in the Lower Don River in the first quarter of the 7th millennium calBC. Based on the described evidence, this centre could be regarded as an initial area for the formation of Early Neolithic cultures in Eastern Europe (*Mazurkevich, Dolbunova 2012; Mazurkevich* et al. *2013*). In the process of distribution further to the north, this 'Neolithic package' lost most of its constituents, and the only indicator of a new epoch that is archaeologically visible is pottery with definite technological, morphological and decorative features. Similar *chaînes opératoires* and their modifications were distributed in areas in the Dnepr-Dvina region (phase 'a-1'), Upper Volga region (Zamostie 2 is an example, see (*Mazurkevich* et al. *2013a*), Sakhtysh sites, type 4 and 7), the Upper Dnepr region, and Valday region (type 1). Similar vessels can be also found in the Middle and Lower Don regions. However, this pottery did not become the only basis for following the formation of Early Neolithic complexes, as at the Raksuhechny Yar site.

The tradition of pottery decorated with triangular impressions, individual linked impressions and lines first appeared in the basin of the Lower Volga and Northern Caspian in the first quarter of the 7th millennium calBC (*Vybornov 2008*). The early pottery in the Lower Volga region is accompanied by a stone industry, which, according to researchers of this region, have Mesolithic traits (*Vybornov 2008*) and could have been connected with the first stage in the distribution of ceramic traditions. This conservation of Mesolithic flint traditions in complexes accompanying the first pottery can be also found in different areas of Western and Eastern Europe (*Lozovsky 2001; Polkovnikova 2003; Nikitin 2013.26; Sinyk 1986; Robinson* et al. *2013*), although some researchers also outline the possibility that different complexes were mechanically mixed (*Viskalin 2013*). Early Neolithic materials in the Northern Caspian have analogues in Neolithic material from the Caucasus, Lower Volga and Azov areas, and the central Asian Neolithic (*Vybornov 2008*).

Cultural impulses from this centre can be traced over a vast territory of the forest-steppe and forest zones of Eastern Europe (*Miklyaev* et al. *1987; Mazurkevich 1995*). In a neighbouring region, at Rakushechny Yar, a few vessels decorated with triangular impressions have been found deposited with undecorated pottery in lower layers (23, 21–11). Also, there were fragments of pots with typical North Caspian decoration, consisting of a triangular composition filled by small triangular impressions (layer 19; Tab. 7.9), and a pot decorated with triangular impressions in a drawn technique with single triangular impressions (layer 11).

A small number of 'archaic' items decorated with very specific triangular impressions or in drawn technique can be found in the Dnepr-Dvina region (phases 'a' and 'b'), Upper Dnepr region, Middle and Upper Volga, and Don areas, and the Desna River, and Valday region. The North Caspian pottery traditions appeared in the forest-steppe and forest regions, were conserved and developed further independently from the 'primary' centre and did not change significantly for several hundred years. In contrast, an endogenous development of pottery occurred in the 'primary' centres, evolving more complex forms and decorations as well as changes in technology.

Another early ceramic complex at sites on the Middle Volga River – in the area of Elshanskaya culture distribution – can be dated to the first quarter of the 7th millennium calBC. The formation of the Early Neolithic complex of the forest-steppe zone in the Volga basin can be connected to the central Asian region (*Andreev 2014.13*). The slab technique and 'S' pottery techniques, the use of certain raw materials, the complex forms of vessels, and decoration with impressions below the rim are typical features. A mixture of organic fluid and grog (crushed pottery) are among the most typical admixtures in the paste recipes (*Vasilieva, Vybornov 2014.38*), and also for pottery from other areas that might be analogical to Elshanskaya pottery. The use of organic fluid is also found in pottery from the North Caspian basin (*Vasilieva 1999.84*). Traces of organic fluid where the coils are joined, as well as a grog temper, can be found in pastes of pottery from sites located on the Sukhona River (*Ivanischeva 2009.278*). Grog temper was also used in pottery of the Elshanskaya-like culture in the Sura-Moksha basin (*Vasilieva, Vybornov 2014.38*) and in pottery from the Koshkinskaya site on the right bank of the Vyatka River (*Gusentsova 2014.91*). Pottery in the Dnepr-Dvina basin was made with another type of grog (crushed clay), which was first used in vessels from phase 'a-1'.

Some types of Elshanskaya culture are similar to pottery from Rakushechny Yar (form 2), made with the 'S' technique with an admixture of grog (only in this case, crushed pottery was used). Also, the straight walls and roundish or pointed rims of the earliest stage of Elshanskaya culture are similar to forms 1 and 5 from Rakushechny Yar (Pl. 1).

The distribution of sites with Early Neolithic pottery reveals particularities in the distribution of different types throughout Eastern Europe. The distribution map of sites where pottery appeared in the first half of the 7th millennium calBC shows a small number of such regions with the oldest dates (Map 1). We might suppose that such pottery would be typologically distinguishable from the later mixed pottery traditions of different regions. However, its quantity and the number of sites with these types of pottery would not be the same as in the following periods. A considerable increase in radiocarbon dates of Early Neolithic pottery can be seen in the period from 6500 to 5500/5300 calBC (Map 2). The absence of radiocarbon dates for certain types of pottery did not allow an analysis of their distribution into more narrow chronological periods within this long period. Also, we might suppose the co-existence of sites with pottery of different origin. For example, in the Upper Don basin, several groups of sites with different pottery types have been found: sites with Karamyshevo-type pottery, Upper Volga culture, Elshanskaya culture and Middle Don culture (*Smolianinov 2009*).

Could we estimate the speed of this process?

It is assumed that the process of Neolithisation was a single event. However, it is now clear that this process could have taken a long time, such as, for example, in north-western Turkey, where this process took 2000 years from when elements of the 'Neolithic package' first appeared. It might be proposed that different forms of Neolithisation occurred simultaneously in different parts of this region (*Özdoğan 2013.190–191*). An interesting scenario has been offered of the population of the coastal regions of north-western Turkey (*Özdoğan 2013.195*), where Mesolithic groups adopted major components of the 'Neolithic package' brought by newcomers: pottery, a productive economy and definite categories of goods with a prestigious and/or high-status role. However, the habitual way of life continued: they lived in huts covered with clay, had a complex economy with hunter-gathering activities, and different types of burial. The economy practised at some of the sites in Anatolia in the 7th millennium calBC was also complex, based on a combination of cattle husbandry, hunting, fishing and collecting shellfish (*Özdoğan 2013.174*). Shellfish occupied a considerable place in ancient diets at some sites, where specialised storage pits have been found (*Özdoğan 2013.182*). Similar accumulations and pits with shellfish were also found at the Rakushechny Yar (*Belanovskaya 1995*) and Surskaya sites (*Telegin 1996.44*).

The distribution of pottery traditions from the three centres described above, according to ^{14}C dates (*Timofeev* et al. *2004*), occurred in a short period along the main water routes of Eastern Europe flowing in a meridional direction, while at first, rivers flowing in latitudinal directions formed natural barriers to the distribution of these traditions. Small groups moved and settled in different areas, the traces of which are difficult to see archaeologically, bringing innovations into the Mesolithic milieu – parts of the 'Neolithic package' – of which pottery became one of the most frequent and well accepted.

According to ethnographic data, a widespread uniformity of pottery styles must exist in communities of hunters-gatherers due to the movement of individuals between groups (*Hodder 1982*). This process may be termed a 'migration of ideas' in cases when physical migration is virtually undetectable. Established in a new place, these 'centres' of innovation began to be 'secondary' centres from which ceramic traditions began to diffuse and develop gradually among people in the surrounding regions. Thus, in the Dnepr-Dvina region, this process is reflected in the appearance of Rakushechny Yar pottery traditions in the first stage, which did not continue and were not adopted by local populations. Triangular impressions as decorative traditions and techniques of coil modelling with the use of polishing and smoothing with a comb-like tool from the Lower Volga – North Caspian centre then appeared here. This tradition was conserved in the local cultural milieu and became widespread.

One of the factors that could have influenced the distribution of pottery traditions in specific regions might be climatic changes accompanied by climate cooling and aridisation, which occurred in the second half of the 7th millennium calBC over a wide area of Europe (*Weninger* et al. *2009; Spiridonova, Aleshinskaya 1999*), including the steppe and forest-steppe of Eastern Europe. This could have led to the forest zone with its huge forests and rich food resources attracting people from more southern areas (*Arslanov* et al. *2009; Mazurkevich 1995*).

The study of the morphology of the earliest pottery from Eastern Europe shows the existence of vessels with predominantly flat and round bases during the first stage in the Rakushechny Yar assemblage, as well as at sites in the Lower Volga, the first stage of Upper Volga culture, and also, probably, in the materials from the Middle Volga River, north-eastern Lake Onega and the Dnepr-Dvina region. Vessels with a conical base spread later and were typical of the forest zone, but much less of forest-steppe and steppe zones. This testifies to the existence of various types of vessels among hunter-gatherer groups in Eastern Europe in the first stages. While richly decorated conical vessels, which are believed to accompany hunter-gatherer communities, were not predominant, they appeared much later in Eastern Europe (see for example, *Budja 2013; Piezonka 2014.272*). The oldest vessels were usually made from a clay paste without temper or from sandy paste without organic temper, which has also been described for some hunter-gatherers of other areas (*Skibo* et al. *1989.140*). On the other hand, conical vessels that appeared in different parts of Europe are often supposed to be of Eastern European origin, such as in the formation of the Ertebølle complex in Northern Europe (*Gronenborn 2009.541*). However, based on our own observations of the earliest Eastern European pottery and the Ertebølle complex, and also based on publications (*i.e. Jennbert 2011; Glykou 2011*), we conclude that these complexes are not directly related, since there are great differences in pottery technologies and forms of the vessels from both these complexes. Conical bases were highly varied in terms of technology and morphology, and the problem of their appearance and development needs to be investigated.

We suppose that the appearance of the oldest pottery in Eastern Europe might have been a much more complicated process than simply some gradual distribution of conical vessels among communities of hunter-gatherers. Pottery was included in the cultural system of local societies from the very beginning, becoming a symbol/sign, where it could have played different roles.

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Appendix

Neolithic sites with Samchinskaya-type pottery: ***1 Tetereuka Noue XV; 2 Soroka I, layer 1, hor. 'a'; 3 Soroka V; 4 Cykynivka; 5 Girzheve; 6 Pechera I; 7 Korzhiv; 8 Samchinci I; 9 Samchinci II; 10 Shurivci-Porig; 11 Shimanovs'ke II; 12 Sokil'ci I, II, VI; 13 Zyan'kivci II; 14 Glyns'ke I; 15 Ladyzhin II; 16 Ladyzhin I; 17 Myt'kiv Ostriv; 18 Baz'kiv Ostriv; 19 Zavallya; 20 Zhakchik; 21 Mel'nychna Krucha; 22 Savran'; 23 Pugach 2; 24 Pugach 1; 25 Gard 4; 26 Gard 3; 27 Korma 1B; 28 Krushnyky; 29 Gyrlo Gnylopyati; 30 Lazarivka; 31 Zavalivka; 32 Borodyanka 3V; 33 Hodosivka; 34 Romankiv; 35 Mutyhy; 36 Dobryanka 1; 37 Stril'cha Skelya; 38 Kizlevyi V; 39 Semenivka 1; 40 Zlyvki; 41 Zelena Gornycya 6; 42 Zelena Gornycya 5; 43 Tuba 2; 44 Starobil's'k.***

Sites in the Lower Don and Northern Azov areas: ***45 Matveev kurgan; 46 Rakushechny Yar.***

Lower Volga River sites. Kairshak-tenteksorskaya group: ***49, 51 Kugat IV, Kulagai-si (I stage); 50 Kairshak III (II etap); Dzhangaro-varfolomeevskaya group: 47 Tu-Buzgu-Huduk I (I stage); 48 Dzhangar (2, 3 layers), 52 Varfolomeevka (3 layer) (II stage).***

Site of Strumel': ***197 Gastyatin type.***

Sites in the Lower Dnepr basin (surskaya culture, I stage): ***194 Surskoi Island; 195 Kodachek Island; 196 Vinogradnyi Island.***

Sites in the Middle Volga basin (Elshanskaya culture, middle Volga culture), Suro-Moksha basin: ***53 Maksimovskaya; 54 Vilovatovskaya; 55 II Staro-Elshanskaya; 56 Ivanovskaya; 57 Krasnyi Yar VII; 58 Lebyazhinka I; 59 Lebyazhinka IV; 60 Il'inskaya; 61 Nizhnyaya Orlyanka II; 62 Chekalino IV; 63 Krasnyi Gorodok; 64 Lugovoe III; 65 Ozimenki I, II; 66 Imerka 8; 67 Utyuzh I; 68 Lake V'yunovo I; 69 Lesnoe-Nikol'skoe III; 70 IV Tetyushskaya; 71 II Sherbet'skaya; 162 Gorodok I; 163 Vadovskie selisha; 164 Starodevich'e 1; 165 Russkoe Maskino 1; 166 Mashkino 1, 3; 167 Kovylyai 1, 3; 168 Volgapino; 169 Andreevka 1; 170 Krasnyi Yar; 171 Potodeevo; 172 Ekaterinovka 2; 173 Bessonovka 3; 174 Grabovo 3; 175 Podlesnoe 3, 4, 5, 7, 8; Bessonovka 1, 2; 176 Penzenskie stoyanki (Ernya, Kalashnyi zaton, Belyi omut); 177 Ust'-Kadada 1; 178 Inderka.***

Sites of Volgo-Kama culture: ***72 Tarhan I; 73 Koshkinskaya; 74 Kyilud II; 75 Chernushka; 76 Chernushka; 77 Levshinskaya; 78 Chashkinskoe ozero VI, VIII.***

Sites of Khoper, Middle Don basin: ***79 Plautino 1,2,4; 80 Rusanovo; 81 Borisoglebskie 1–3, Lovchak 7–8, Strel'bishe 4–5, Stela; 82 Kozlinovskaya; 83 Staroanninskaya; 84 Kopanishe 1, 2; 86 Monastyrskaya; 87 Droniha; 88 Cherkasskaya; 89 Inyasevo; 90 Shapkinskie stoyanki; 91 Uvarovo; 92 Mozharovka; 93 Kipec.***

Sites in the Upper Don basin: ***85 Yamnoe; 94 Ust'e reki Izlegoshi-2, 3; 95 Karamyshevo 1, 5, 9, 19, m. Krasnyi Bugor; 96 Yarlukovskaya protoka, Rybnoe ozero-2, 1, Punkt 207. site 'Natasha'; 97 Lake Lipeckoe; 98 Studenovka 3; 99 Kulikovka 2, Berezovka 4B, Monastyrshina 2A; 100 Vasil'evskii kordon-1,3,5,7, 16, Podzorovo-1,2; 101 Dobroe-1, site 87: Lake Bogorodickoe, Bogorodickoe 1; 102 site 1. Shlyuz 1, p.97 v urochishe Gorodishe, site 382, 380, 100, Sokol'skii most 8, 9, 11, 3, pos. u pamyatnika Narodovol'cam; 103 settlement 2 (site 105), 6 (site 109) near Gudovskogo kordona, site 8 in Malininovsky district, site 1 near Pervomaiskoe lesnichestva, site 343, site 5, site 2 near village of Krutogor'e; 104 site 3 at the mouth of the Borovica River, site 259 (site 1 near Lake Krugloe), site 346 (site 6 near Lake Lyubovickogo), site 340 (site 7 near Barkovskii); 105 Savickoe 1; 106 location near the village of Preobrazhenovka, Buhovoe 9, 10, Glinishe, Torbeevo XV, XVII, Kriveckoe Lesnichestvo 1; 107 Kurino 1; 108 Universitetskaya 1, 3, Chertovickaya, Chernavskaya, st.Yaht-klub, Shilovskaya 1, Otrozhka; 109 Zamyatino 10; 110 Krivobor'e 2; 111 Ksizovo 6.***

Sites of Desninskaya culture: ***112 Zherenskaya protoka; 113 Zhereno III; 114 Vithovka I, III; 115 Chernetovo I; 200 Krasnoe V, VI, X.***

Sites in the Upper Dnepr: ***116 Romanovichi; 117 Strelice; 118 Borok; 119 Zaval'e; 120 Katyn' 2; 121 Katyn' 3; 122 Katyn' 1, st. 21, 6; 198 location at Kasplya lake; 199 Zaozer'e; 201 Lavki.***

Sites of Dnepr-Dvina basin: ***123 sites in the Serteysky micro-region; 124 sites of the Usviatsky micro-region; 125 sites in the Sennitsky micro-region.***

Sites of the early stage of Upper Volga culture (including Volgo-Oka culture sites): ***126 Ozerki 5, sloi III; 127 Al'ba I, III; 128 Davydkovskaya; 129 Zamost'e 2; 130 Yazykovo I; 131 Kuhmar' 1; 132 Pol'co; 133 Belivo II; 134 Maslovo boloto 8; 135 Shadrino IV; 136 Alekseevskoe I; 137 Sahtysh I, II, VIII; 138 Ivanovskoe III, V, VII; 139 Okaemovo 3, 5,18; 140 Varos; 179 Somino II; 180 Kosyachevo I, II; 181 Zav'yalka 1; 182 Bobrinka II; 183 Strelka I; 184 Malaya Lamna; 185 Volosovo; 186 Davydkovo; 187 Zhabki III; 188 Teren'kovo III; 189 Korenec I; 190 Seima I.***

Sites of Valdaiskaya culture (with materials of Kotschischensky-type pottery): ***141 Kotchishe 1,2; 142 Shepochnik; 143 Dubovec (Peno 3); 161 Zabel'e; 191 Zales'e I, II, Nizhnie Koticy 5, Zehnovo III, IV, Lanino I; 192 island Koshelev; 193 Zabolot'e II.***

Sites in north-east Europe (sites of the type Dutovo I, Chernaya Vad'ya, chernoborskaya group, Kama culture sites located in the basin of the Sukhona River and Lake Onega): ***144 Tudozero V; 145 Berezovaya slobodka II–III; 146 Prilukskaya; 147 Yavron'ga I; 148 Chernaya Vad'ya; 149 Chudgudor'yag, En'ty V; 150 Pezmog IV; 151 Seb'yag; 152 Ust'-Kulom I; 153 Kochmas B; 154 Niremka I, s.6; 155 group of Vis sites; 156 Dutovo I; 157 Chernoborskaya III; 158 Zubovo; 159 Koneshel'e; 160 Timoshel'e VI.***

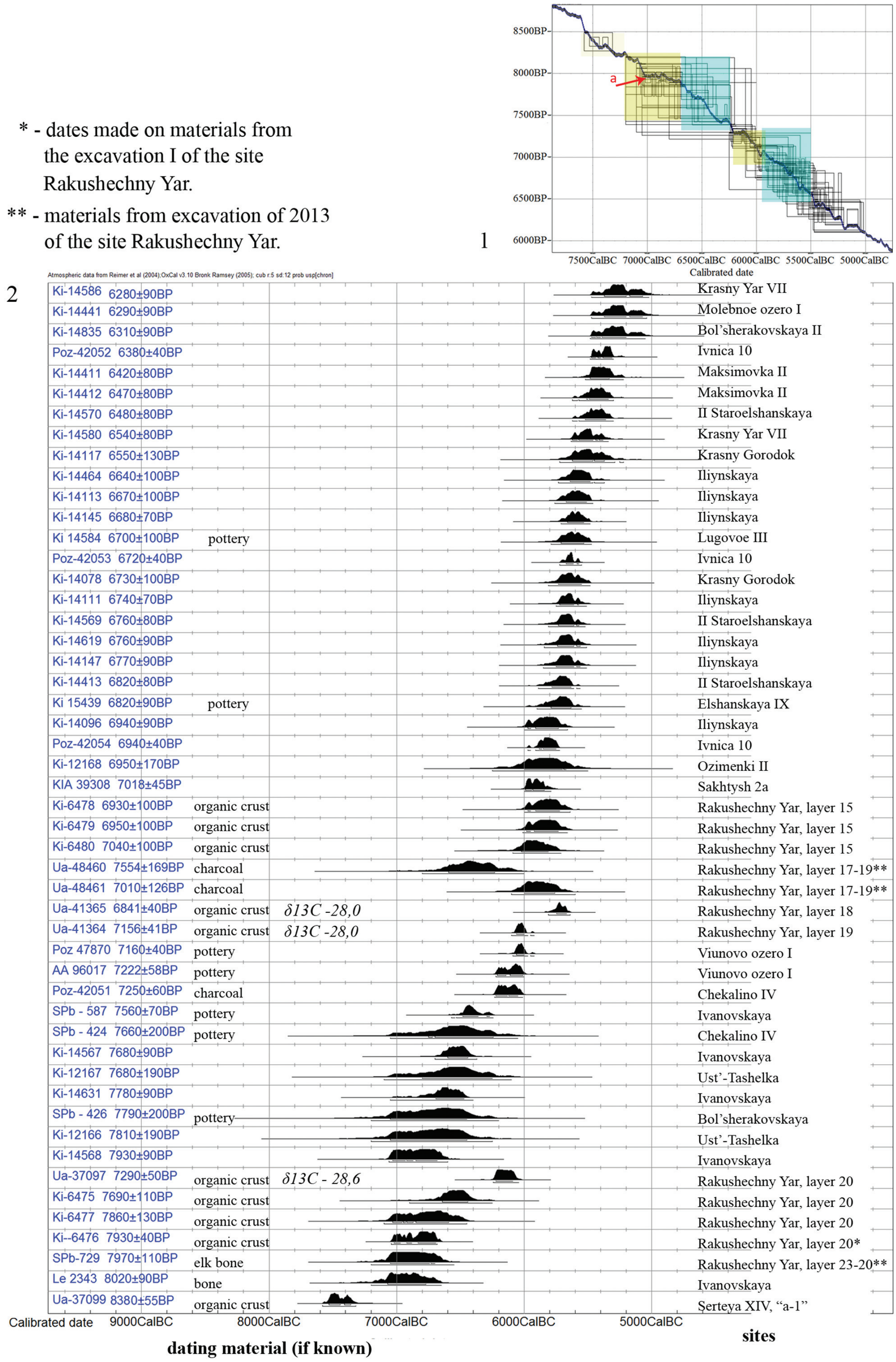
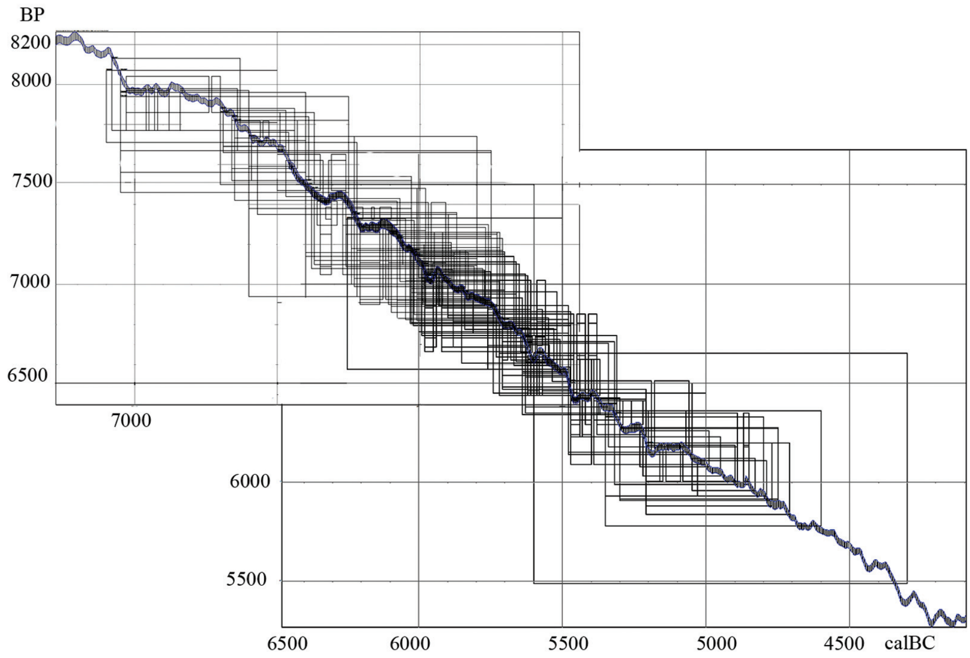
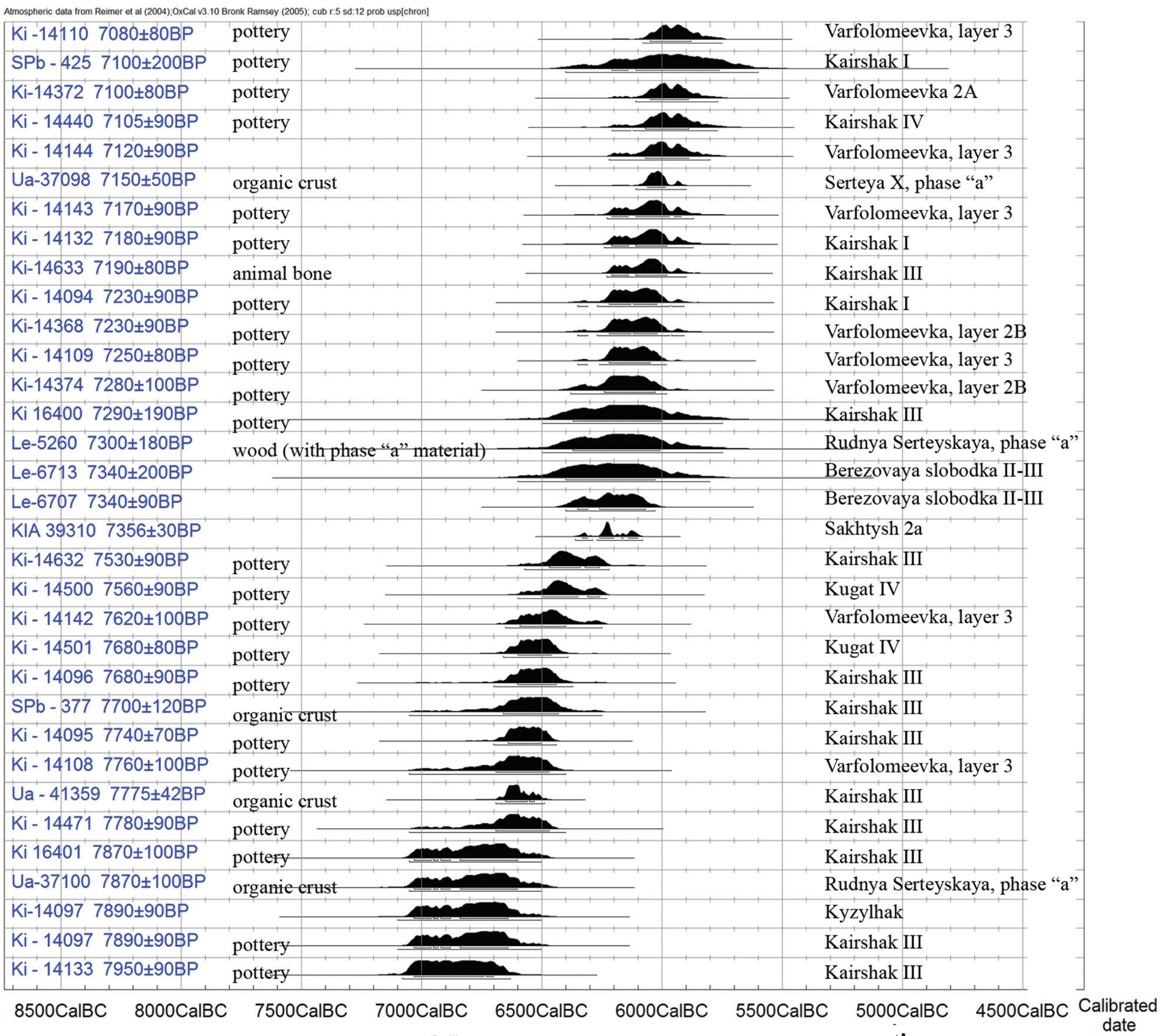


Fig. 4. Histogram (1) and a list of calibrated values (2) (made in OxCal 3.10 (*Bronk Ramsey 2005*) of radiocarbon dates of sites with undecorated pottery (dates of figures 2, 4, 5 – after* Vybornov 2008; Vybornov *et al.* 2008; 2012; 2013; Ivanisheva 2009; Hartz *et al.* 2012; Smol'yaninov, Surkov 2014; Tovkailo 2010; Gaskevich 2010; Karmanov 2008; Zaiceva *et al.* 2014; Tsybriy *et al.* 2014*) and indication of a 'calibration plateau' 8000–7500 BP (1a).

1


BP
8200
8000
7500
7000
6500
7000
6000
5500
6500
6000
5500
5000
4500
calBC

2


Atmospheric data from Reimer et al (2004);OxCal v3.10 Bronk Ramsey (2005); cub r:5 sd:12 prob usp[chron]
Ki -14110 7080±80BP pottery Varfolomeevka, layer 3
SPb - 425 7100±200BP pottery Kairshak I
Ki-14372 7100±80BP pottery Varfolomeevka 2A
Ki - 14440 7105±90BP pottery Kairshak IV
Ki - 14144 7120±90BP Varfolomeevka, layer 3
Ua-37098 7150±50BP organic crust Serteya X, phase "a"
Ki - 14143 7170±90BP pottery Varfolomeevka, layer 3
Ki - 14132 7180±90BP pottery Kairshak I
Ki-14633 7190±80BP animal bone Kairshak III
Ki - 14094 7230±90BP pottery Kairshak I
Ki-14368 7230±90BP pottery Varfolomeevka, layer 2B
Ki - 14109 7250±80BP pottery Varfolomeevka, layer 3
Ki-14374 7280±100BP pottery Varfolomeevka, layer 2B
Ki 16400 7290±190BP pottery Kairshak III
Le-5260 7300±180BP wood (with phase "a" material) Rudnya Serteyskaya, phase "a"
Le-6713 7340±200BP Berezovaya slobodka II-III
Le-6707 7340±90BP Berezovaya slobodka II-III
KIA 39310 7356±30BP Sakhtysh 2a
Ki-14632 7530±90BP pottery Kairshak III
Ki - 14500 7560±90BP pottery Kugat IV
Ki - 14142 7620±100BP pottery Varfolomeevka, layer 3
Ki - 14501 7680±80BP pottery Kugat IV
Ki - 14096 7680±90BP pottery Kairshak III
SPb - 377 7700±120BP organic crust Kairshak III
Ki - 14095 7740±70BP pottery Kairshak III
Ki - 14108 7760±100BP pottery Varfolomeevka, layer 3
Ua - 41359 7775±42BP organic crust Kairshak III
Ki - 14471 7780±90BP pottery Kairshak III
Ki 16401 7870±100BP pottery Kairshak III
Ua-37100 7870±100BP organic crust Rudnya Serteyskaya, phase "a"
Ki-14097 7890±90BP Kyzylhak
Ki - 14097 7890±90BP pottery Kairshak III
Ki - 14133 7950±90BP pottery Kairshak III
8500CalBC 8000CalBC 7500CalBC 7000CalBC 6500CalBC 6000CalBC 5500CalBC 5000CalBC 4500CalBC
Calibrated date

continue

2

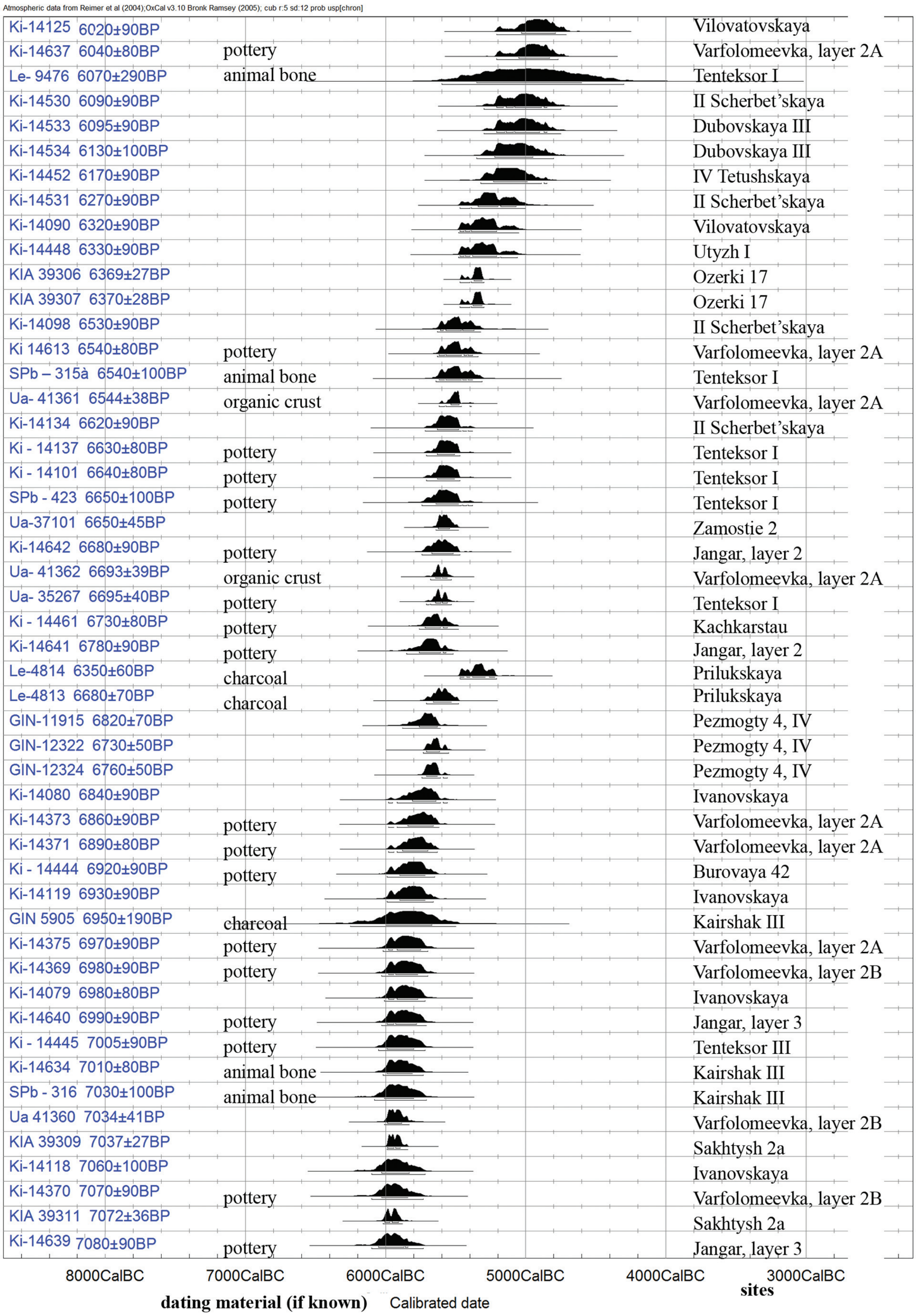


Fig. 5. Histogram (1) and calibrated values (2) of radiocarbon dates (made in OxCal 3.10 (*Bronk Ramsey 2005*) from sites with pottery decorated by triangular impressions, drawn and oval impressions.

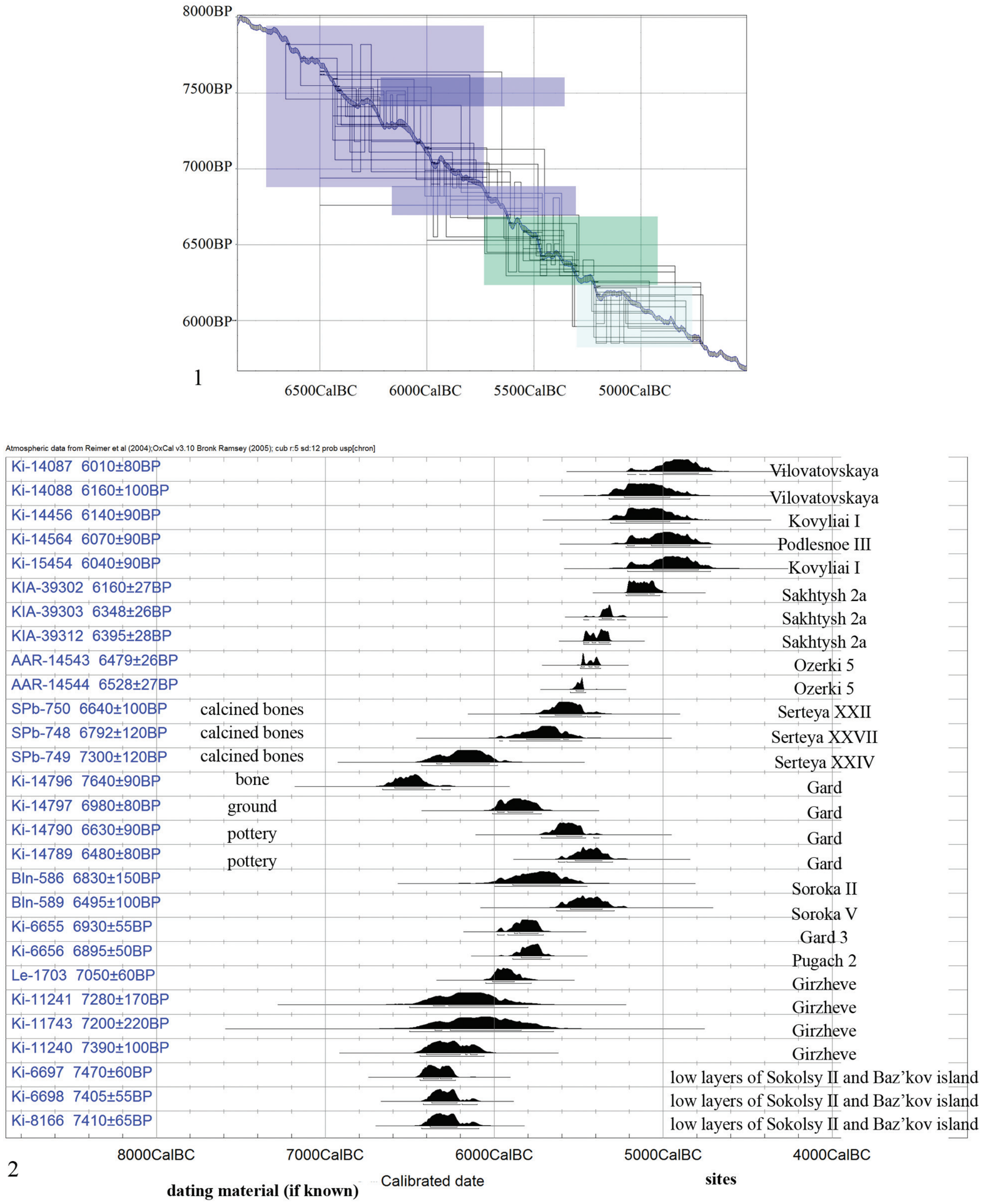


Fig. 6. Histogram (1) and calibrated values (2) of radiocarbon dates (made in OxCal 3.10 (*Bronk Ramsey 2005*) from sites with pottery decorated with impressions made by various comb-tools.

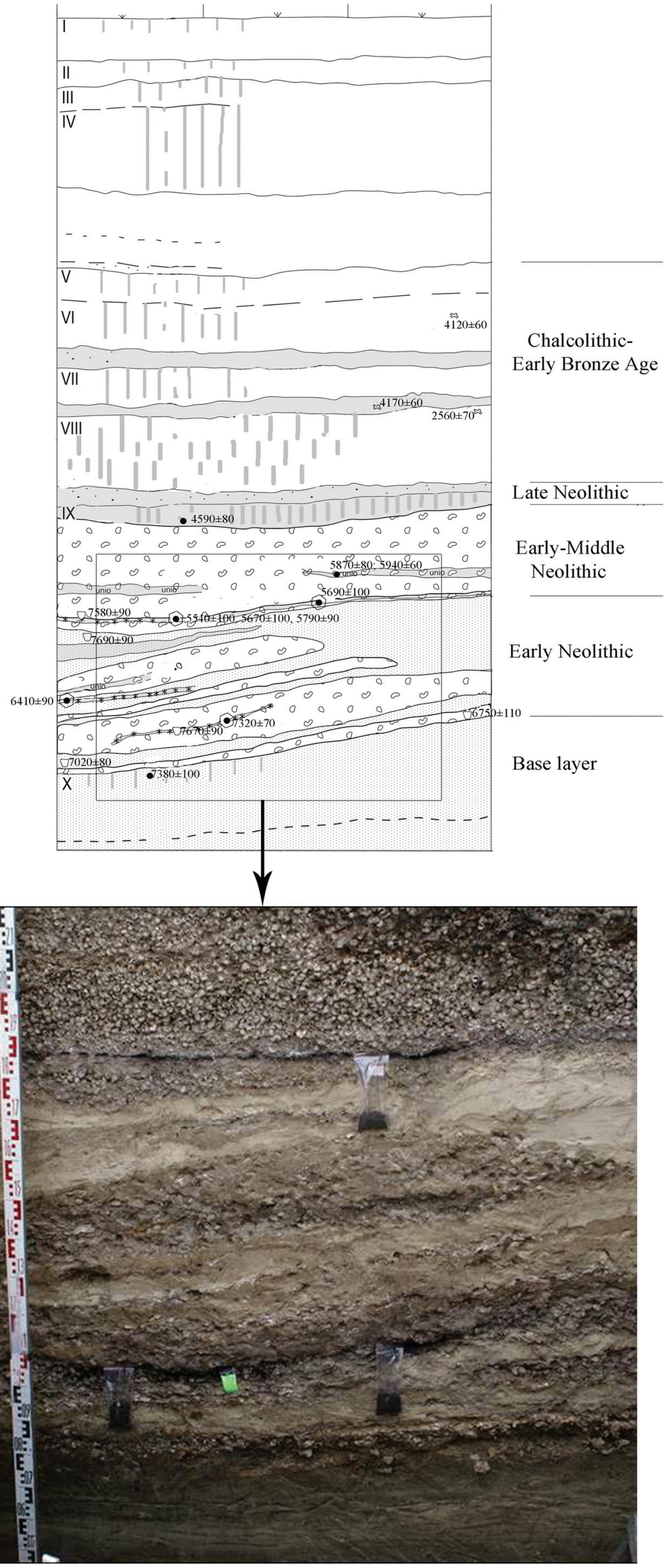


Fig. 7. Stratigraphy of the 2008 test-pit (after* Aleksandrovsky *et al.* 2009.Fig. 3*) with date distributions in the layers, and photograph of the low part of the 2008 test-pit (photo: A. Mazurkevich).

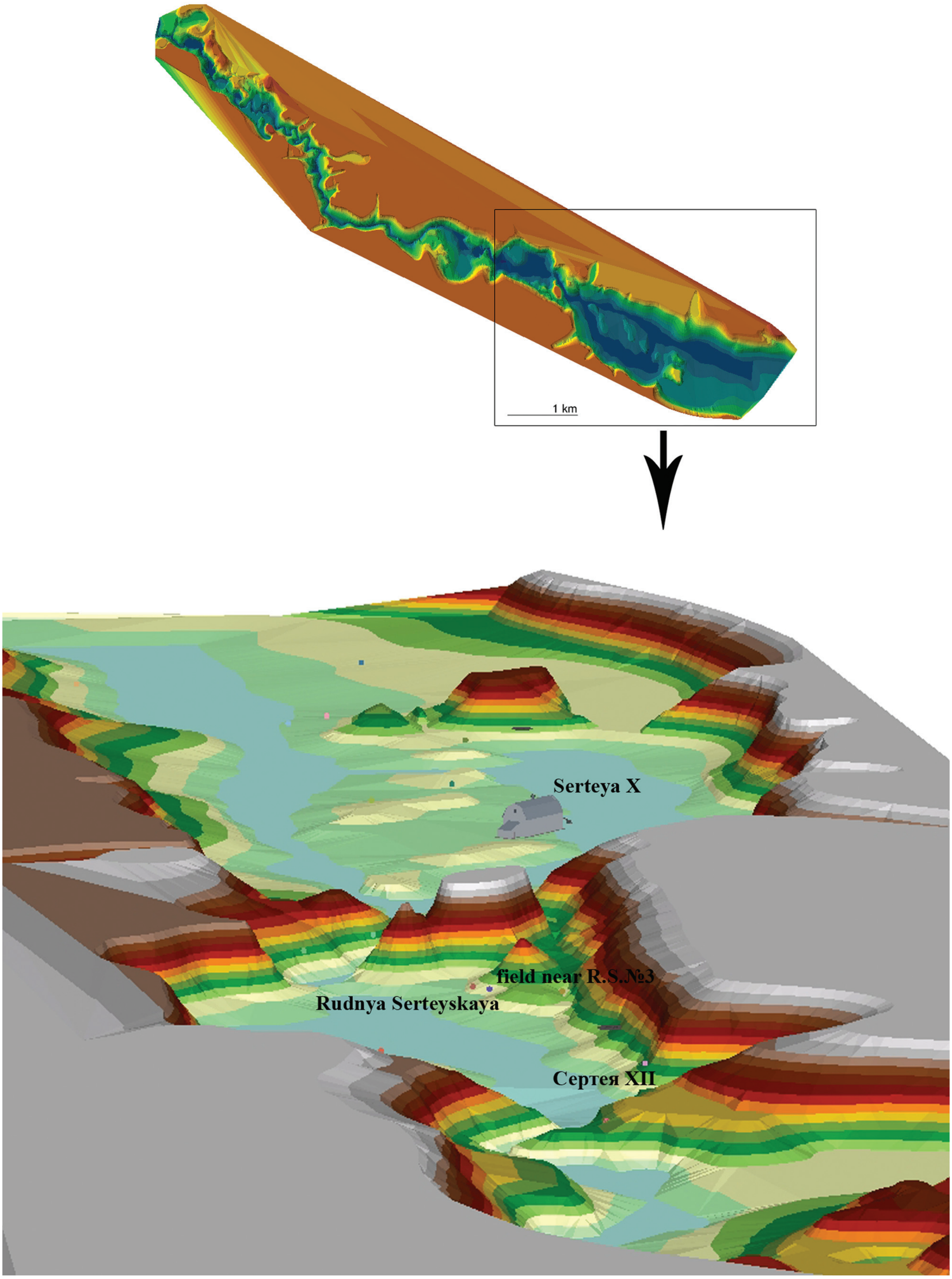


Fig. 8. Early Neolithic sites' distribution in the southern part of Serteysky microregion.

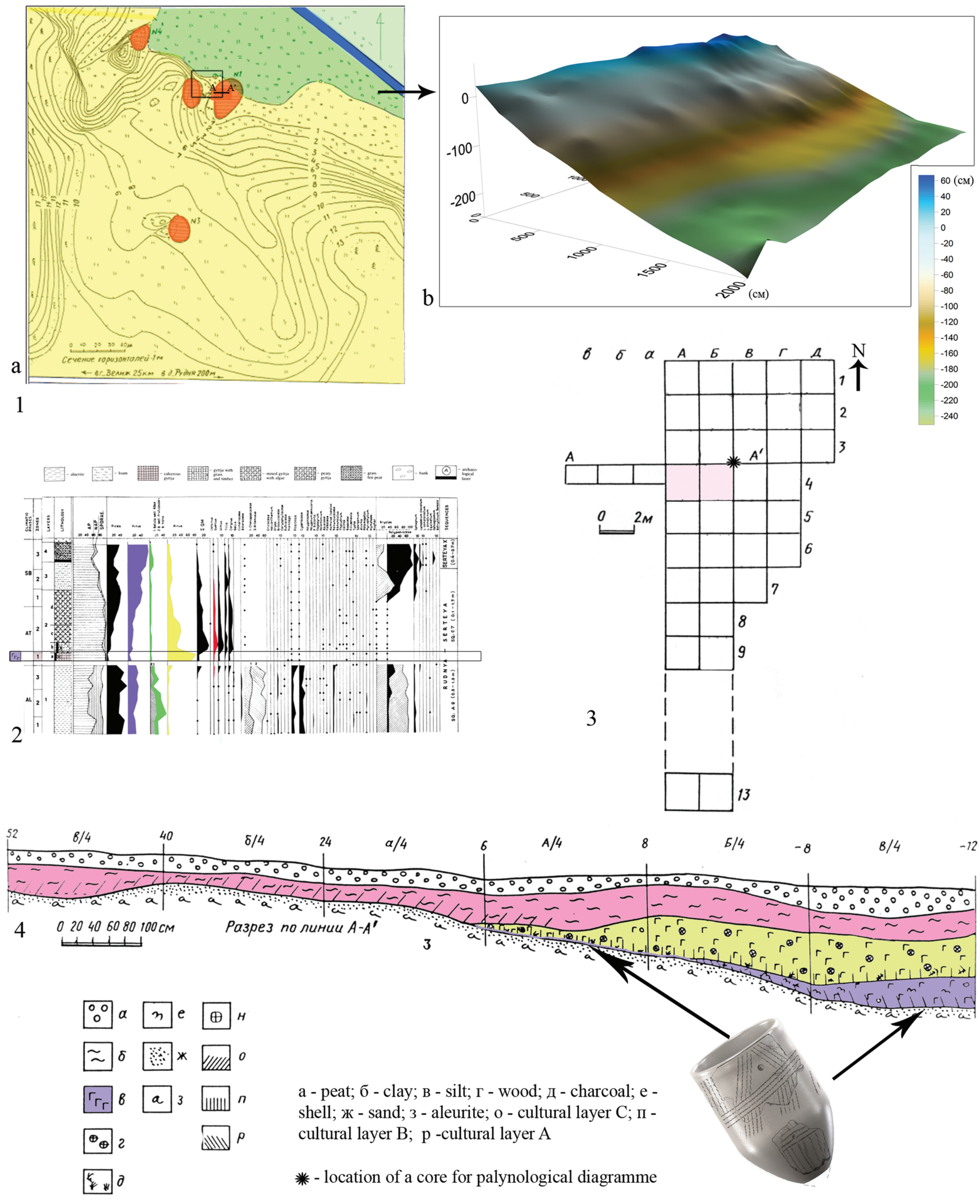
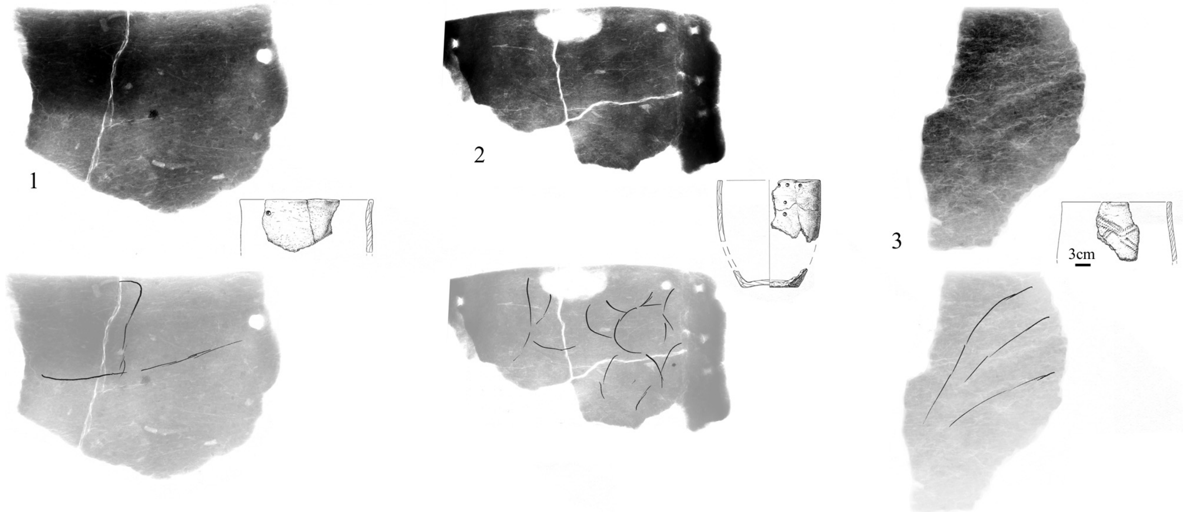


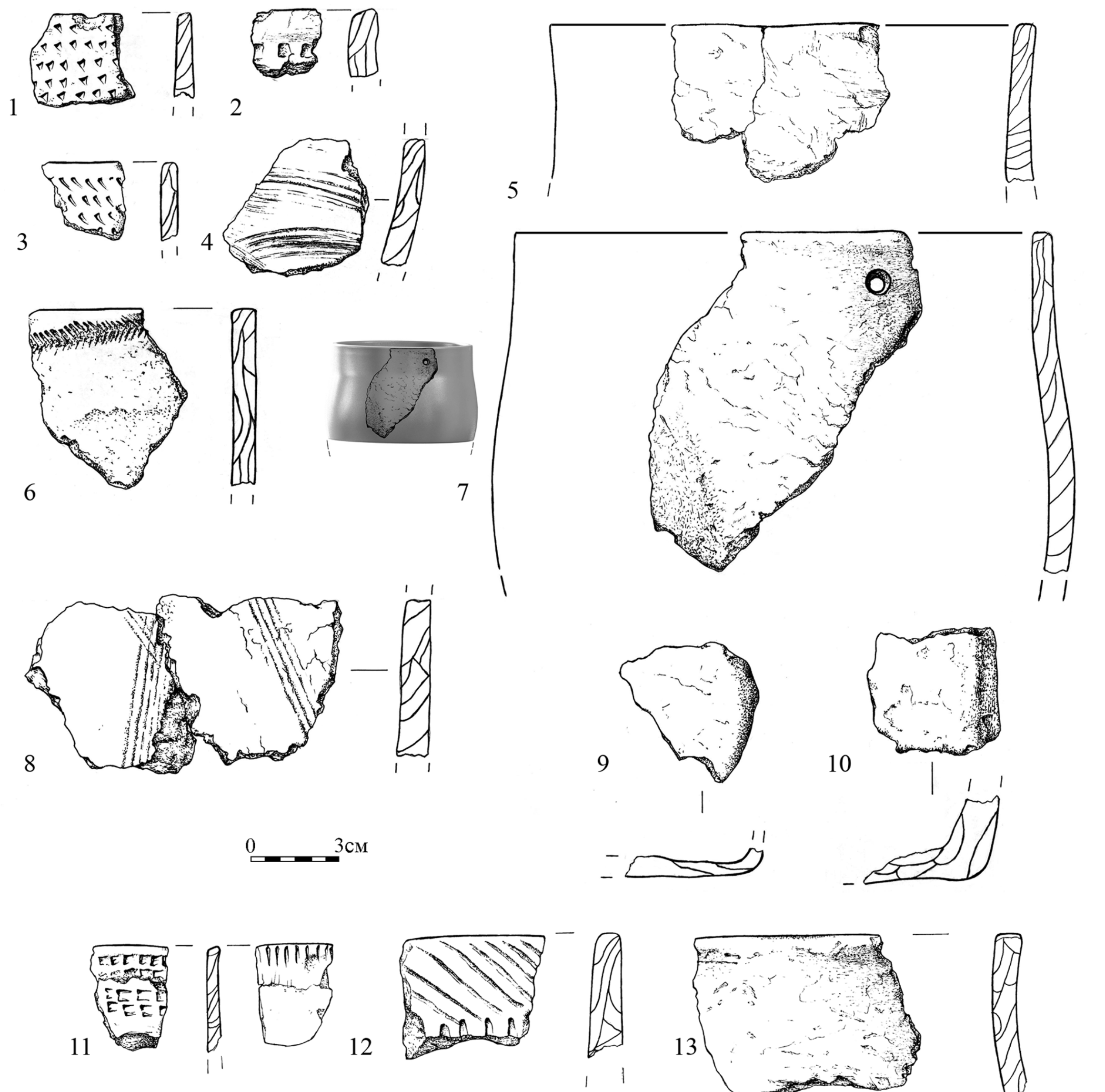
Fig. 9. Rudnya Serteyskaya. 1a location of the site and field near Rudnya Serteyskaya 2–4 in the Dnepr-Dvina region (after* Mazurkvich, Miklyaev 1998.Fig. 2, 1*); 1b relief reconstruction; 3 plan of the excavated part with indication of position of phase 'a' vessels; 2 stratigraphy with indication of vessel fragments of phase 'a' position and palynological diagram with indication of layer that covered the layer containing Early Neolithic pottery (after* Dolukhanov *et al.* 1989.Fig. 1*).

Tab. 1. Rakushechny Yar. Macro-traces on vessel surfaces. 1 U-junction of coils; 2 N-junction with slight stretching; 3a junction of coils greatly stretched, 3b part of the coils (3.1 reconstruction of vessel modelling); 4 traces of coils and modelling of the walls on a conical base; 5 traces of slabs joining conical bases (5.1 reconstructed modelling of conical base); 6 places where coils join while the flat base was modelled with coils (6.1 reconstruction); 7 'groove' left on the perimeter of the flat base (a), fractures left where coils were joined (b), curved fracture, which marks the junction of coils (c) (7.1 reconstructed base).

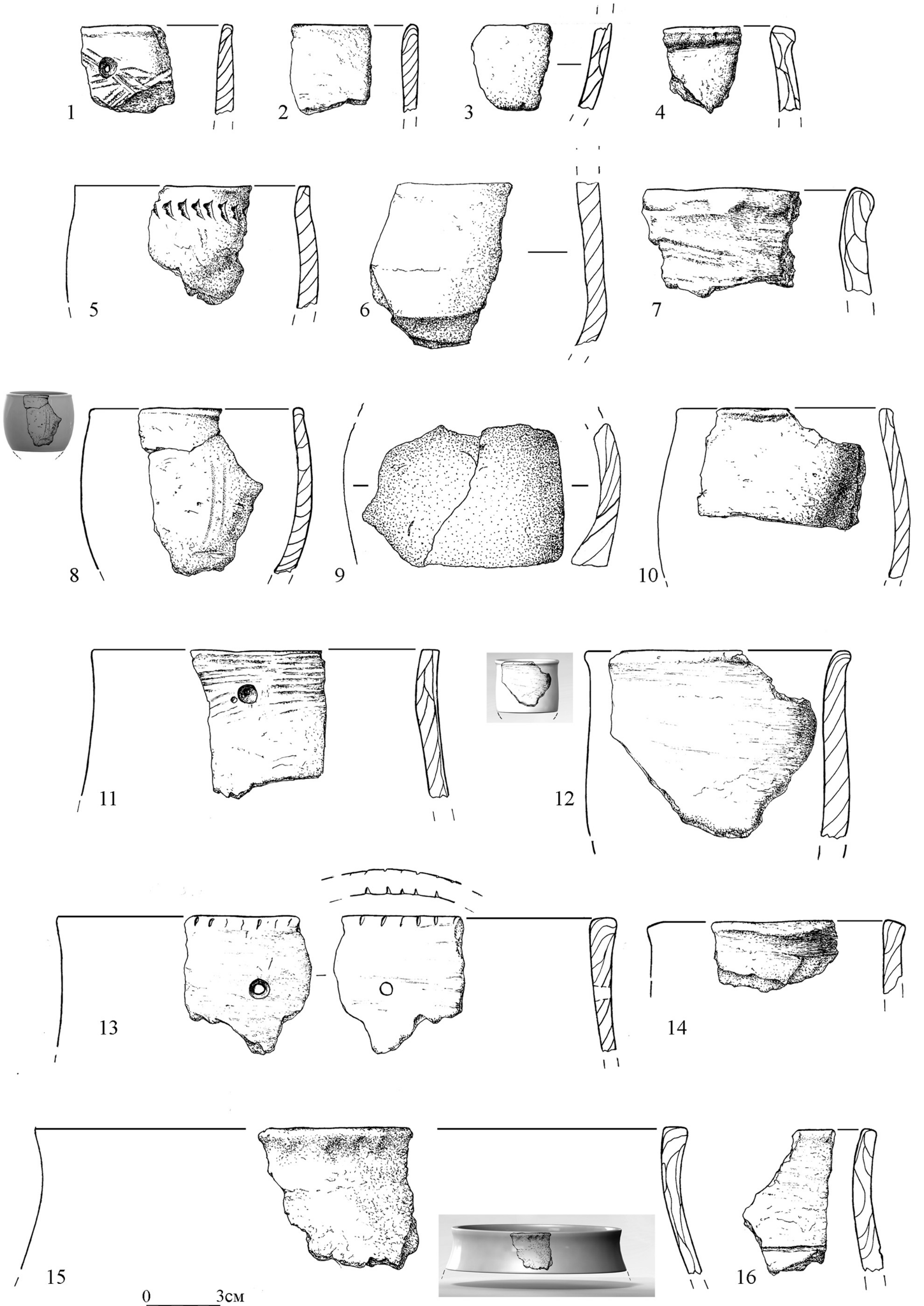
Tab. 2. Rakushechny Yar. Macro-traces on vessel surfaces. 1 traces left by a comb-like tool on the inner side of the base; 2, 3a, 4a, b, 5b smoothed surface; 3b traces left after inner surface treatment; 3c oblique direction of coils' in profile; 4b two slabs/fragments of coils; 4c vertical fracture marking two slabs/coils; 5a coils on flat base; 6 traces left after smoothing with pebble; 7 imprint on outer side of flat base.



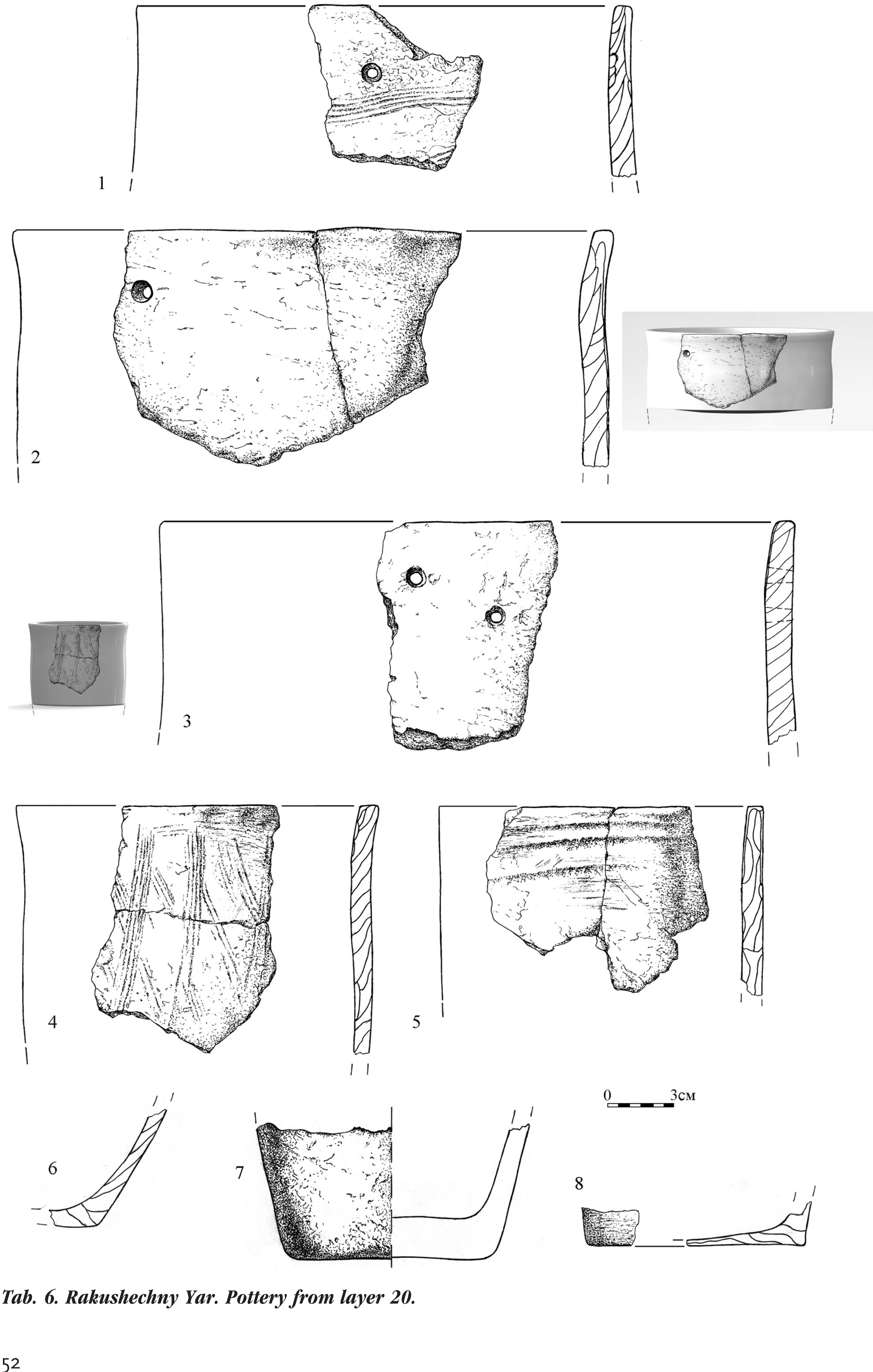
Tab. 3. Rakushechny Yar. Radiography of the vessel fragments, with indication of different technological traces.



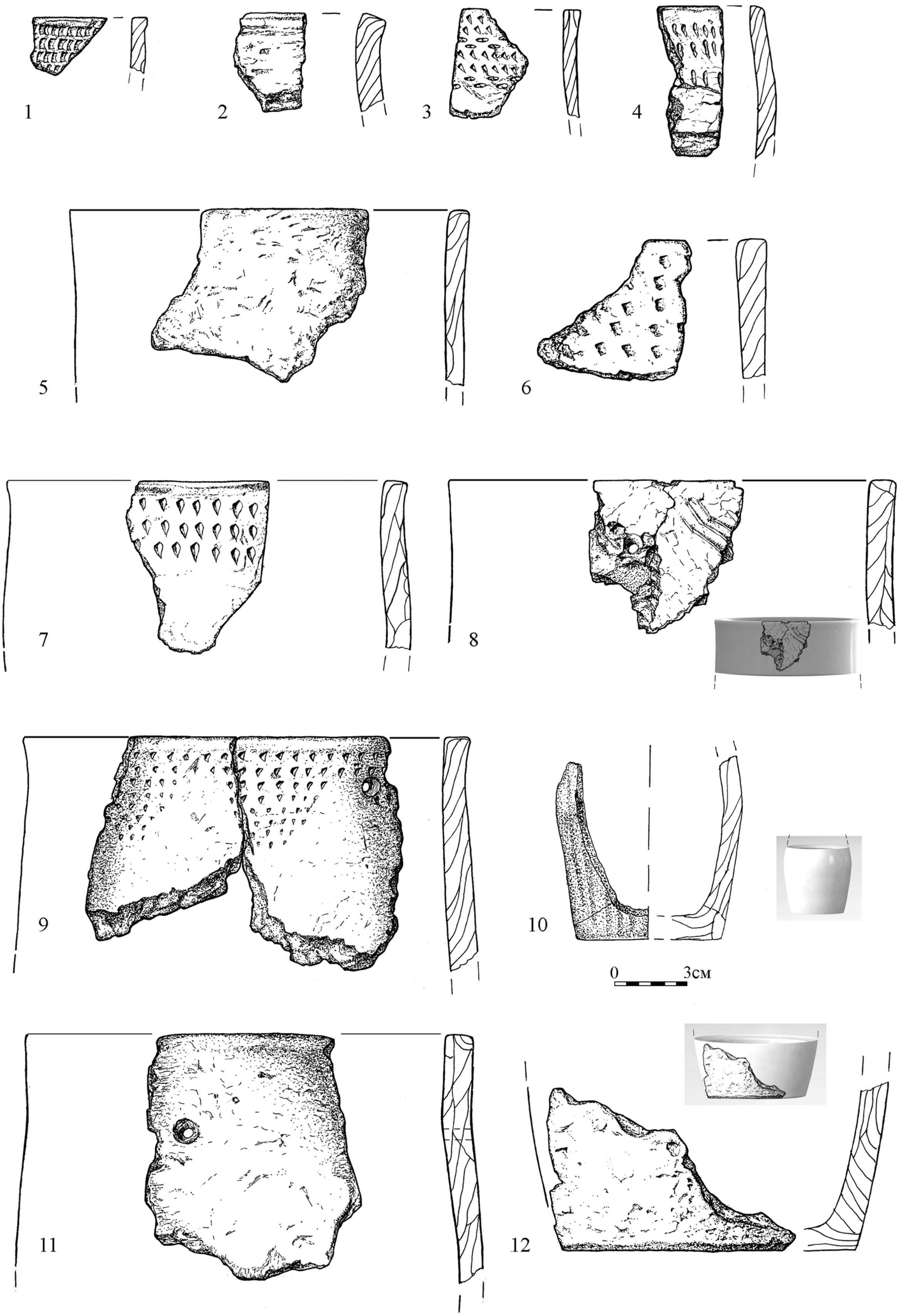
Tab. 4. Rakushechny Yar. Pottery. 1–10 layer 23; 11–13 layer 22.



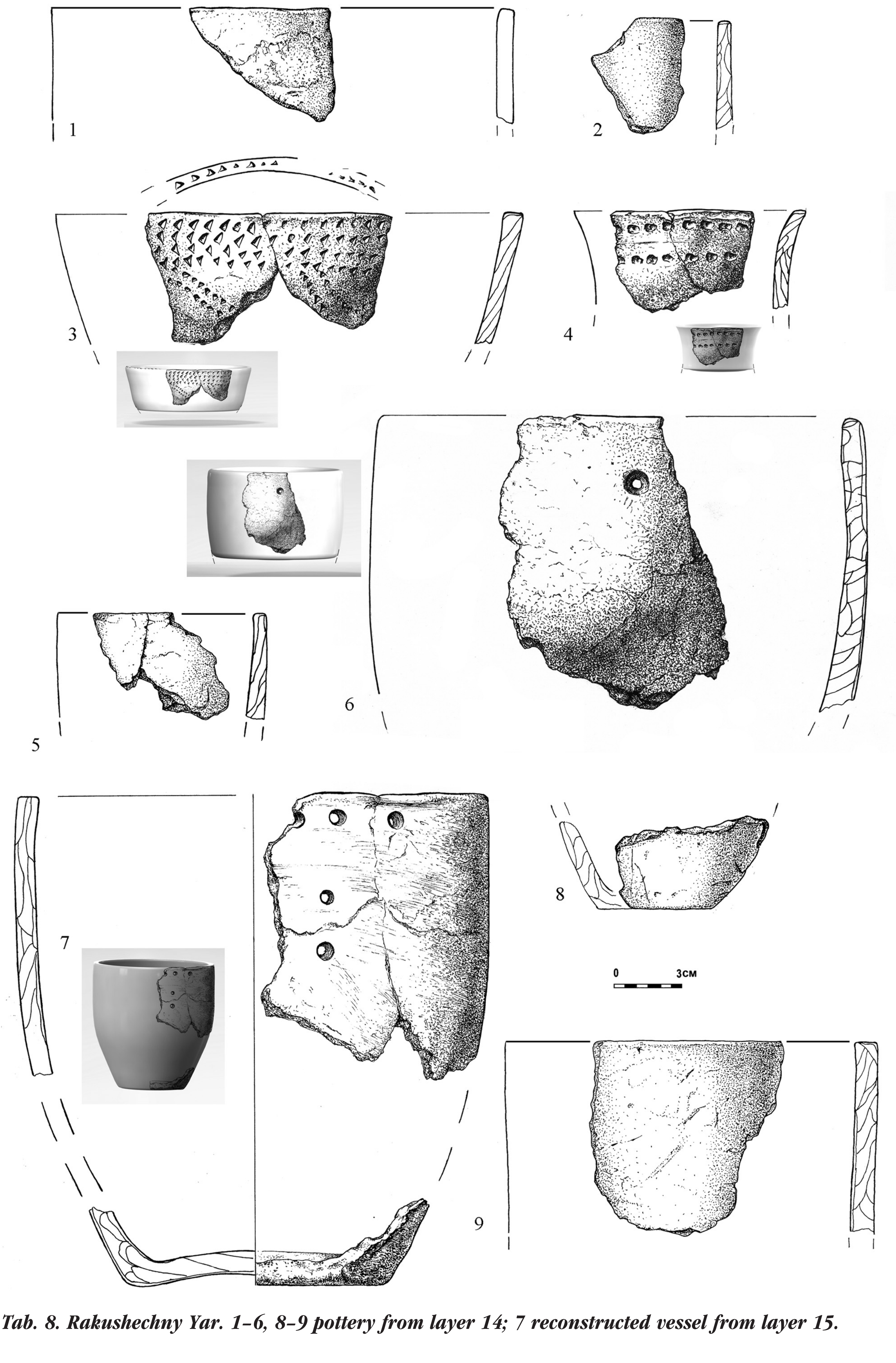
Tab. 5. Rakushechny Yar. Pottery from layer 20.



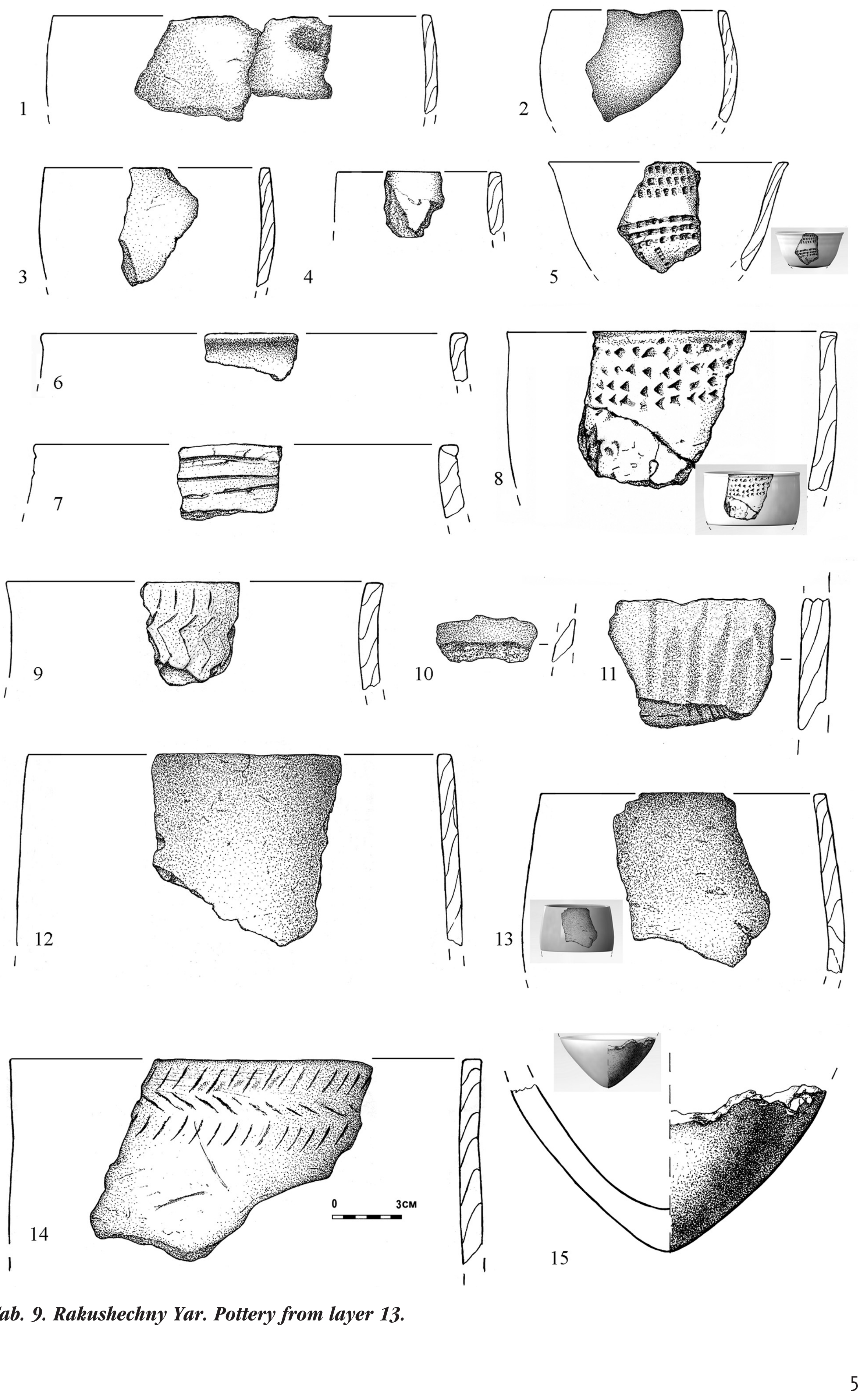
Tab. 6. Rakushechny Yar. Pottery from layer 20.



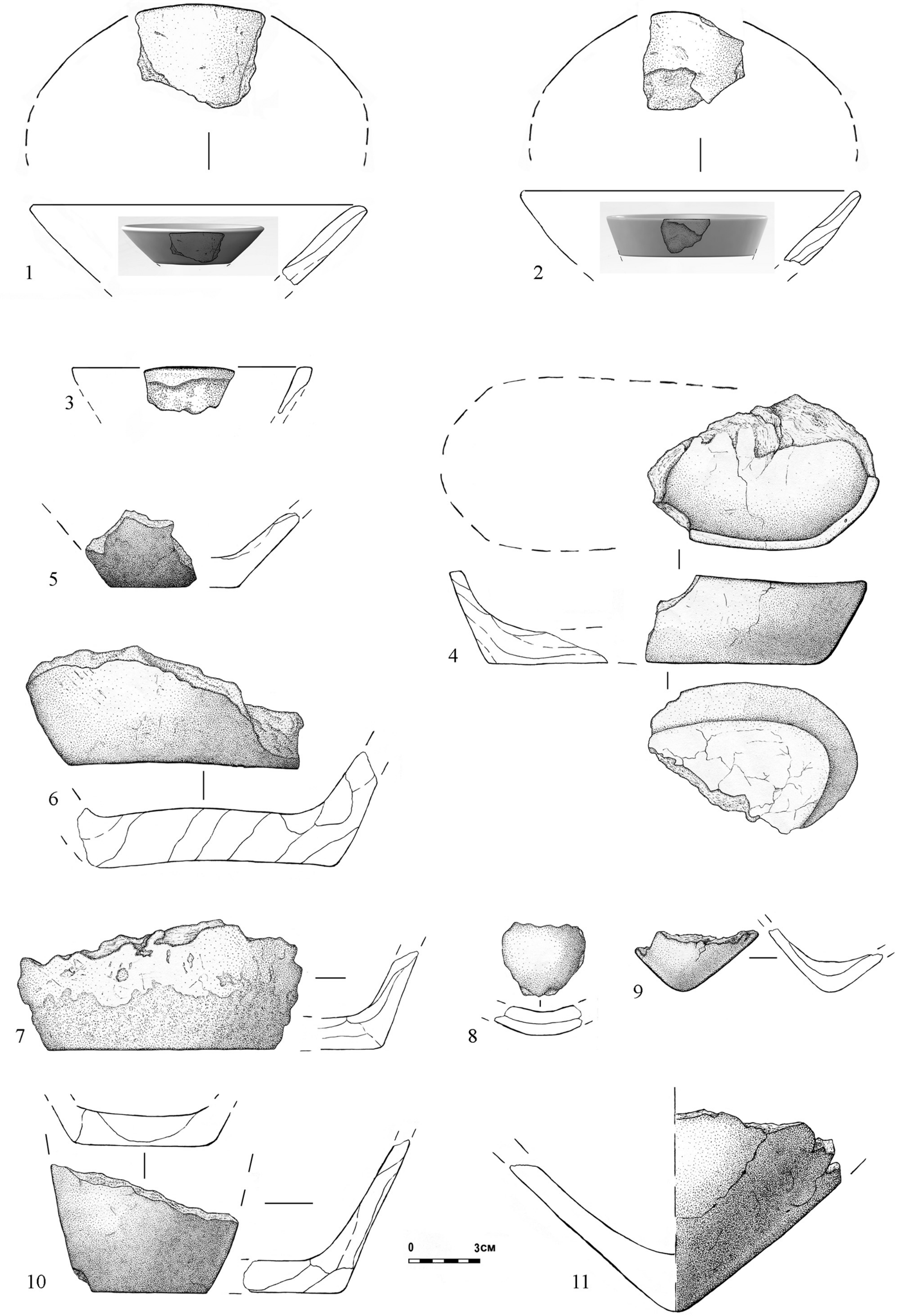
Tab. 7. Rakushechny Yar. Pottery from layer 19.



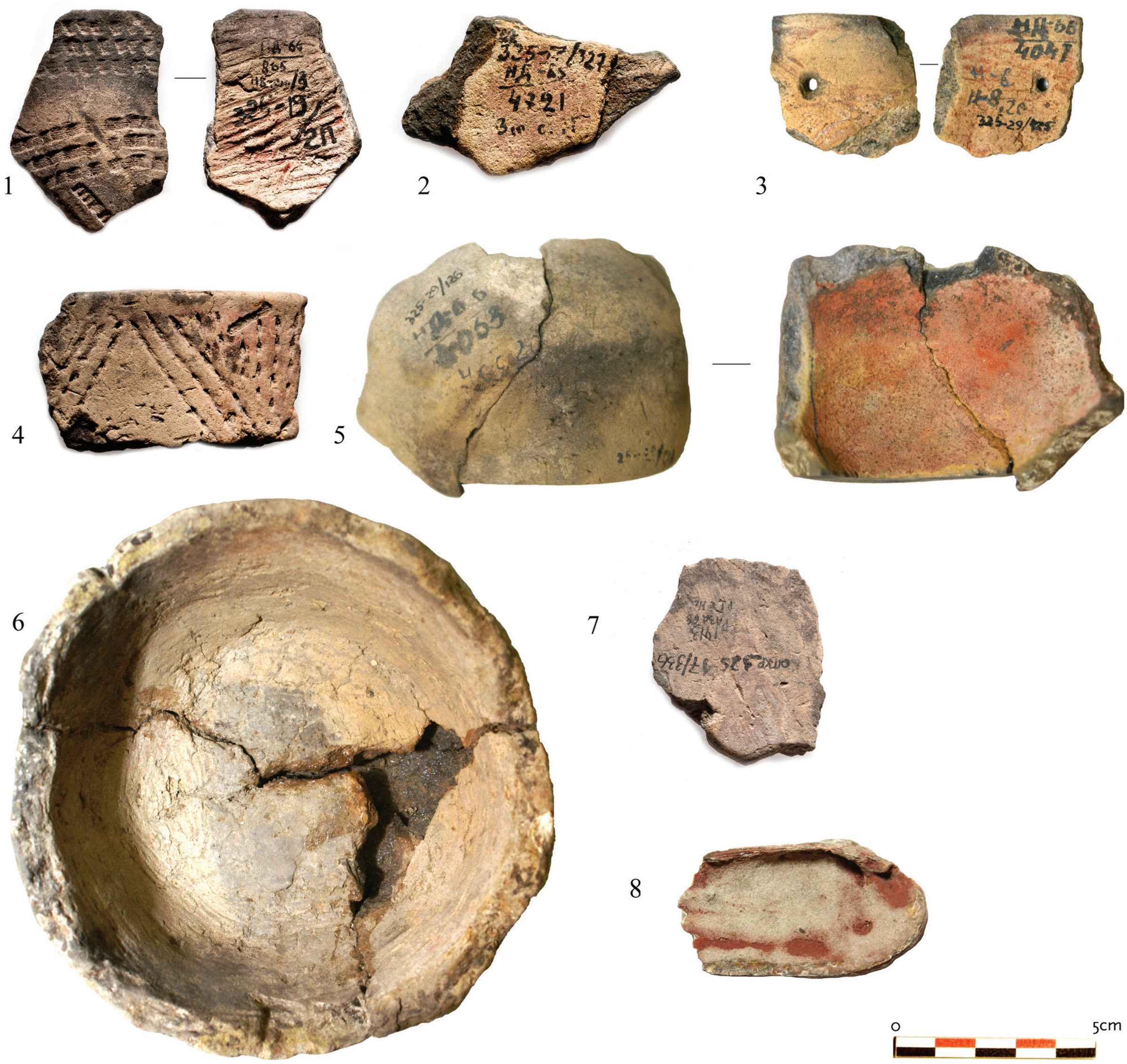
Tab. 8. Rakushechny Yar. 1-6, 8-9 pottery from layer 14; 7 reconstructed vessel from layer 15.



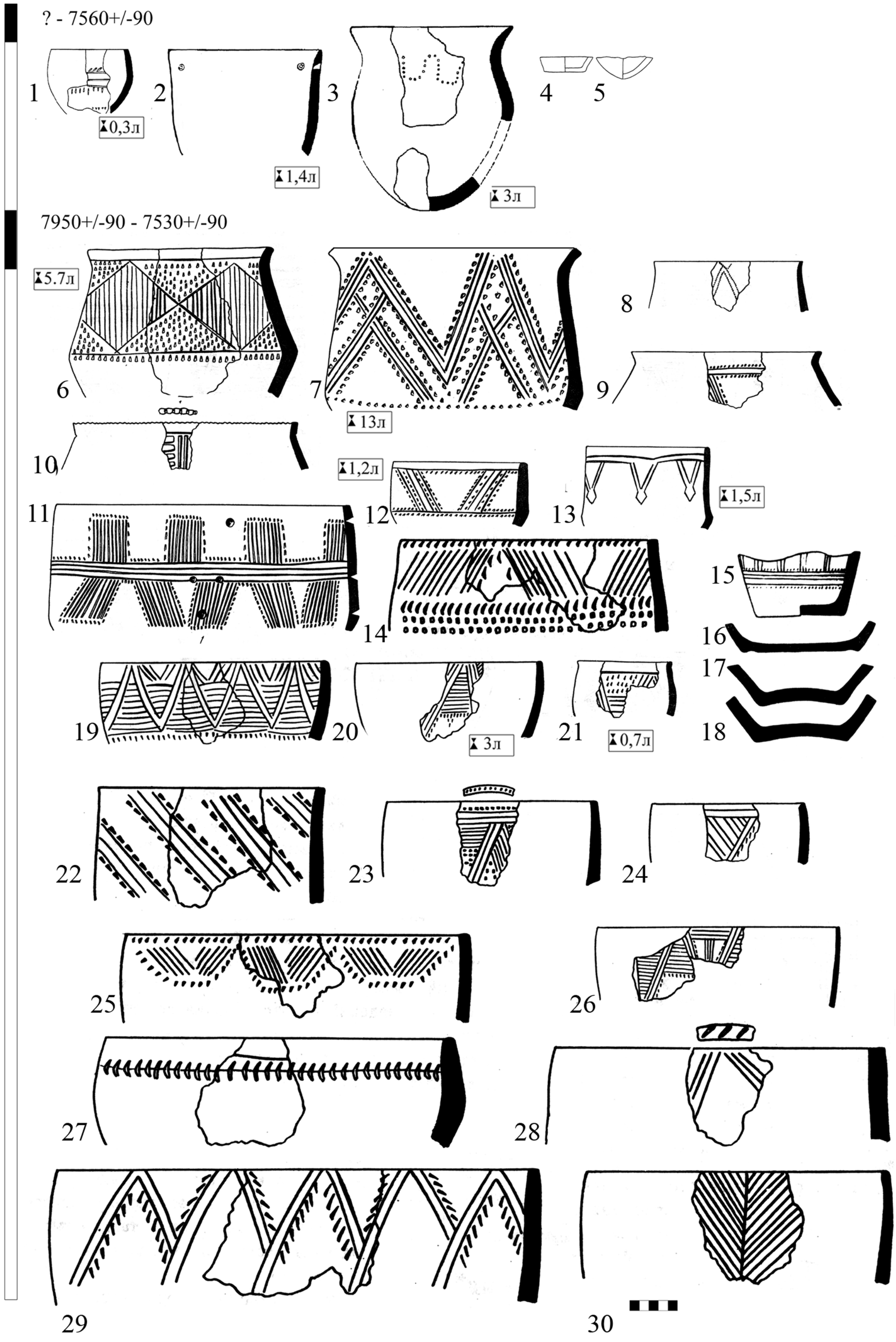
Tab. 9. Rakushechny Yar. Pottery from layer 13.



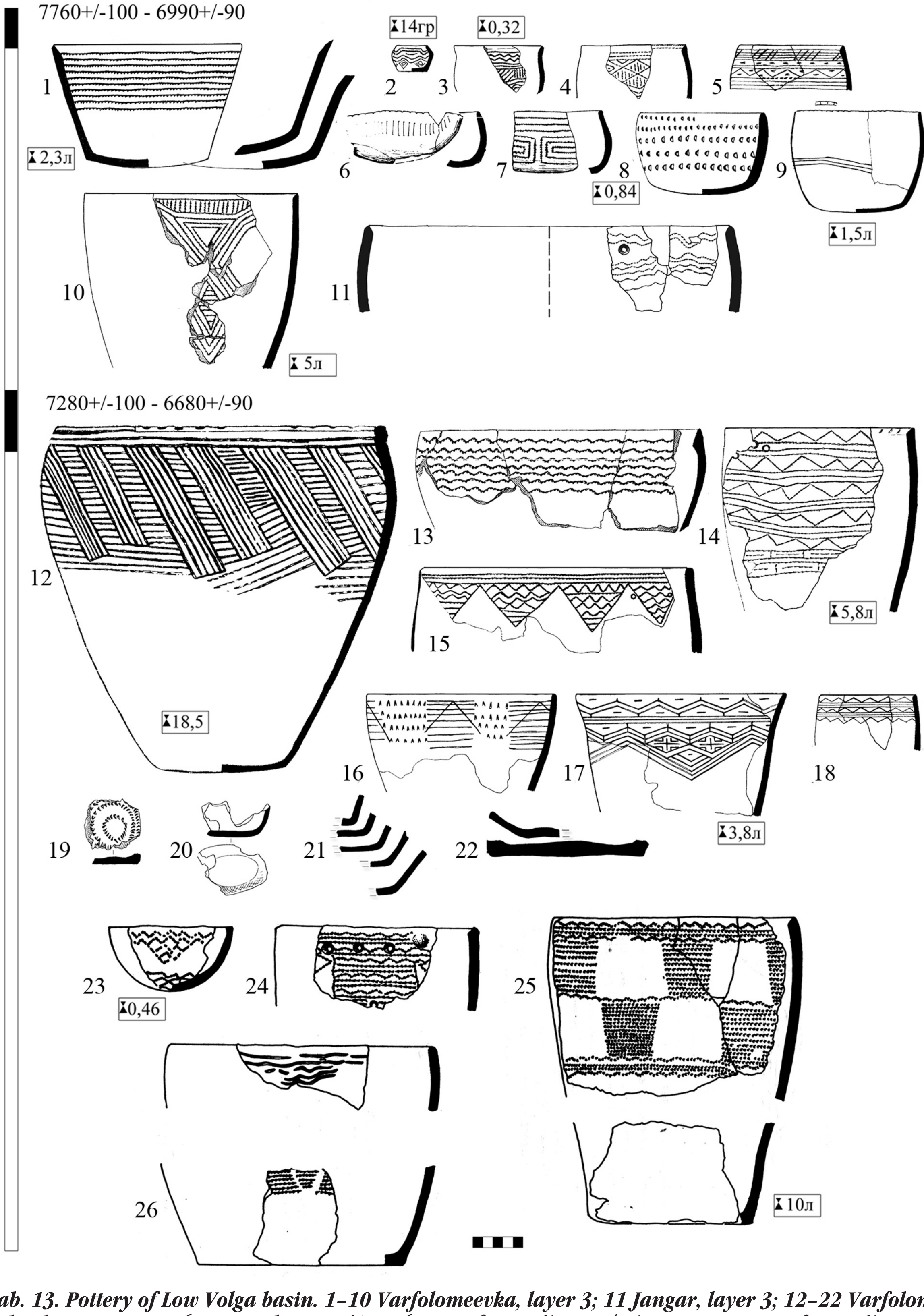
Tab. 10. Rakushechny Yar. Pottery from layer 11.



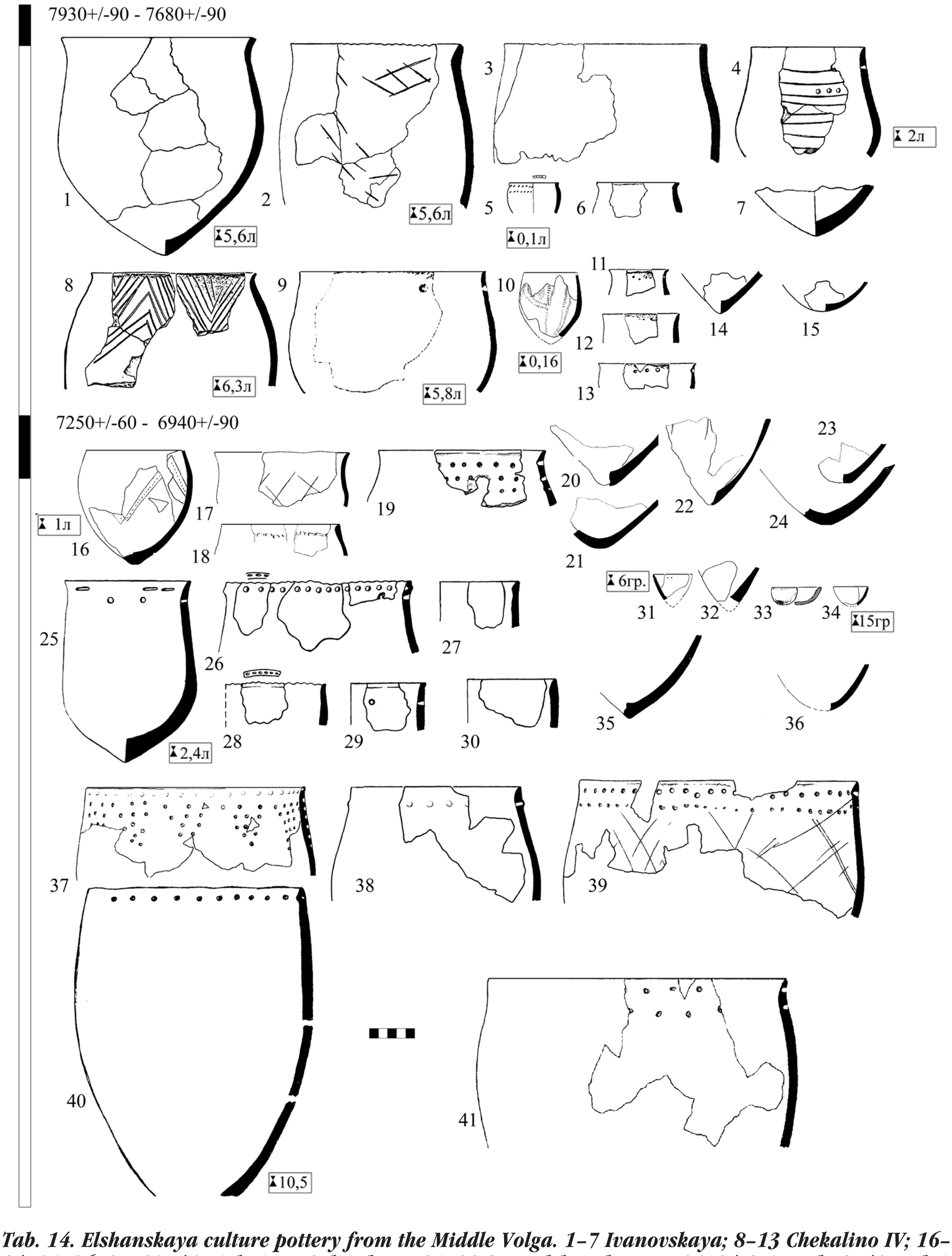
Tab. 11. Rakushechny Yar. Vessels covered with ochre (1 – layer 13; 2, 4, 7– layer 11; 3, 5–6, 7 – layer 20) and Unio shell with ochre (8).



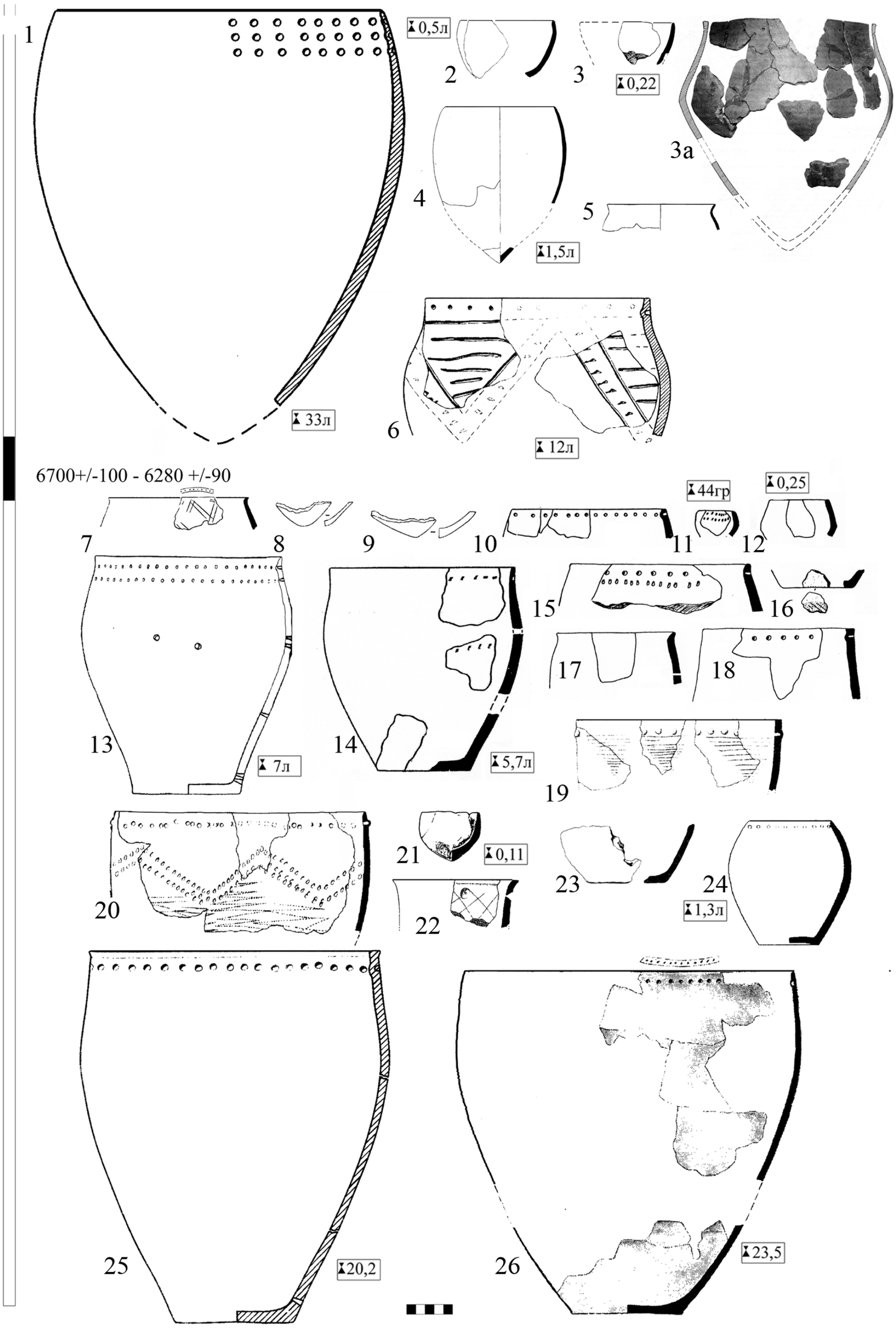
Tab. 12. Pottery of Low Volga basin. 1–2 Kugat IV; 3 Kulagaisi; 4–5 Tu-Buzgu-Huduk I; 6–30 Kairshak III (1–3 after **Vybornov 2008.Fig. 3*****; 4–5 after*** **Vybornov 2008.Fig. 23*****; 6–30 after*** **Vasiliev *et al.* 1989.Fig. 2–6*****).***



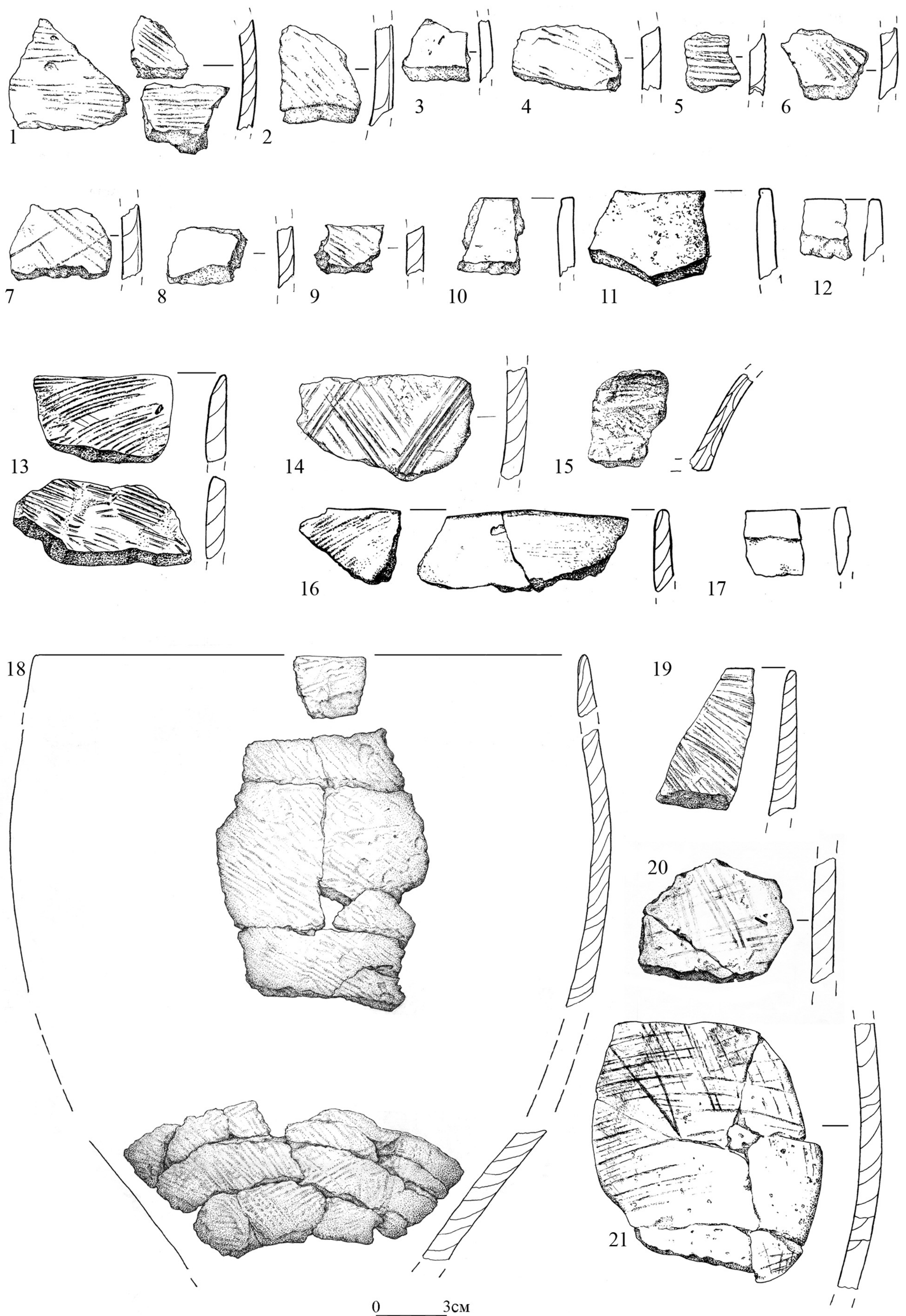
Tab. 13. Pottery of Low Volga basin. 1–10 Varfolomeevka, layer 3; 11 Jangar, layer 3; 12–22 Varfolomeevka, layer 2B; 23–26 Jangar, layer 2 (1–2, 6–7, 9 after* Yudin 2004.Fig. 8*; 3–5, 8, 10 after* Yudin 2004. Fig. 12*; 11 after* Kolcov 1988.Fig. 15*; 23–26 after* Kolcov 1988.Fig. 12*).



Tab. 14. Elshanskaya culture pottery from the Middle Volga. 1–7 Ivanovskaya; 8–13 Chekalino IV; 16–24, 35–36, 37–39, 41 Nizhnjaya Orljanka II; 25–30 Staroelshanskaya II; 31–34 Ozimenki 2; 40 Maksimovskaya (1, 3 after* Vybornov 2008.Fig. 46*; 2, 4, 7 after* Vybornov 2008.Fig. 47*; 5 after* Morgunova 1995. Fig. 5*; 6 after* Morgunova 1995.Fig. 4*; 8, 11–15 after* Vybornov 2008.Fig. 49*; 9 after* Vybornov *et al.* 2000. Fig. 2*; 10 after* Vybornov *et al.* 2000.Fig. 7*; 16–18, 20–23 after* Vybornov 2008.Fig. 52*; 19 after* Vybornov 2008.Fig. 53*; 24 after* Morgunova 1995.Fig. 25*; 25–30 after* Vybornov 2008.Fig. 45*; 31–32, 34 after* Vybornov *et al.* 2000.Fig. 33*; 33 after* Vybornov 2008.Fig. 168*; 37–38 after* Vybornov 2008.Fig. 53*; 39 after* Vybornov *et al.* 2000.Fig. 4*; 41 after* Vybornov *et al.* 2000.Fig. 5*; 40 after* Morgunova 1995.Fig. 13*).

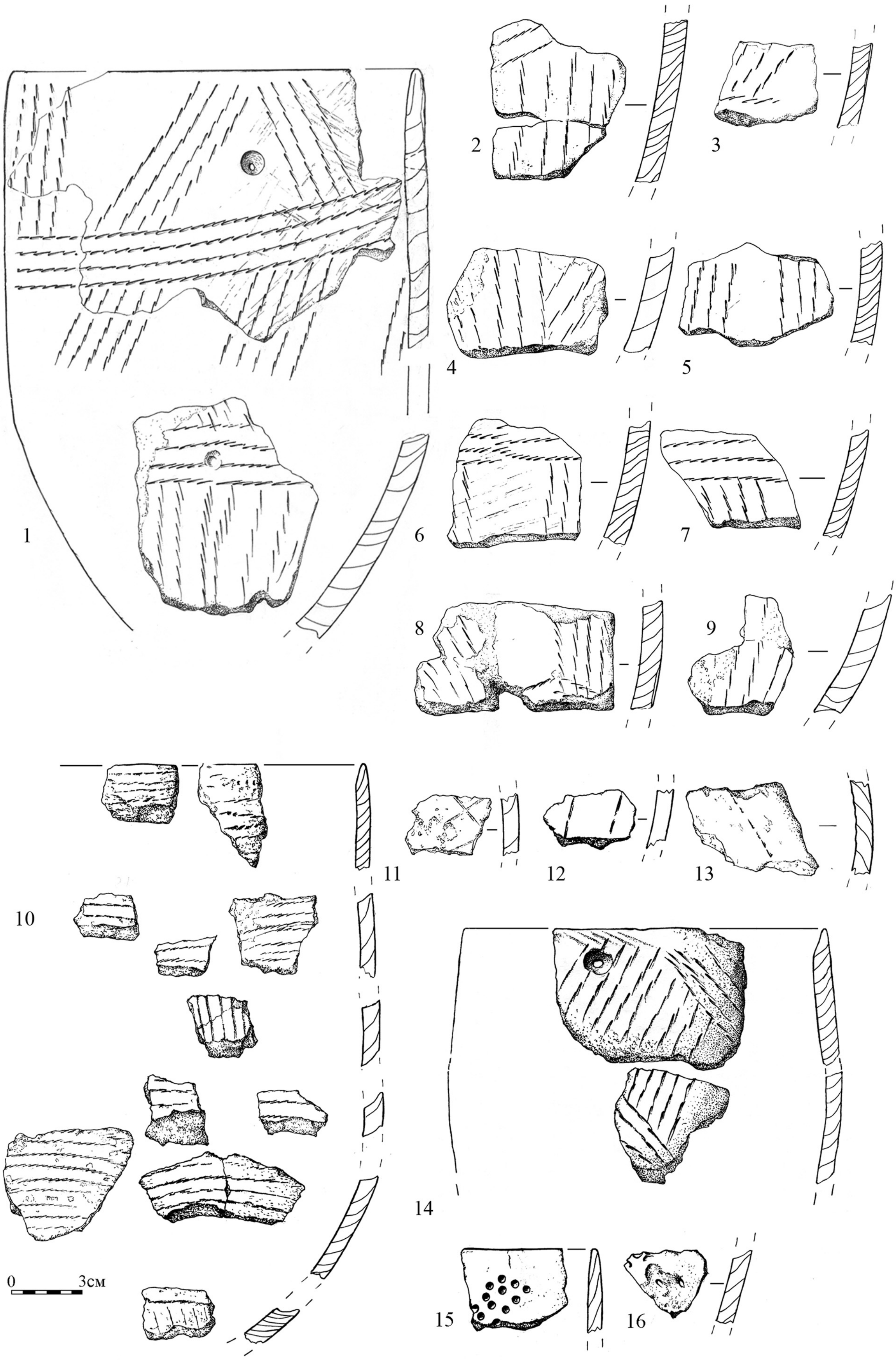


Tab. 15. Elshanskaya culture pottery of the Middle Volga. 1, 23–24 Iljinka; 2–5 Imerka 8; 3a Viunovo lake I; 6, 19, 25 Bol'shaya Rakovka II; 7–9, 13 Krasny gorodok; 10–12, 14–18 Lugovoe III; 20 Lebjazhinka I; 21–22, 26 Lebjazhinka IV (1 after **Vybornov *et al.* 2000.Fig. 3*; 2–3 after*** **Arheologiya Mordovskogo kraya 2008.Fig. 32*; 3a after*** **Berezina *et al.* 2013.Fig. 4, 5*; 4–5 after*** **Vybornov 2008.Fig. 181*; 7 after*** **Vybornov *et al.* 2000.Fig. 6*; 8–9,13 after*** **Vybornov 2008.Fig. 59*; 10–12, 14–18 after*** **Vybornov *et al.* 2012.Fig.10*; 19 after*** **Vybornov *et al.* 2000.Fig. 5*; 20 after*** **Vybornov *et al.* 2000.Fig. 11*; 21 after*** **Vybornov *et al.* 2000.Fig. 3*; 22 after*** **Vybornov *et al.* 2000.Fig. 4*; 23 after*** **Vybornov 2008.Fig. 62*; 23 after*** **Vybornov *et al.* 2000.Fig. 3*; 25 after*** **Vybornov *et al.* 2000.Fig. 18*; 26 after*** **Vybornov *et al.* 2000.Fig. 2*).***

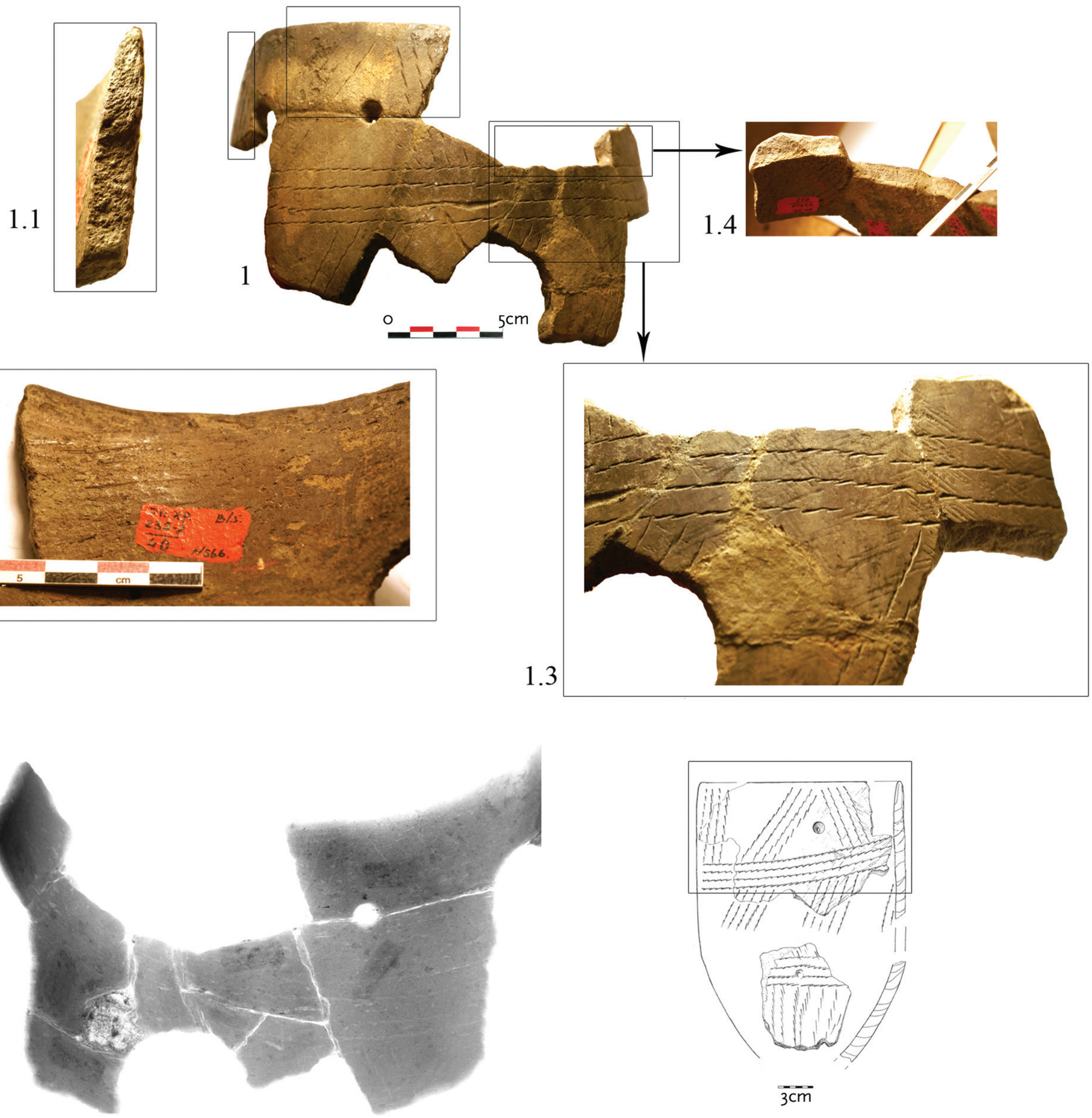


Tab. 16. Early Neolithic pottery of phase 'a-1' in the Dnepr-Dvina region.

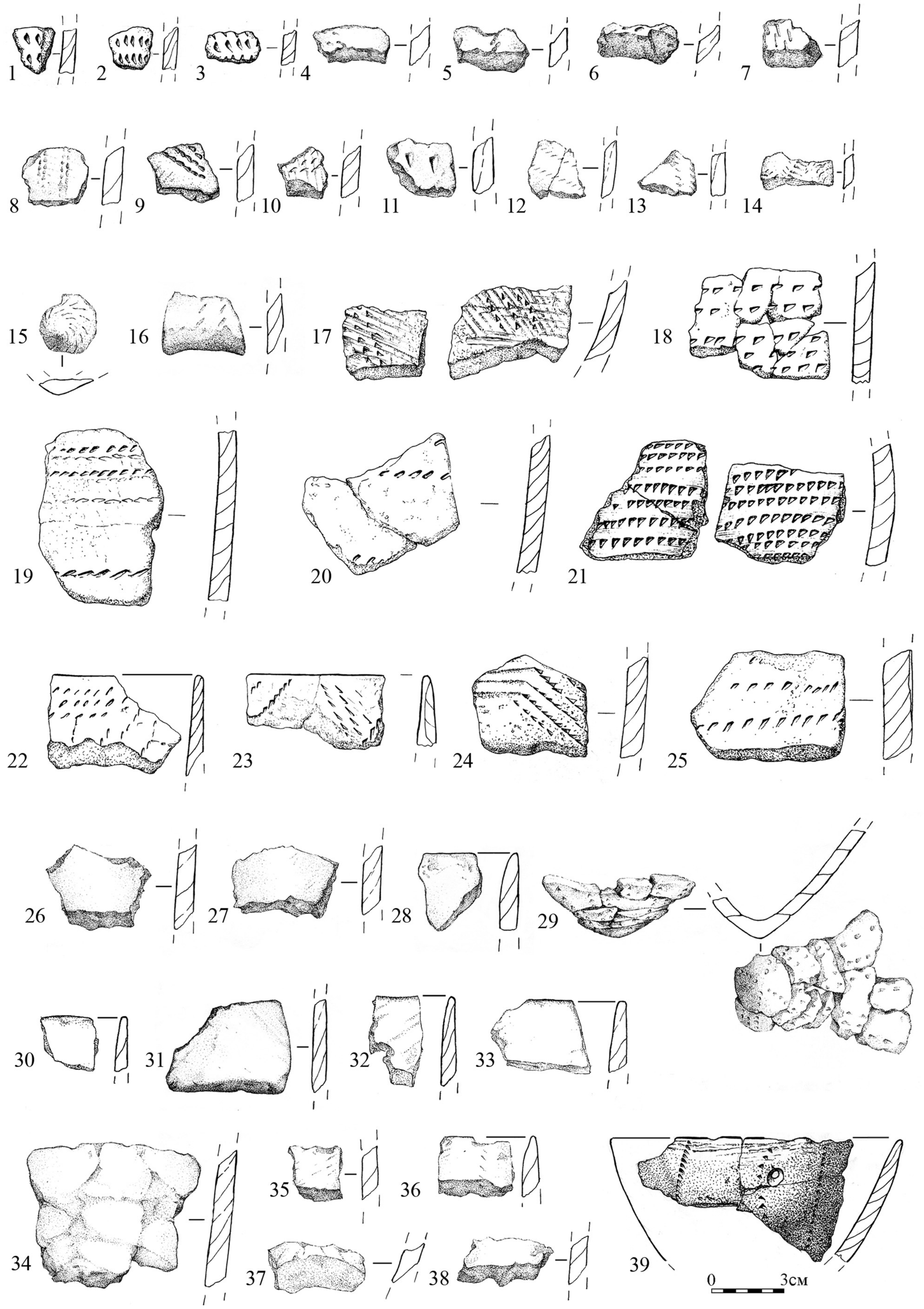
Tab. 17. Macro-traces on a vessel of phase 'a-1' in Dnepr-Dvina region: 1.1, 3, 4 fractures where coils join; 1.2, 3, 6 horizontal / slightly oblique porous structure and fractures, marking coil junctions; 2, 4, 5 horizontal fractures at coil junctions.



Tab. 18. Early Neolithic pottery of phase 'a' in the Dnepr-Dvina region.



Tab. 19. Macro-traces (1) and radiograph (2) of the vessel of phase 'a' in the Dnepr-Dvina region. 1.1, 1.4 horizontal / slightly oblique porous structure and fractures, marking coil junction; 1.2 traces of surface roughening left by a comb-like tool; 1.3 traces of surface roughening left by a comb-like tool and further polishing of the surface.



Tab. 20. Early Neolithic pottery of phase 'b' in the Dnepr-Dvina region.

The origin of farming in the Lower Volga Region

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ABSTRACT – *The paper focuses on the results of archaeological, palaezoological, and radiocarbon analyses of Neolithic and Eneolithic sites in the Northern Caspian and Lower Volga regions. New analyses show that only wild animal species inhabited the territory in the Neolithic. Animals were not domesticated until the Eneolithic period.*

IZVLEČEK – *Članek predstavlja rezultate arheoloških, paleozooloških in radiokarbonskih analiz na neolitskih in eneolitskih najdiščih v severno kaspijski regiji in na področju Spodnje Volge. Rezultati kažejo, da so bile v neolitiku prisotne samo divje živali. Prve udomačene živali se pojavijo v eneolitiku.*

KEY WORDS – *Neolithic; Lower Volga region; farming; absolute chronology*

Introduction

The Lower Volga region has an extraordinary geographical position, as it borders with Caucasia to the west, Central Asia to the east, and the Caspian region to the south (Fig. 1). Many archaeologists proposed that farming already existed in the Neolithic age in this area. The specific central position of the region was the reason for the close interaction of their inhabitants. It was thought that this allowed for the beginning of cattle domestication in the semi-desert area and in the Volga steppe region already in the Neolithic (*Melentiev 1980; Naumov 2002; 2004; Yudin, 2003; 2004; Koltsov, 2004; 2005*). However, some archaeologists have shown that only wild animals were present in the Neolithic of Middle Asia (*Vinogradov 1981*), while others do not agree that the Caucasian artefacts can be attributed to the Neolithic age (*Trifonov 2009*). Thus the problem of the origin of farming in the Lower Volga region in the Neolithic should be solved by focusing our attention to the analysis of material in this region, not on adjacent territories.

Methods and materials

Archaeologists distinguish between Neolithic artefacts from three cultural groups in the Lower Volga: Seroglazov (including the sites of Kairshak III, Baibek, and Tentexor) which spread in the Northern Caspian region; Jangar (Jangar and Tubuzgu-Khuduk sites) in the North-Western Caspian region, and Orlov (Varfolomeev, Aglay, Orlovka sites) in the Volga steppe region. On the basis of the analyses of cultural assemblages of these sites, researchers have singled out a number of general distinctive features: the flat-bottomed pottery was made of clay containing silt and clamshells, and was decorated with incised ornaments and geometric motifs; flint tools include blades and abundant geometric microliths. On the basis of the specific artefacts, they were grouped together into the Lower Neolithic Volga culture (*Yudin 2004; Koltsov 2005; Vybornov 2008; 2010; 2011; 2013*).

Some points need to be discussed: one of them is whether farming evolved in the Neolithic in the re-

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gion or not. This is one of the most important questions, because it determines the definition of the Neolithic age; at the same time, this is one of the most difficult problems, as it cannot be solved only in terms of archaeology; an interdisciplinary study needs to be carried out. In order to study the Neolithic assemblages of the Lower Volga, it is essential to make a thorough and consistent assessment of the material and analyse the context of each artefact.

Fig. 1. Map of the Lower Volga region.

Archaeologists face certain methodological problems when working on early cattle breeding in the region considered, as this work is based on differentiating domestic from wild animal bones. Wild animal species lived in the area in the Holocene: auroch (*Bos primigenius*), wild boar (*Sus scrofa*), and tarpan (*Equus ferus*; wild horse). These species were the ancestors of domestic animals: cattle (*Bos taurus*), the domestic pig (*Sus scrofa domestica*) and the horse (*Equus caballus*). The morphological characteristics of the bones of wild and domestic animals are very similar, but they vary in size.

The size of auroch and wild boar declined after domestication (*Tsalkin 1970.164–165, 80–182*); however, in the Neolithic period, cattle bones were as big as those of aurochs (*Tsalkin 1970.60–62*). Bovid bones became smaller after domestication, and, ultimately, domestic male cattle bones came to be the same size as those of female wild aurochs. Another problem is connected with differentiating between domestic and wild horse bones. Since domestication did not influence bone size, it is impossible to know whether animal bones should be attributed to horses or tarpans. The size of wild boar changed very rapidly after domestication, and pig bones in the Neolithic were considerably smaller than those of wild boar (*Tsalkin 1970.180–182*). Wild sheep (*Ovis aries*) and goat (*Capra hircus*) never inhabited the region, so only domestic ones appeared.

Bone fragments from six Neolithic (Tab. 1) and five Eneolithic (Tab. 2) settlements were analysed in the present study. The bones from the site of Jangar were identified by Vladimir P. Danilchenko and Irina V. Kirillova. The bone descriptions from Tentexor I, Kurpezhe-Molla, and Karakhuduk I are already published (*Kuzmina 1988.175*). The bone collection is kept in the Zoology Institute of the Russian Academy of Sciences (St. Petersburg) and was reanalysed by one of the authors of this paper. The results (Tab. 1) were different from the previously published data (*Kuzmina 1988.175*). The bone collection from Varfolomeev site was also analysed (*Gasilin* et al. *2008.27*) and our results varied from previously published information (*Yudin 2004.195*).

The bones found at the sites were kitchen waste, so most of the bone find were fragmented. Bone mesurements were taken using standard methods (*Driesch 1976.40–93*). The identification of aurochs and cattle bones was made on the basis of their dimensions; large bones were identified as aurochs and small ones as cattle. The dimensions of auroch bones from European Holocene sites (*Boessnek 1957*, cited in *Tsalkin 1970.52–57; Degerbøl 1942* cited in *Tsalkin 1970.52–57; Gasilin* et al. *2008.70; Kobryn, Lasota-Moskalewska 1989.73; Requate 1957*, cited in *Tsalkin 1970.52–57*) and Kazakhstan (*Gayduchenko 1998*) are listed in Table 3. The dimensions of cattle from Neolithic and Eneolithic sites in Western Europe are also shown in the table (*Kobryn, Lasota-Moskalewska 1989.73; Petrenko 2000.10–11; Vörös 1980.59; Zalkin 1970.52–57*). As shown in Table 3, the size of the Neolithic bones is the same as the auroch bones and bigger than the largest do-

	Cultures					
	Seroglazovskaya			Jangarskaya	Orlovskaya	
	Kairshak III	Baibek	Tentexor I	Jangar	Varfolomeevka	Algay
Sheep – *Ovis aries*			1/1			
Wild ass – *Equus hemionus*	619/12	1891/91	1290/40	615/28	714/19	266/37
Saiga antelope – *Saiga tatarica*	19/3	48/7	79/9	2006/103	423/17	297/21
Aurochs – *Bos primigenius*	1/1	4/2	79/4	55/9	684/11	630/31
Red deer – *Cervus elaphus*	56/5	17/5	3/1	14/6	8/2	4/2
Tarpan – *Equus ferus*			32/2	298/15	724/21	357/38
Boar – *Sus scrofa*		5/2		2/2	18/4	3/2
Dog – *Canis familiares*	+	8/2			43/5	6/3
Hare – *Lepus europaeus*	1/1	1/1		1/1		1/1
Fox – *Vulpes vulpes*	3/1	12/4		10/3	18/4	
Wolf – *Canis lupus*	8/2	11/4	+		41/7	
Corsac fox – *Vulpes corsac*	2/1	35/8		57/7	13/4	
Gazelle – *Gazella* sp.				118/24		
Tolai hare – *Lepus tolai*		2/1				
European badger – *Meles meles*					1/1	
Birds – *Aves*	1	1			21	
Tortoise – *Chelonia*					2	
Fish – *Pisces*		40			6	2

Tab. 1. The species composition and the numbers of vertebrate bone remains.

mestic cattle bones. For example, the M3 tooth length from the Neolithic sites changed from 44.7 to 47.1mm; the European aurochs from 41.0 to 54.0mm; the Kazakhstan aurochs from 39.1 to 53.4mm, and the Khvalinskiy cattle from the Volga region from 36.0 to 38.0mm. Only the biggest teeth from the sites of the Linear Pottery, Boyan, Gumelnitsa, and Maykopskiy cultures were of the same size, but this is because auroch bones were found with cattle bones at the same sites (*Tsalkin1970.50–53*). The same results were obtained by comparing the length of ankle bones (Tab. 3). Based on this information, we identified all Bos bones from Neolithic sites as aurochs.

Discussion

Jangar is the first site at which archaeologists supposed farming appeared in the region. Three cultural layers have been distinguished which included the bones of the saiga (*Saiga tatarica*), the onager (*Equus hemionus*), the horse, and cattle (*Bos* sp.). We believe that in the ratio domesticated to wild animals, the number of the first group increased, while the number of the second was reduced (*Koltsov 2004.134*). However, the statistics in the published table do not show such a tendency. Petr M. Koltsov (*2005.19–20*) states that materials which evidence a step in the evolution in people's lives

	Cultures				
	Caspian		Khvalynskaya		
	Kurpezhe-Molla	Oroshaemoye I	Karakhuduk I	KairshakVI	Kombak-Te
Sheep – *Ovis aries* and goat – *Capra hircus*	120/8	8/3	152/10	168/24	94/47
Cattle – *Bos taurus*			18/2	22/2	1/1
Wild ass – *Equus hemionus*	78/5	2/1	17/2	21/2	25/3
Saiga antelope – *Saiga tatarica*	154/5*	13/4	7/2	13/2	3/1
Tarpan – *Equus ferus*	1/1	10/3		19/2	
Red deer – *Cervus elaphus*	26/2			4/1	5/2
Aurochs – *Bos primigenius*	8/1	17/4	3/1		
Corsac fox – *Vulpes corsac*			10/1		3/1
Boar – *Sus scrofa*		2/1			
Wolf – *Canis lupus*	9/2				
Dog – *Canis familiares*				4/2	

Tab. 2. The species composition and the numbers of vertebrate bone remains.

Sites, culture	Date	Measurements [N–Min–Max–M]
	L M3	
Algay, Orlov	6800 ± 40, Neolithic	6 – 34.4–38.7 – 36.6
	L m3	
Aurochs (Denmark)[1]	Holocene	? – 46.0–53.3 – ?
Aurochs (Germany)[2]	Holocene	? – 44.0–54.0 – ?
Aurochs (Germany)[3]	Holocene	? – 41.0–44.5 – ?
Kozhai I[4], Tersek culture	mid. of 4th mil. BC, Eneolithic	9 – 39.1–48.1 – 44.8
Kumkeshu I[4], Tersek culture	mid. of 4th mil. BC, Eneolithic	28 – 41.5–53.4 – 46.2
Kaindy 3[4], Tersek culture	mid. of 4th mil. BC, Eneolithic	6 – 43.2–45.4 – 44.2
Algay, Orlov	6800 ± 40, Neolithic	3 – 44.7–45.1 – 44.9
Oroshaemoel, Caspian	5667 ± 100, Eneolithic	47.1
Cultures of Linear Band Pottery and Boyan[5]	mid. of 5th mil. BC, Neolithic	41 – 34,1–46,0 – 38,7
Gumelnitsa Culture[5]	1st half of 5th mil. BC, Neolithic	41 – 34,1–46,0 – 38,8
Maykopskiy Culture[5]	end of 5th mil. BC, Eneolithic	41 – 34,1–46,0 – 39,8
I Khvalinskiy site[6], Khvalinskiy culture	beginning of 5th mil. BC, Eneolithic	6 – 36.0–38,0 – 37,1
	GLl astragalus	
Aurochs (Eastern Europe)[5]	Holocene	125 – 74.1–95.0 – 83.2
Aurochs (Poland)[7]	Holocene	84 – 70.0–98.0 – ?
Algay	6800 ± 40	3 – 82.7–89.6 – 86.4
Ten-TeksorI, Seroglazov	6695±40; 6540±100	83.0
Varfolomeevka[8], Orlov	1st half of 6th mil. BC, Neolithic	32 – 71.3–91.9 – 82.6
Karakhuduk I, Khvalinskiy culture	beginning of 5th mil. BC, Eneolithic	74.0
Kairshak VI, Khvalinskiy culture	beginning of 5th mil. BC, Eneolithic	74.3
Körös[9] culture	6th millennium BC, Neolithic	18 – 58–76 – 69.7
Early Tripolye	2nd half of 5th mil. BC, Neolithic	20 – 62.0–96.0 – 77.2
Gumelnitsa Culture[5]	1st half of 5th mil. BC, Neolithic	50 – 59.0–93.0 – 71.9
Maykopskiy Culture[5]	end of 5th mil. BC, Eneolithic	73 – 60.0–86.0 – 72.2
Neolithic, cattle[7]		132 – 54.0–78.0 – ?

1 *Degerbøl 1942* (cited in *Tsalkin 1970*)
2 *Requate 1957* (cited in *Tsalkin 1970*)
3 *Boessnek 1957* (cited in *Tsalkin 1970*)
4 *Gayduchenko 1998*
5 *Tsalkin 1970*
6 *Petrenko 2000*
7 *Kobryn, Lasota-Moskalewska 1989*
8 *Gasilin* et al. *2008*
9 *Vörös 1980*

Tab. 3. Bone dimensions (in mm) of auroch (**Bos primigenius*****) and cattle (*****Bos taurus*****).***

were found in the upper layer of the site, because auroch, tarpan, and sheep bones similar to domestic species were collected. This means that the tarpan and auroch bones from the lower and middle layers were not domesticated. The sheep bones from the upper layer are not mentioned in the table. At the same time, Koltsov (*2005.316–321*) reports that Neolithic ceramics and flint were mixed with those of the Eneolithic in the same layer, which is why archaeologists identified the appearance of domestic animal bones with the Eneolithic materials (*Vybornov 2008*). This concerns only sheep bones, because it has not been proved that other bones from the upper layers of Jangar could be attributed to domesticated animals. Therefore, the suggestion that the context provides the evidence of Neolithic farming in the steppe (*Koltsov 2004.137*) cannot be regarded as realistic. According to the recently obtained radiocarbon dates, the lower and middle layers at the site date to the first quarter of the 6th, and the upper layer to the middle of the 6th millennium calBC (*Vybornov* et al. *2013*). The upper layer that contains Eneolithic material and sheep bones was dated to the beginning of the 5th millennium BC (*Koltsov 2004*). Varfolomeev is another site with a well-preserved cultural layer. It was differentiated into several levels: the lower level (layer 3) was attributed to the middle Neolithic; the middle layers (2B and 2A) were attributed to the late Neolithic, and an upper layer was attributed to the early Eneolithic age (*Yudin 2004*). On the basis of sheep bones, Yudin dated the appearance of farming to the second stage of the late Neolithic (layer 2A; *Yudin 2003*). However, we should note the author's statement that houses were built into the ground in the lower levels of the site (*Yudin 2004.18*). This means that the deposits of the lower layers could have included mixed artefacts as well as bone fragments. In addition, taphonomic processes may have caused the intrusion of auroch and tarpan bones from the upper layer 20 to layer 4 bellow (*Yudin 2004.195*). In Koltsov's opinion, the increasing quantity of these bones indicates that they were domesticated, but the example of the Varfolomeev site dis-

Sites, culture	Date	Measurements [N–Min–Max–M]
	GLl astragalus	
Ten-TeksorI, Seroglazov	6695 ± 40; 6540 ± 100, Neolithic	31.6
Oroshaemoe I, Caspian	5667 ± 100, Neolithic	2 – 29.4–32.0 – 30.7
Kuperzhe-Molla, Caspian	endof 6th mil. BC, Neolithic	9 – 28.6–31.9 – 30.4
Karakhuduk I, Khvalinskiy	beginning of 5th mil. BC, Neolithic	5 – 28.7–33.0 – 30.7
KairshakVI, Khvalinskiy	beginning of 4th mil. BC, Eneolithic	13 – 27.8–37.0 – 30.2
Kombak-Te, Khvalinskiy	Eneolithic	57 – 25.9–33.5 – 29.9
I Khvalinskiy site[1], Khvalinskiyculture	beginningof 5th mil. BC, Eneolithic	62 – 27.0–32.0 – 29.2
II Khvalinskiy site[2], Khvalinskiyculture	beginningof 5th mil. BC, Eneolithic	28 – 26.0–33.0 – 28.8
	GL metacarpale III+IV	
KairshakVI, Khvalinskiy	beginning of 5th mil. BC, Eneolithic	153.0
I Khvalinskiy site[1], Khvalinskiyculture	beginning of 5th mil. BC, Eneolithic	2 – 158–159 – 158.5
	GL metatarsale III+IV	
I Khvalinskiy site[1], Khvalinskiyculture	beginning of 5th mil. BC, Eneolithic	2 – 164–172 – 168

1 *Petrenko 2000* 2 *Bogatkina 2010*

Tab. 4. Bone dimensions (in mm) of sheep (*Ovis aries*).

proves the idea. Significantly, the number of saiga bones fell from 19 to 5 units in the layers mentioned. There was no precise diagnostic data proving horse domestication at this site. Concerning sheep bones, according to the published table (*Yudin 2004*), three animals were found in the upper layer (layer 1), but the level relates to the Eneolithic period. According to the radiocarbon dates, the late Neolithic materials in layer 2B date to the first quarter of the 6th millennium calBC, and layer 2A was attributed to the second quarter of the 6th millennium cal BC (*Vybornov* et al. *2013*). The same dates were obtained from the corresponding layers of Jangar. The dates of the Varfolomeevskaya site upper (Eneolithic) layer correspond to the dates of the upper layer of Jangar, the beginning of the 5th millennium calBC. During the second analysis of the Varfolomeevskaya bones, archaeologists failed to identify sheep bones in the upper and middle 2A layers (*Gasilin* et al. *2008.27*).

The Lower Volga Neolithic site at Algay was discovered and analysed in 2014 (*Vybornov* et al. *2015*). The cultural layer contains artefacts of the Orlov Neolithic culture only. According to the radiocarbon dates the site is embedded into the first half of the 6th millennium calBC. Only wild animal species were identified at the site such as auroch, tarpan, onager, saiga, and dog bones that predominate (see Tab. 1). Only the dog was definitely domesticated.

Animal bones have also been discovered at the main Neolithic sites of the Northern Caspian region, at Kairshak III (*Kozin 2004*) and Tentexor I (*Kuzmina 1988*). The Kairshak sites were attributed to the early Neolithic and dated from the turn of the first and second quarters of the 7th millennium calBC to the turn of the 7th and 6th millennium calBC (*Vybornov* et al. *2013; Vybornov 2014*). Onager, red deer, saiga, wolf, corsac fox, hare, and dog bones were identified at the sites. Late Neolithic sites such as Tentexor date between the beginning and middle of the 6th millennium calBC (*Vybornov* et al. *2013*). In Tentexor I, onager, saiga, aurochs, wolf, and horse bones were found. Irina E. Kuzmina did not believe they were domesticated, and dated the domestication process to the later Eneolithic culture (*Kuzmina 1988.182*).

The new Neolithic site at Baibek in the Northern Caspian region, excavated in 2013–2014, is attributed to the Seroglazov culture (*Grechkina* et al. *2014*). The cultural layer was found *in situ* and contained artefacts attributed to the early Neolithic only. Bones of onager, saiga, red deer, wolf, corsac fox, wild boar, auroch, fox, and hare (Tab. 1) were identified here. Dog was the only domesticated animal identified. The site was dated to between the end of the 7th and the beginning of the 6th millennium calBC (*Vybornov 2014*).

As we have discussed above, the analyses of Neolithic assemblages of the Lower Volga region showed the presence of wild animal species only. The dog is the only animal which can be regarded as definitely domestic if we consider the timeframe of the early Neolithic.

The bones of domestic sheep were identified in the territory of the Khvalinskiy culture in the middle

No.	Site	Index	Age (BP)	Age (calBC (2σ))	Material
1.	Kairshak III	Ua-41359	7775 ± 42	6690–6490	Crust
2.	Kairshak III	SPb_377	7700 ± 100	6830–6370	Crust
3.	Kairshak III	Ki-14633	7190 ± 80	6230–5890	Animal bone
4.	Kairshak III	SPb_316	7030 ± 100	6200–5710	Animal bone
5.	Baibek	Poz-57060	7350 ± 50	6370–6070	Crust
6.	Baibek	SPb_973	6955 ± 80	6010–5700	Animal bone
7.	Tenteksor I	Ua-35277	6695 ± 40	5680–5530	Crust
8.	Tenteksor I	SPb_315a	6540 ± 100	5640–5310	Animal bone
9.	Jangar layer 3–2	IGAN-2819	6870 ± 130	6010–5550	Carbon
10.	Jangar layer 2	Ki-14641	6780 ± 90	5840–5510	Pottery carbon
11.	Jangar layer 1	Hela-3255	6564 ± 44	5575–5470	Crust
12.	Varfolomeevskaya layer 3	GIN-6546	6980 ± 200	6250–5500	Carbon
13.	Varfolomeevskaya layer 2B	Poz-52697	6850 ± 40	5816–5659	Crust
14.	Varfolomeevskaya layer 2A	Ua-41361	6544 ± 38	5620–5580	Crust
15.	Varfolomeevskaya layer 2A	SPb_938	6650 ± 150	5900–5300	Crust
16.	Algay	Poz-65198	6800 ± 40	5741–5631	Crust
17.	Algay	SPb-1509	6654 ± 80	5708–5479	Animal bone
18.	Kurpezhe-Molla	Ki-14831	6050 ± 80	5150–4770	Pottery carbon
19.	Kurpezhe-Molla	Ki-14832	6020 ± 80	5080–4710	Pottery carbon
20.	Oroshaemoye I	SPb_938	5667 ± 100	4725–4336	Animal bone
21.	Karakhuduk I	Ki-14907	5980 ± 90	4850–4490	Pottery carbon
22.	Karakhuduk I	Ki-14911	5820 ± 80	5040–4680	Pottery carbon
23.	Kairshak VI	Ki-14909	5920 ± 80	4810–4450	Pottery carbon
24.	Kairshak VI	Ki-14910	5780 ± 80	5220–4600	Pottery carbon

Tab. 5. Radiocarbon dates for Neo-Eneolithic sites of the Lower Volga region.

Eneolithic (*Kuzmina 1988*). The sites of the culture date to the first part of 5th millennium calBC (*Morgunova* et al. *2010*). A few Caspian culture sites of the late Neolithic/early Eneolithic date to the second part of 6th millennium calBC.

At the Northern Caspian site of Kurpezhe-molla (*Barynkin, Vasylyev 1985*) only wild animal bones were identified through preliminary analysis, including saiga, onager, and auroch (*Kuzmina 1988.175*). However, after further study, we obtained different information showing the presence of sheep and goat (see Tab. 2). It is possible that they relate to a small quantity of later materials from the middle Eneolithic period of the Khvalinskiy culture. The site dates to the end of the 6th millennium calBC (*Vybornov 2008*).

Until recently, no Eneolithic sites with animal bones have been found in the Volga steppe region until recently. The situation changed in 2014, when the site Oroshaemoye I was analysed and a cultural layer found in situ with artefacts related to the Caspian culture. According to the archaeozoological results, the bones belong to saiga, auroch, tarpan, wild boar, onager and domesticated sheep and goat (Tab. 2). Thus it is the only site which could be attributed to the transition from the Neolithic to the Eneolithic where the bones of domestic animals may be observed. According to the radiocarbon analysis of animal bones, the site dates to the second quarter of the 5th millennium calBC. Similar dates were obtained in analyses of other sites of the culture in the Volga-Ural interfluve (*Morgunova* et al. *2010*). If we consider the sites of the Khvalinskiy culture which include undisturbed layers, such as Kara-Khuduk (*Barynkin, Vasylyev 1988*) and Kairshak VI (*Barynkin 1989*), they yielded both sheep as well as cattle bones (Tab. 2).

As mentioned above, no wild species of sheep or goat inhabited the territory in question; all bone finds are from domestic animals. The earliest example of domesticated sheep, an ankle bone, was discovered in Tentexor I and dated to the first half of the 5th millennium calBC (Tab. 1). It is now unclear whether it dates to the Neolithic or to a later period. However, it is possible to answer this question by radiocarbon dating. As already discussed, all the other Neolithic sites in the region lacked bones of domestic animals other than dog bones.

Confirmed bones of domestic animals appeared at sites of the Caspian culture. Sheep bones, which comprise the majority of the bone assemblage, and rare goat bones were discovered at sites Oroshaemoye I and Kurpezhe-Molla (Tab. 2). The sheep bones were large; their height, calculated on the basis of ankle bones (*Teichert 1975.63*), varied between 64–72cm, with an average of 69cm. This is suggested by the size of metapodia (see Tab. 4). No cattle bones were found at sites of this culture. These results probably reflect limited bone sampling (Tab. 2). At Kurpezhe-Molla, sheep and goat bones represent 47% of wild and domestic ungulate bones, which shows that these species played a very important role in nutrition.

Sheep and goats appeared together with cattle for the first time at sites of the Khvalinskiy culture (Tab. 2). In all areas, sheep (again comprising the majority) and goat bones predominated. Cattle were large, according to the analysis of ankle bones (*Tsalkin 1970.162*), as their average calculated height was 138cm. The sheep were also large, according to the analysis of ankle bone (Teichert 1975.63); their height varied from 59–84cm, with an average of 68cm. In the areas of the Khvalinskiy culture, sheep and goat bones were more numerous than ungulate hooves (Tab. 2) and comprised between 68–77%, while cattle made up from 1–9% and ungulates from 14–26%. Cattle breeding was of great importance in the Khvalinskiy culture, which is attested by the great abundance of cattle, sheep, and goat bones (*Bogatkina 2010.400–402; Petrenko 2000.13–14*).

Equus remains were discovered on the territory of all cultures (Tabs. 1, 2). We suppose the horse was domesticated later than cattle, sheep, goats, and pigs. The domestic horse appeared when people already had domesticated ungulates, which is why equid bones are from wild species, such as tarpan. It is more difficult to identify the equid bones from Eneolithic sites, since there were fewer equid remains, and other domestic ungulates were also found (Tab. 2). Equid bones were collected at Khvalinskiy culture sites, at Khvalinskiy I and Khvalinskiy II (*Bogatkina 2010.400–402; Petrenko 2000.13–14*), where both wild and domestic animals could have been used in mortuary rites. So the use of equid bones in such ceremonies did not indicate that people had domestic horses. In our opinion, the bones from the Khvalinskiy culture sites should be attributed to wild species of horse, possibly tarpan.

Conclusion

The analysis of faunal remains found at sites with undisturbed Neolithic layers in the Lower Volga region suggests that only wild animals were exploited. According to the radiocarbon dates, the Neolithic in the area dates to between the second quarter of the 7th and the middle of the 6th millennium calBC. The only domestic animal present in this time period was the dog. Thus the transition to the Neolithic age was not accompanied by a food-producing economy in the region. Domestic animal bones were found at early Eneolithic Caspian culture sites dating to between the middle of the 6th and the first half of the 5th millennium calBC. Cattle and sheep appeared in the Middle Eneolithic Khvalinskiy culture with other domestic animals, dating to the first half of the 5th millennium calBC. Further analysis is needed to understand how the Lower Volga population learned cattle husbandry.

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The 8200 calBP climate event and the spread of the Neolithic in Eastern Europe

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ABSTRACT – *At 8200 calBP, the beginning of the Atlantic period, there was a drastic change from warm and humid climatic conditions to cold conditions. The abrupt cooling at 8200 calBP has been documented in different parts of Europe. In western, and some parts of southern, Europe, this event was a trigger for new forms of economy and migrations of groups of Neolithic farmers. This paper considers the different ways in which ceramic traditions developed in eastern Europe in the steppe, steppe-forest and forest zones as a result of the rapid climate changes at about 8200 calBP.*

IZVLEČEK – *V času okoli 8200 calBP, to je na začetku obdobja atlantika, je prišlo do korenite spremembe klime, od toplih in vlažnih pogojev do ohladitev. Nenadna ohladitev v času 8200 calBP je dokumentirana v različnih delih Evrope. V zahodni in v delu južne Evrope je dogodek sprožil nove oblike gospodarstev in preseljevanje skupin neolitskih poljedelcev. V članku razpravljamo o različnih oblikah razvoja keramičnih tradicij na stepskih, gozdno-stepskih in gozdnih območjih v vzhodni Evropi kot posledico te hitre klimatske spremembe v času 8200 calBP.*

KEY WORDS – *rapid climate change; Neolithic; pottery; Eastern Europe*

Introduction

Until now, the Holocene has been considered as an interstadial period, with stable climatic conditions. According to Richard Tipping *et al.* (*2012*) the old paradigm of slow, gradual change (*Lamb 1977; 1995*) has been replaced by one in which change can be described as abrupt, occurring over short timescales of centuries or less, separated by comparatively long periods of quasi-stasis (*Mayewski* et al. *2004*). The 8.2ka years event was part of a climatic cooling period from *c.* 8600 to 8000 calBP (*Rohling, Pälike 2005; Thomas* et al. *2007; Walker* et al. *2012*) that interrupted the long-term trend of rising early-Holocene temperatures. The event lasted approx. 160 years (*Daley* et al. *2011; Kobashi* et al. *2007*). It has been detected as a marked cold snap in multiple paleoclimatic records from the Greenland ice cores and a variety of sedimentary records, especially in northern Europe (*Alley, Ágústsdóttir 2005; Seppä* et al. *2007; Thomas* et al. *2007; Walker* et al. *2012*). The abrupt cooling at 8200 calBP has also been documented in different parts of Europe. This evidence includes the stratigraphic record of lake drainage (*Barber* et al. *1999*), reconstructions of sea level rises (*Li* et al. *2012; Tornqvist, Hijma 2012*), and geochemical reconstructions of freshwater discharge from the Hudson Strait and northwest Labrador Sea (*Carlson* et al. *2009; Hoffman* et al. *2012*). The last global syntheses of proxy data around 8200 calBP were published recently (*Wiersma, Renssen 2006; Morrill, Jacobsen 2005; Rohling, Pälike 2005; Morill* et al. *2013*). There are fewer data available for Eastern Europe, and they are based mainly on data of pollen analysis. The high-resolution pollen diagram focusing on the 8400–7700 calBP interval in-

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dicates that the taxa with the most marked decline were Alnus, Corylus and Ulmus. In deposits from lakes located in Finland, the pollen analysis also registered abrupt climatic cooling at 8200 calBP (*Sarmaja-Korjonen, Seppä 2007; Seppä 2004; Veski* et al. *2004*). The end of this event is reflected as a sudden change between *c.* 8075 calBP and *c.* 8050 calBP, when the pollen proportions of Alnus (10%), Corylus (2%) and Ulmus (1.5%) increase to 13%, 4% and 2.5%, respectively. Some evidence for this event was obtained on the basis of geochemical analyses of lake deposits and radiocarbon date distributions for sites in the north-western part of Eastern Europe (*Kulkova* et al. *2015*).

At the beginning of the Atlantic period, the warm and humid climatic conditions changed to cold conditions drastically at 8200 calBP. It was the first considerable cooling after the Younger Drias. The temperature fell to 0.5–1.5°C in Europe, Greenland, Northern America, Asia, Northern Africa and the eastern part of northern Atlantic Ocean (*Seppä, Poska 2004; Rasmussen* et al. *2006; Vinther* et al. *2006; Morrill* et al. *2013*). According to the data of Ane Wiersma *et al.* (*2006*), the cooling was accompanied by dry climatic conditions. However, a dry climate prevailed in northern and southern Europe (*Magny* et al. *2003*). The humid climate in this period has been registered in several places in the middle latitudes of Europe, approx. between 43° and 50° north.

One of the main factors in climatic change is variation in solar activity (*Bond* et al. *2001; van Geel* et al. *2004*). There is a wealth of empirical evidence to support this theory, mostly based on isotopic data. The model experiments of Hugues Goosse *et al.* (*2002*) showed that variations in solar radiation could cause variations in thermohaline convection in oceans, as well as the polar atmospheric flows in both of hemispheres. These processes (*Lamy* et al. *2010; Magny* et al. *2003; Mullins, Halfman 2001*) weaken African and Asian monsoons and result in a fall in temperature and a thermal contrast between terrestrial and oceanic air masses. On the other hand, the increase and drift of Westerlies regulates the humidity balance in low and middle latitudes in response to changes in the thermal gradient between high and low latitudes. The territories affected by Westerlies are characterised by more humid conditions (*Bush 2005*).

The sensitivity of ecosystems to abrupt climate changes in the past has been considered by different scholars (*Hofmann 2000; Birks, Ammann 2000; Duigan, Birks 2000; Williams* et al. *2002; Baldia 2013*). The climatic changes caused by the abrupt cold event, most notably the cooling in the Northern Hemisphere and an increase in aridity in the lower latitudes are thought to have affected human populations in many parts of Europe and beyond (*cf. Binford 2001; Dincauze 2000; Kelly 1995*). The coincidence in the timing of this hemispheric-scale abrupt climate change or a rapid climatic change (RCC) (*Bond* et al. *1997; Mayewski* et al. *1997; 2004*) with transformations in prehistoric societies and economies in north-western Europe has been considered elsewhere (*Berger, Guilaine 2009; Berglund 2003; Turney* et al. *2006; Karlen, Larsson 2007*). The environmental changes were reflected in the records in various ways that are determined by such things as the severity of the effects of the changes on the ecosystem, the readiness of any given group to adapt, and the threat to group territory, as well as migrations, conflicts, and technological changes (see *Manninen 2014*). The demographic collapses caused by such crises and the following social and economic reorganisation can therefore be expected to be reflected in rapid changes in the record (*Riede 2009*).

The warm and humid climatic conditions at the beginning of the Holocene, the environmental changes, the increasing of availability and the diversity of food resources could have been factors in social transformation, such as an increase in population density (*Adger* et al. *2012; Gronenborn 2009; Munoz* et al. *2010; Riede 2009; Robinson* et al. *2013*). One of these events was the development of Mesolithic societies, whereas the formation of Mesolithic groups occurred probably during a cold climatic period. The transition from the Paleolithic to Mesolithic attributed to the Younger Drias period resulted in the complication of social structures, the occupation of new territories and the diffusion of small, independent Mesolithic groups over considerable distances (*Bell, Walker 2005; Bassetti* et al. *2009*). In western and some parts of southern Europe, the abrupt cold event at 8.2ka BP could have triggered new forms of economy, such as the Neolithic, and also triggered the migration of groups of Neolithic farmers (*Berger, Guilaine 2009; Weninger* et al. *2006; Budja 2007*). In the steppe and forest zones of Eastern Europe, these processes are not so clearly manifested.

The 8200 calBP climate event and the Neolithic population dispersal

A warm and humid monsoon climate prevailed in North Africa at the beginning of the Holocene, favourable to savannah with numerous lakes. The cooling and decreasing of African monsoons at 8200 calBP caused dry climatic conditions. Some authors (*e.g., Brooks* et al. *2005*) suggest that this period was a key point in the development of cattle pastoralism in the Sahara. Increased aridity is believed to have played a key role in encouraging the integration of cattle herding with existing hunting and foraging systems (*Holl 1998; Hassan 2002*). The exploitation of mountain pastures for goat and sheep grazing (possibly developed first in western Asia) was a result of drier conditions in the foothills of Libya. In this period, the dispersal and isolation of different cultural groups occurred all across the Sahara. These groups migrated to unknown territories in search of water and pastures. Subsequently, settlements grew up around water basins (*Brooks 2006*). The earliest settlements in the southern part of Egypt consisted of small groups engaged in cattle husbandry and pottery making (*Wendorf, Shild 1998*). The 8200 calBP climate event resulted in economic developments such as the appearance of small cattle and the growth of settlements with numerous fireplaces near large water basins.

According to Bernhard Weninger *et al.* (*2006*), the influence of the 8200 calBP event in Europe was greatest in Central Anatolia. The flourishing and well-established settlement at Catalhöyük-East was deserted quite abruptly around 8200 calBP. The site was reoccupied later, with a shift of the settlement by approx. 200m to a new position (Çatalhöyük-West). This settlement shift marks the beginning of the Early Chalcolithic in Central Anatolia. The impact of climate event on prehistoric groups in Anatolia, Cyprus, Greece and Bulgaria has been considered by various authors (*Staubwasser, Weiss 2006; Migowski* et al. *2006; Weninger* et al. *2006*).

The 8200 calBP climate event was associated with the transition from the Pre-Pottery to the Pottery Neolithic era, which was marked by the collapse of the 'ritual economy' and agricultural PPN aggregation centres in the Levant (*Budja 2007*). As he noted, this climatic anomaly correlates chronologically with the process of the neolithisation in the Near East and south-eastern Europe. The collapse of the agricultural PPN aggregation centre in the Levant correlates with the cooling period and aridity. The initial agriculture in the Peloponnese and most of the Balkans predate the climate event at around 8150–7950 calBP, but the 'Neolithic package' (for more detail, see *Cilingiroğlu 2005*) seems to have crossed the Danube and entered the southernmost region of the Pannonian Plain after the major climate fluctuations, and remained there for centuries (*Budja 2007. 196–197*).

Archaeological data and palaeoecological records suggest that the Neolithic acculturation process of the Carpathian Basin took place between approximately 8450–7450 calBP (*Sümegi* et al. *1998; Banffy, Sümegi 2012*). It was a period of various transformations in Neolithic society.

The spread of the Neolithic in Eastern Europe

The process of neolithisation in Eastern and Southeastern, Central and Western Europe differed significantly. While the 'Neolithic package' distribution, 'agricultural frontiers' spread and 'demic diffusion' (*Zvelebil 1998; Özdoğan 2001; Cilingiroğlu 2005; Budja 2013*) mark it in the latter, in Eastern Europe, the main marker of the Neolithic process was pottery appearance without any other Neolithic components. However, some different components of the Neolithic package have been be found at the site Rakushechny Yar in the Low Don River region (9050–8450 calBP) (*Belanovskaya* et al. *2003*) (Fig. 1). The earliest pottery and adobe architecture can be found in the Low Volga region (the Varfolomeevka site) (*Yudin 2000*). Also, the earliest pottery in this region appeared at sites in the Kairshak-Tenteksor group and Dzgangar-Varfolomeevka (9050–8650 calBP), and the Elshanian group in the Middle Volga River region (9150–7950 calBP) (*Vybornov* et al. *2008a; 2008b; 2010*).

The steppe and forest-steppe zones of Eastern Europe

Rakushechny Yar in the Low Don River region

One of crucial Early Neolithic sites in Eastern Europe, where almost all the components of Neolithic were found is at Rakushechny Yar (*Belanovskaya 1995*), located in the Lower Don River region (Fig. 1). Some types of pottery found at this site closely resemble ceramic types from other cultures of Eastern Europe. The artefact assemblage of this site is significant for understanding the process of neolithisation in the north-eastern Black Sea region. The radiocarbon dates, typological analogies of pottery, the specific bone industry, cattle husbandry, and adobe architecture reveal a similarity with Near Eastern sites, indicating an allochthonous character of the site (*Belanovskaya, Timofeev 2003; Belanovskaya* et al. *2003; Kotova 2002; Mazurkevich* et al. *2012*). Therefore, it should be considered a 'primary' centre for the development of some Neolithic ceramic traditions in the Low Volga and Don regions, the Upper Volga region, and the Dnepr-Dvina region.

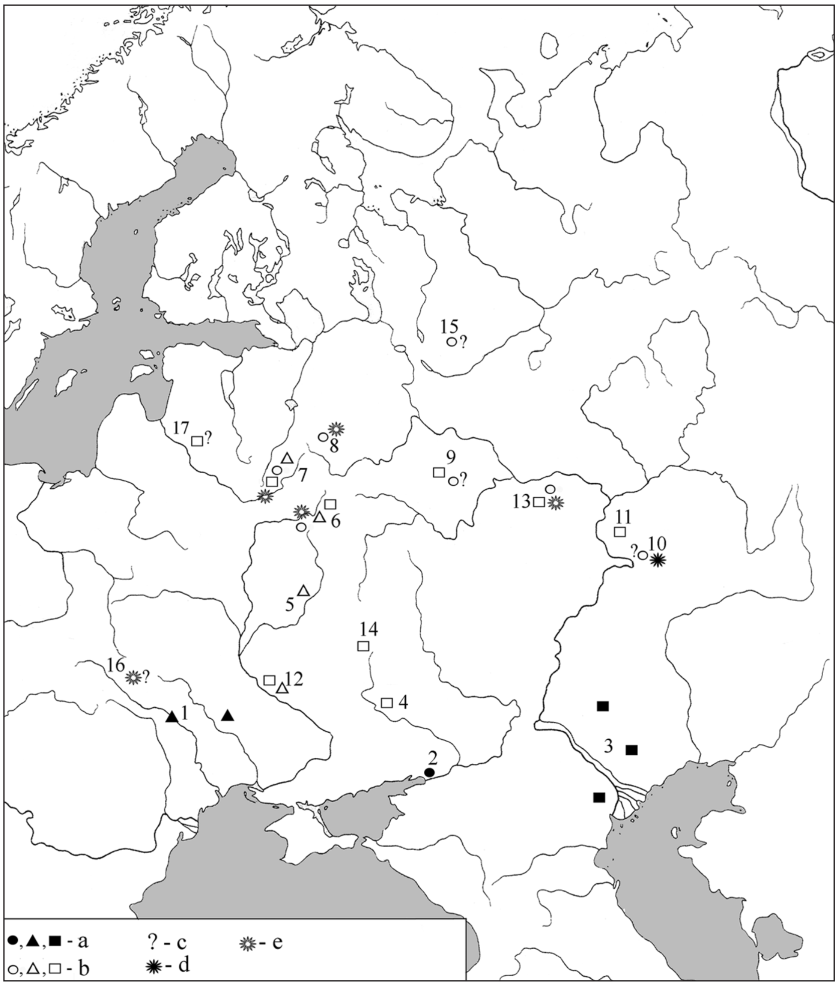

Fig. 1. Map of Early Neolithic site locations in eastern Europe. a – *'primary centres': 1 Bugo-Dnestr sites; 2 Rakushechy Yar site of the Lower Don region; 3 Kairshak-Djangar-Varfolomeevka sites in the Low Volga region.* b,c,d,e – *'secondary centres': 4 Middle Don River sites; 5 sites in the Desna River basin; 6 sites in the Upper Dnepr River basin; 7 sites in the Dvina River basin; 8 sites in the Valday region; 9 sites in the Upper Volga River basin; 10–11 sites in the Middle Volga river basin; 12 sites in the Dnepro-Donezk region; 13 sites in the Sursko-Mokshanian basin; 14 Karamishevo 9 site; 15 Berezovaya slobodka II-III, IV sites; 16 Gora Strumel site; 17 Zvidze site.*

The pottery from the Rakushechy Yar site has different shapes with flat bottoms (Fig. 2). Silt clay from deep and shallow water areas of the Don River basin was used for ceramic moulding. According to the petrographic analysis (*Mazurkevich* et al. *2013*) the ceramic paste consists of clay loam tempered with sand and grog (dried and ground clay). The coil technique with stretching of strips of clay was used to make some of the earliest types of ceramics. The surface of the pottery was smoothed after scratching, or polished and smoothed without scratching. This type of pottery was undecorated.

Another ceramic type from these cultural layers has decoration; the decorated fragments make up about 9% of the ceramic collection. A variety of ornamentation can be observed here: simple compositions consisting of triangular signs, I-shaped motifs made with the impression technique, combing incisions, lines and denticulated impressions made with the 'rocking-chair' technique. Different types of raw clay deposits were used for making this type of pottery.

The radiocarbon dates on food crusts from the early types of pottery date this site to *c.* 8700–7840 calBP.

The Kairshak-Tenteksor and Dzgangar-Varfolomeevka groups in the Lower Volga River region

According to Alexander Vybornov *et al.* (*2012*), sites of Kairshak complex existed on the semi-desert northern coast of the Caspian Sea from *c.* 8600 calBP onward. The pottery is characterised by flat bottoms, incisions as pottery decorations (after *Vybornov 2008a*) (Fig. 3), and is made of clay mixed with silt and shell. The local Mesolithic stone industry that persisted during the Neolithic period is characterised by artefacts such as geometric microliths in the form of segments and parallelograms. These Neolithic sites present a local type of neolithisation.

On the north-west coast of the Caspian Sea, the earliest sites of the Dzhangar type (Tu-Buzgu-Huduk I site) were dated to the first half of the 8th milennium BP. The main innovation was the appearance of pottery (Fig. 3). The Kairshak and Dzhangar cultures influenced the development of the Orlovskaya cultural tradition in the Middle Volga River region around *c.* 8500–8400 calBP. The earliest Neolithic

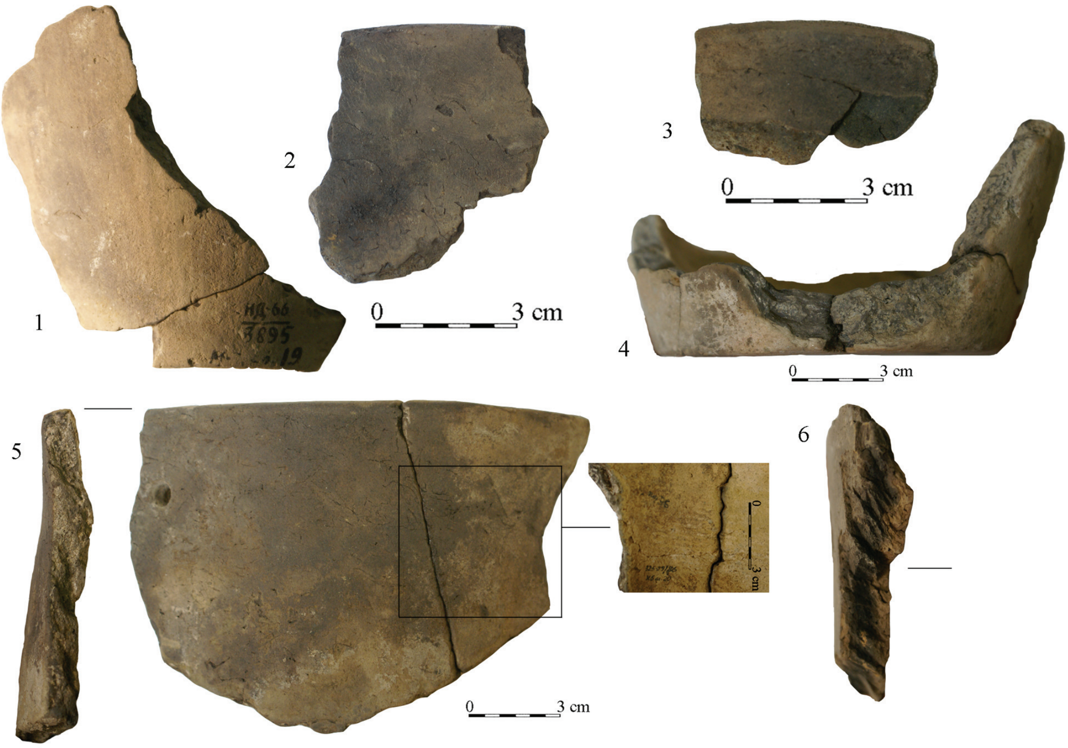

Fig. 2. The earliest (8700–7840 calBP and earlier) Neolithic pottery from the site Rakushechny Yar (bottom layers).

ceramics from the Djangar-Varfolomeevka sites were made from silt clay with sand and organic inclusions. The pottery has a closed shape with flat walls and flat or roundish bottoms. The decoration in the upper part was made with triangular and oval pins; the motifs consist of horizontal rows and horizontal zigzags (*Vasilieva, Vybornov 2013; Vybornov 2008b*).

The Elshanian cultural group in the Middle Volga River basin

The earliest Neolithic sites with 'Elshanian-type' pottery are located between the steppe and forest steppe zones in the Middle Volga River basin (Fig. 1). The most important sites of the early stage are the Ivanovo site on the Samara River and the Chekalino on the Sok River (*Vybornov 2011*). The pottery was made of plastic clay. It has pointed bases with impressions and incisions (Fig. 4) (*Vasilieva, Vybornov 2013*). The ^{14}C dating of different materials (such as foodcrusts, bones, pottery) from these sites dates the Elshanian ceramics to *c.* 8760–8000 calBP. The closest analogues to the typological and technological characteristics of Elshanian pottery were found on the eastern coast of the Caspian Sea and the Central Asian interfluves at the Uchaschy, Daryasay, and Dzhebel sites (*Vybornov* et al. *2012*). Radiocarbon dates on the earliest Neolithic materials in Central Asia have the same age (*Brunet* et al. *2012*). No sites in the Volga region of the steppe forest dating to 8350–8100 calBP have been found (*Vybornov* et al. *2010*).

At the end of the 8th millennium BP, some Elshanian groups occupied the north-western Middle Volga region in the Sura River valley. The Vyunovo Ozero I and Utuzh sites, the Ozimenky site in the Moksha River basin (*Vybornov 2011*), the Imerka 7 site, the Plautino I and IV sites in the south-western part of the middle Khoper River, the Ustie Izlegoshy site in the Upper Don region, and sites of the Karamishevo type (Ivnitsa and Karamishevo 5 and 9 sites; see *Smolyaninov 2012*) date to this period.

Because of the 8200 calBP climatic event the groups which produced the 'Kairshak type' pottery moved from the northern Caspian shore towards the steppe region of the Volga River basin and the northwestern coast of the Caspian. They influenced the development of the Varfolomeevka and Dzhangar traditions in these regions. The characteristics of the pottery, the ornamentation techniques, and motifs support this. The process of neolithisation on the north coast of the Caspian and the Lower Volga regions was embedded in the period *c.* 8500–7900 calBP (*Vybornov* et al. *2008b*) (Fig. 1).

The climate in the steppe and forest steppe regions was more arid than today (*Lavrushin, Spiridonova*

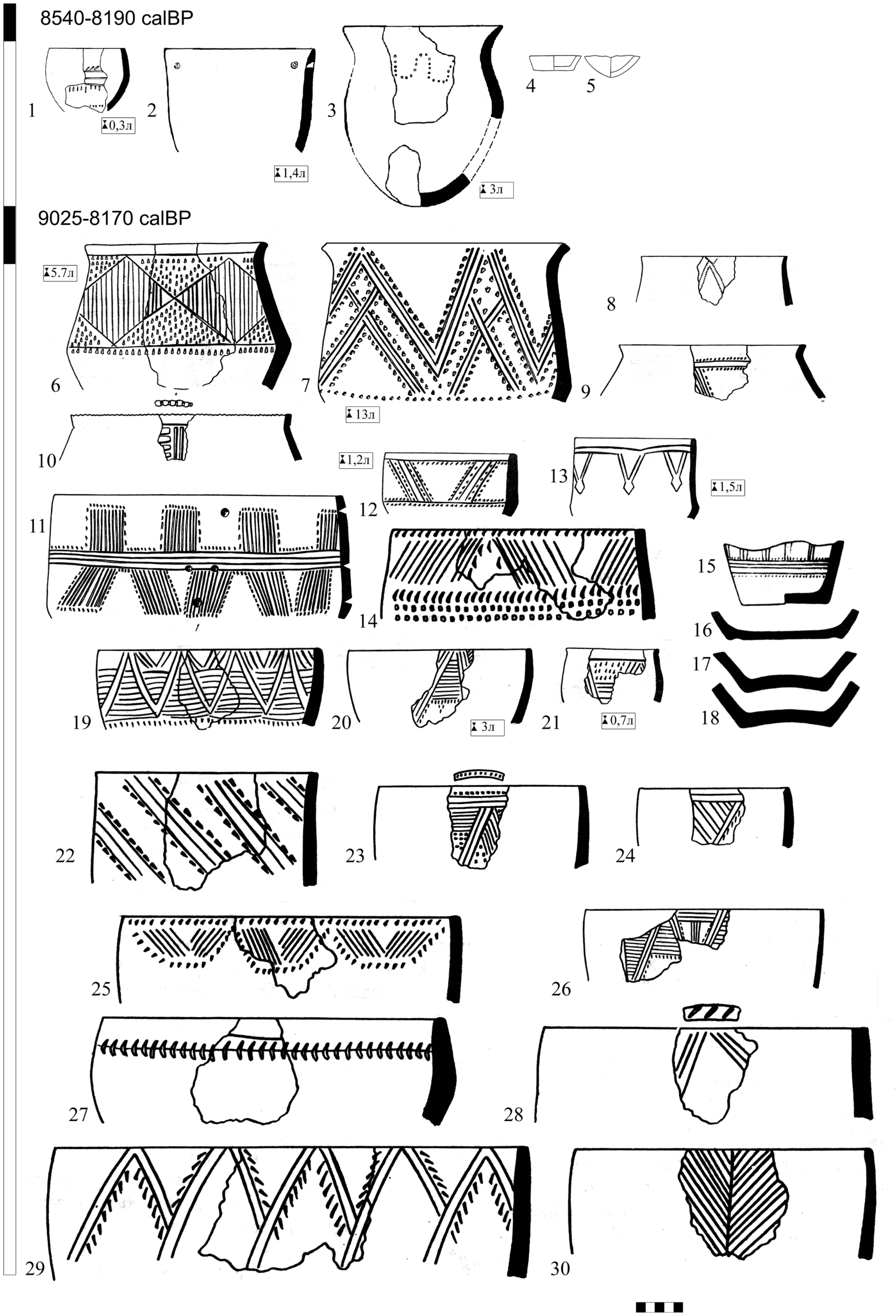

Fig. 3. Pottery from the Lower Volga region: 1–2 Kugat IV; 3 Kulagaisi; 4–5 Tu-Buzgu-Huduk I; 6–30 Kairshak (after **Vybornov 2008*).***

1990; 1995; Levkovskaya 1995; Spiridonova, Aleshinskaya 1999; Mamonov 2006). The forest steppe zone transformed into the forest zone only recently. There was steppe, with patches of forest inside river valleys. Naturally, in dry periods the forest zone with woodlands and rich food resources was a favourable area for people from more southerly regions (*Arslanov* et al. *2009; Vybornov 2011*).

The forest zone of Eastern Europe

In the forest zone of Eastern Europe generally only one component of the Neolithic was distributed, namely pottery, the characteristics of which allow to us to make conclusions about the process of neolithisation in this part of Europe.

The Dvina-Lovat River region

The detailed studies of artefact assemblages of the Dvina River Region allow us to distinguish several ceramic traditions that were defined as 'ceramic phases' (see *Miklayev 1994*).

Lakes in the Dvina-Lovat River region were mainly formed at the end of the Pleistocene – beginning of the Holocene within fluvioglacial and moraine depressions after the recession of the Late Würm stage ice-sheet. The further development of the lake systems relates to the humid period, when most of them were transformed into peat-bogs in the Late Holocene (*Davidova 1992*). However, some authors (*Miettinen 2002; Lak 1975*) argue that the tectonic processes of the Fennoscandian shield had more influence on the development of the drainage network on the north-western Russian plateau and the water fluctuations in the lake basins than climatic changes during the Holocene.

At the beginning of the Holocene, the Serteya valley consisted of large and deep lakes with steep slopes. More than 38 early Neolithic sites have been found in this region (Fig. 1) (*Mazurkevich* et al. *2012*). The Early Neolithic Serteya culture includes ceramic phases 'a', 'b', and 'b–1'. Other cultural traditions comprise the ceramic phases 'a–1', 'c–1' and also 'a–2', and 'b–2' (*Mazurkevich* et al. *2008*) (Fig. 5).

Ceramics from the 'a–1' phase (Fig. 5) were made from clay tempered with sand and grog. The coil technique was used to make the pottery, which consisted of small circular coils. Traces of scratching treatment were visible both on the outer and inner surfaces of vessels. There are sherds with smoothed and polished surfaces. Ceramics of this type has no decoration. The pots are open or straight, with small cambered flat edges, similar to a cylindrical form. This type of pottery has analogues with undecorated vessels from the lowest layers of the Rakushechny Yar site.

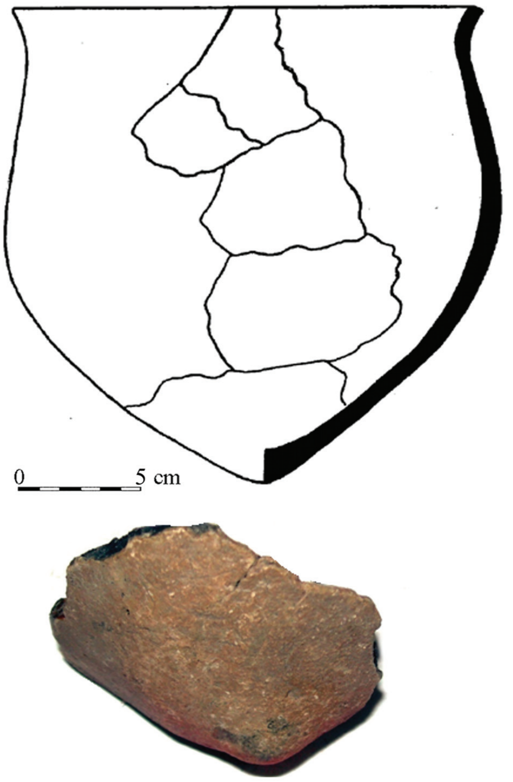

Fig. 4. 'Elshanian type' pottery from the site Chekalino at 8760–8000 calBP (after **Vybornov** *et al.* **2010*).***

The radiocarbon date on food crust of ceramic type 'a–1' from Serteya XIV site falls within the interval between 9520–9270 calBP; due to the reservoir effect, this date is probably too old ($\delta^{13}C$ in food crust is –33.8‰) (*Fischer, Heinemeier 2003*). Nevertheless, it falls into the earliest typological interval of ceramic tradition (see more detail in *Mazurkevich* et al. *2013*). Due to the proposed correction based on modern sample dating (*Kulkova* et al. *2014*) it can be attributed to the beginning of the 9th millennium calBP; the lowest cultural layers from the Rakushechny Yar site also match this date.

Another ceramic type relates to phase 'a' (Fig. 5). This type of pottery was formed from clay tempered with sand and grog, or from silt clay with organic inclusions without temper. The coil technique was used for moulding. The outer and inner surfaces were treated by scratching and then smoothed. This pottery was decorated with incisions and has analogues with ceramics from sites in the Low Volga River basin and in the Middle and Upper Don River basin.

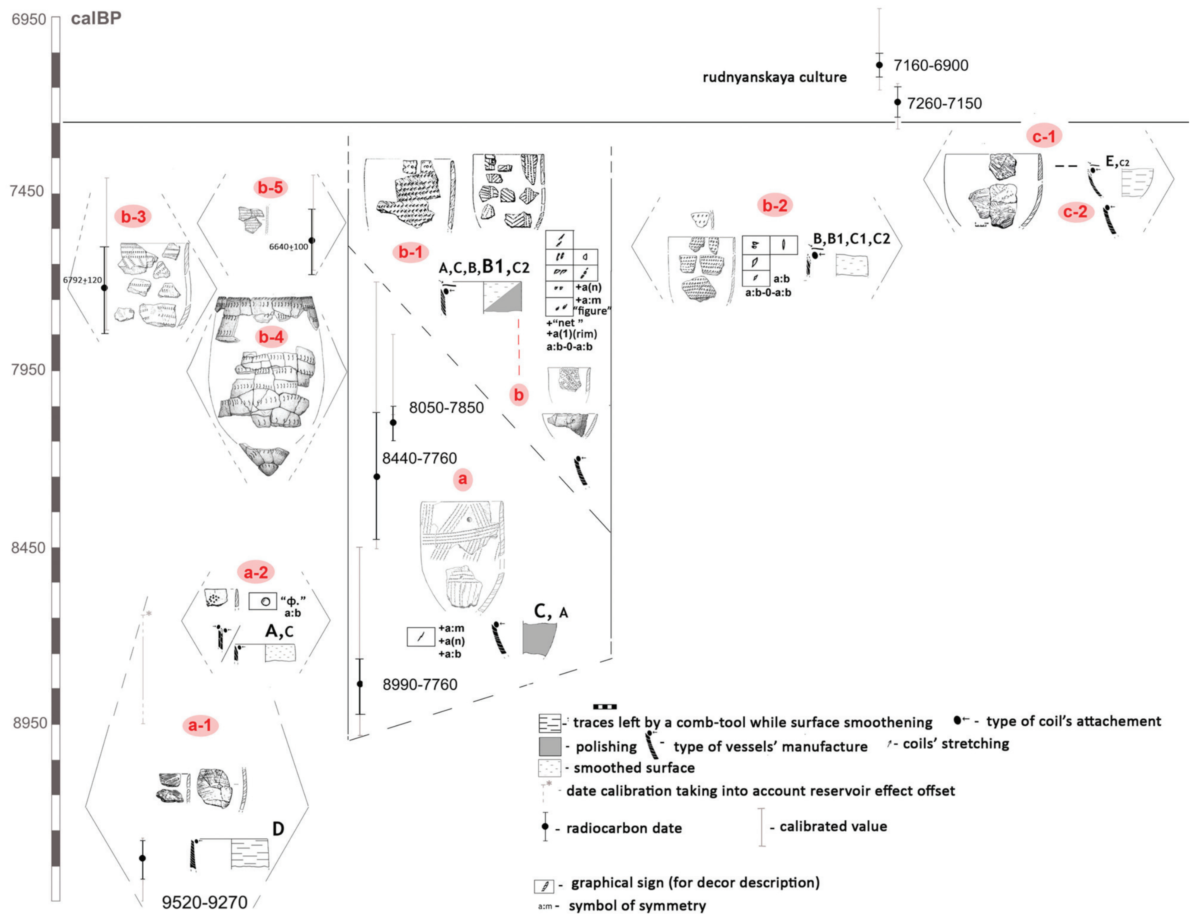

Fig. 5. Types of Early Neolithic pottery from the Serteya River basin.

The radiocarbon date of wood from the layer with ceramic type of phase 'a' is 8400–7760 calBP (*Timofeev* et al. *2004*) (Fig. 5). The age of the food crust on pottery from Rudnya Serteya site is 8990–8500 caBP. The cultural tradition represented by ceramic phase 'a–2', which is similar to Elshanian cultural traditions, can be dated to the same time. The ceramic tradition of local phase 'b' was formed on the base of ceramic phase 'a' between *c.* 8200–7900 calBP (*Mazurkevich* et al. *2013*).

After *c.* 9450 calBP, the water level fell in the Serteya valley lakes. The regression minimum was dated to *c.* 8550 calBP. This was quite a warm period, but the climate remained dry. The bio-productivity of the lakes decreased. Data shows a decrease in population during this period (*Mazurkevich* et al. *2009*). Paleogeographical studies indicate that there was a short period of cooler and drier climate beginning at *c.* 8200 calBP, which coincided with the rapid regression of lakes in the Serteya valley due to tectonic processes in Fennoscandia and the transgression of the Baltic Sea. This caused an increase in the lake's bio-productivity, as well as strengthening the anthropogenic influence on the lake system. The data provides evidence of population growth. Thus, the 'a-1' and 'a' phases of the Serteya tradition began earlier than 8200 calBP, and further pottery groups of the phases 'a-2' and 'b' were formed (*Mazurkevich* et al. *2012; Mazurkevich, Dolbunova 2012; Mazurkevich* et al. *2013*).

The Upper Volga River region

According to various studies (*Krainov, Khotinsky 1977; Zetlin 2008; Engovatova* et al. *1998; Zaretskaya, Kostyleva 2008*), the Neolithic culture of the Upper Volga River went through several stages. Undecorated ceramics constitute an element in the first stage of the Upper Volga culture. The data obtained show that various typological and technological styles can be differentiated within the undecorated pottery. Because of the complicated cultural processes present in the Volga-Oka basin, it is probable that similar ceramic groups from other sites of the Upper Volga River basin varied in the same way.

The earliest ceramics were cylindrical shape or with a partly closed rim (Fig. 6a). Only a few fragments of this type have been found. Similar examples of this type can be found in the pottery assemblage from the Rakushechny Yar site, the Dvina River basin sites (ceramic phase 'a-1') and the Valday culture ('type 1'). The radiocarbon dates of this type from the Zamostje 2 site obtained from the food crust on vessels fall into the long interval from 8600–7300 calBP (*Meadows* et al. *2015*).

Another undecorated ceramic type from this collection is characterised by the use of coil stretching and molding with slabs. The clay paste contains shells. The outer and inner surfaces were treated by pebble smoothing and, as a result, coarse particles appear on the surface of the pottery walls (Fig. 6b). The shapes are either closed in the form of convergent cones or biconical. The radiocarbon dates of the food crusts on pottery fall into the period between 8200–7620 calBP (*Meadows* et al. *2015*). This ceramic tradition is represented by different types of undecorated pottery which has analogues in assemblages from the Middle Volga River sites, the Valday site, and the Berezovaya Slobodka II-III site. The radiocarbon dates on the wood and charcoal from Berezovaya Slobodka II, III cultural layers with the finds of decorated and undecorated pottery fall into the interval between 8200–7980 calBP (*Timofeev* et al. *2004*). Organic material (bone, peat) from layers containing Upper Volga pottery dated between 8200–7400 calBP (*Lozovski 2003*).

The Early Neolithic cultural layers containing the Upper-Volga ceramics were found in the Mesolithic layers of the sites at Ivanovskoe 3, 7, Sahtish 2a, Stanovoe 4, Ozerki 5 and Zamostje 2 (*Kostyleva 2003*).

For the period from *c.* 8400–8100 calBP, some authors (*Spiridonova, Aleshinskaya 1996; Aleshinskaya* et al. *2001*) have found the beginning of a reduction in water levels in the basin in this region on data from proxy indicators from peat-lake deposits. This process is connected with aridisation, mostly in the steppe and forest-steppe zones. Complete aridisation occurred at *c.* 8100 calBP, which the authors suggest marked the natural transition from the Mesolithic to Neolithic in central Russia.

The appearance of Neolithic traditions among Mesolithic hunter-gatherers can be connected with migration of Neolithic farmers. Environmental factors were probably among the causes: the transition from the Mesolithic to the Neolithic (at *c.* 8200 calBP) was characterised by complete aridisation not only in the steppe and forest-steppe zones, but also in the forest zones in Eastern Europe. These changes have been recorded in the pollen spectra for various parts of Eastern Europe (*Spiridonova, Aleshinskaya 1999*). As noted by Elena Kostyleva (*2003*), migration did not include the whole population, but instead could have been in the form of small groups dispersing from the southern to northern regions.

Discussion and conclusion

At around 8200 calBP cold and dry climatic conditions were present in the Dvina-Lovat basin and the Upper Volga river region. These cold and dry conditions were an abrupt event that occurred in many areas of Eastern and Western Europe, as well as in the Middle East (*Kofler* et al. *2005; Magny 2003; Mayevsky* et al. *2004, Aleshinskaya, Spiridonova 1999*). A fall in river and lake water levels caused significant environmental transformations, provoking widespread migration (*Mazurkevich* et al. *2013*). The high water level in the lakes of Dvina-Lovat basin, related to isostatic processes in the Baltic Sea, was one of the factors that attracted people in this area from the dry regions of the centre and south of the East European Plain (*Kulkova* et al. *2015*).

The earliest Neolithic pottery appeared in the period from 9500 to 8950 calBP. This is the undecorated pottery found at various sites in Eastern Europe (*Mazurkevich, Dolbunova 2012; Mazurkevich* et al. *2013*) including at Serteya XIV (Dniepr-Dvina region, phase 'a-1'), Rakushechny Yar (Low Don River, bottom layers), and later, at the Zamostje 2 (Upper Volga region, types '4' and '7') sites.

In the period from 8950 to 8200 calBP, ceramics decorated with a retreating incised style have been found at North Caspian sites (*Vybornov* et al. *2012*) (Kairshak III site, Kizilkhak, Varfolomeevka (layer 3), Kugat IV), in the Low Volga region, and in the Dnepr-Dvina basin (Rudnja Serteya, phase 'a'). At almost the same time, *c.* 8200 calBP, the ceramic types 'b' and 'a-2' appeared in the Dvina-Lovat basin.

Pottery decorated with retreating incised style and with impressions in the period between 8200–7350 calBP was found at North Caspian sites and in the Low Volga region (including at sites such as Kairshak I and III, Djangar – layer 3, Varfolomeevka – layer 2B), in the Middle Volga region (II Sherbetskaya), the Dniepr-Dvina region (Serteya X – phase 'a'), Upper Volga region (Sakhtysh 2a, Zamostie 2), Sukhona River region (Berezovaya Slobodka II-III), and other regions of Eastern Europe. During the period from 7950 to 7350 calBP, new types of undecorated pottery also appeared at several of these sites.

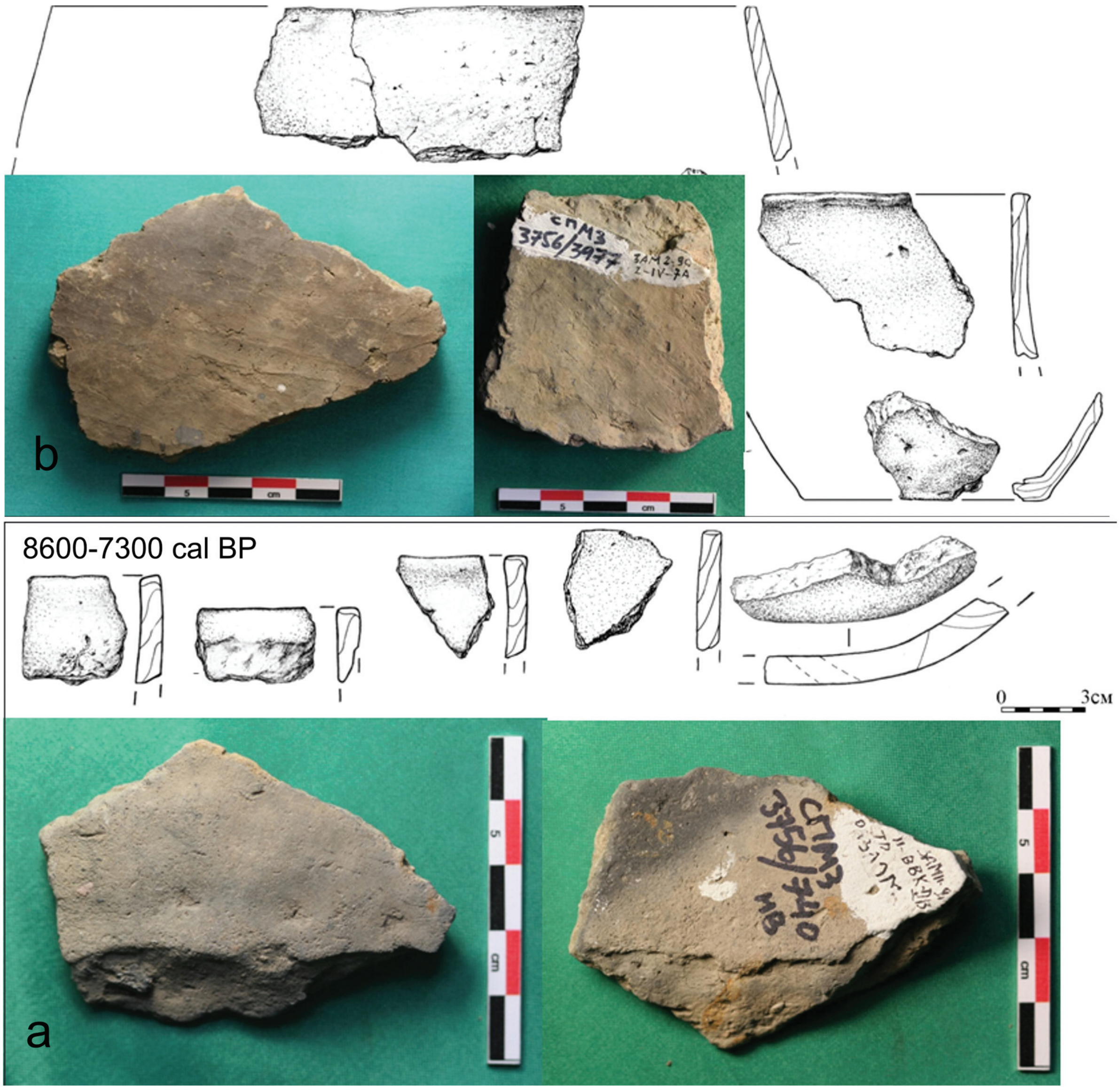

Fig. 6. a – Typology of 'type 1' undecorated Early Neolithic ceramics from site the Zamostje 2 at 8200–7620 calBP; b – typology of 'type 2' undecorated Early Neolithic ceramics from Zamostje 2.

The radiocarbon dates show the very fast propagation of the pottery within groups of local Mesolithic people in Eastern Europe (*Belanovskaya, Timofeev 2003*). There is a 'paradox of speed' in the spread of pottery. Both the appearance of Neolithic traditions at primary sites and the spread of pottery to other regions occurred during a short time. The migrants bearing ceramic traditions probably moved along the main waterways of Eastern Europe in meridional directions. At the same time, the river currents in latitudinal directions became natural barriers to the distribution of earliest pottery traditions, according to the distribution of early Neolithic sites (*Dolukhanov* et al. *2009a*). These sites where pottery traditions were newly established, 'small islands of innovations', were secondary centres from which ceramic traditions spread among local Mesolithic groups (during the second half of 9th and in the beginning of 8th millenium BP). The ceramic traditions remained the same for a long time and, therefore, pottery from different periods has very similar typological characteristics (*Mazurkevich* et al. *2006*). A small population occupied ecological niches as poor soil fertility, long winters and abundant terrestrial and water food resources were features of most of Eastern Europe (*Dolukhanov* et al. *2009b*).

The most drastic climatic changes connected with the global climatic fluctuations were reflected in the distribution of different cultural traditions. The main migrations were probably from regions with the worst environment, in which the biomass had decreased, to regions with more favourable environmental conditions. Some evidence can be traced on the basis of the ceramic traditions at sites in the steppe, forest-steppe, and the forest zones of Eastern Europe. In the period of sharp climatic deterioration, ancient groups of people began to relocate. The density of population and settlements of different groups of people increased in certain micro-regions, as a rule with a more favourable environment. The most cold and dry climatic event occurred *c.* 8200 calBP, which influenced the reduction of water and food resources in the steppe and forest-steppe zones of Eastern Europe. In the forest zone, these changes were less clear. The transgressions in the Baltic Sea and inner lake basins connected by a hydrological network in regions such as the Dvina-Lovat basin, which were rich in natural resources, were one of the causes that attracted people in this period. Groups with different cultural traditions interacted, and exchanged experience and technologies. These groups arrived in several places in Eastern Europe. Different stylistic types of pottery dated to the same period can be found at one site. We can suggest that people of different cultures occupied the most favourable places at the same time during the period of climatic deterioration, for example, in the migration from the steppe and forest steppe zones to the forest zone.

The analysis allows us to consider impulses in the development of human groups in the period of the climatic cold event at 8200 calBP. In the drastic cooling and arid event population density was redistributed, and settlements were consolidated in places favourable for survival. The appearance of ceramic traditions among Mesolithic groups in Eastern Europe illustrates this event: this was a distribution of technology from less favourable to more favourable places. The 'primary centres' of neolithisation emerged in the Eastern Europe territory before the climatic cold event, but the appearance of pottery traditions at secondary centres began in the same period. Local Mesolithic people accepted only pottery technology, while hunting and gathering remained their main form of subsistence in the forest zones for a long time.

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Cultural and demic diffusion of first farmers, herders, and their innovations across Eurasia

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ABSTRACT – *Was the spread of agro-pastoralism from the Eurasian founder regions dominated by demic or by cultural diffusion? This study employs simulations that unfold a complex inter-regional and time varying pattern of demic and diffusive exchange processes during the Neolithisation, and thus supports from a modelling perspective the hypothesis that there is no simple or exclusive demic or cultural diffusion, but that in most regions of Eurasia a combination of demic and cultural processes were important.*

IZVLEČEK – *Je bila pri širitvi kmetijstva iz evrazijskih jedrnih območij pomembnejša demska ali morda kulturna difuzija? V študiji uporabimo simulacijo, ki proces neolitizacije modelira kot kompleksne medregionalne in časovne vzorce demske difuzije in širitve skozi menjave. Model pokaže, da ni preproste in izključujoče razlage, bodisi demske ali kulturne difuzije; v večini evrazijskih regij je bila na delu kombinacija demskih in kulturnih procesov.*

KEY WORDS – *cultural diffusion; demic diffusion; modelling; Neolithic; Eurasia*

Introduction

The transition to agriculture and pastoralism, termed the 'Neolithic revolution' by Vere Gordon Childe (*1925*) fundamentally changed social systems and the relationship of people and their environments. However revolutionary – even termed 'traumatic' (*Rowley-Conwy 2004*) – this transition was locally, the more gradual it appears on the continental scale, spanning almost 10 000 years of human prehistory and history (*e.g.*, *Barker 2006*).

The spatial diffusion of the new agro-pastoral and animal husbandry innovations, technologies, and lifestyles played a major part in the abandonment of a foraging lifestyle following local innovations in only a few places worldwide that are associated with the domestication of plants and animals (*Fuller* et al. *2014*). From these few founder regions, the new domesticates, knowledge of their cultivation and the idea of farming and herding itself spread to all but the most secluded or marginal regions of the world; not only did these cultural traits spread, but also the people who carried along their 'hitchhiking' traits (*Ackland* et al. *2007*).

Consequently, the spatio-temporal pattern of dated Neolithic sites radiates outward from the founder regions. For different cultural and individual traits, the apparent rates of spreading can be determined (*Edmonson 1961; Bocquet-Appel* et al. *2012*), but it is unclear from the spatio-temporal analysis of dated sites as to what process dominated the expansion (*Lemmen* et al. *2011*). Within a broad spectrum of diffusion mechanisms that include, *e.g.*, leapfrog migration and elite replacement (*Zvelebil 1998*) demic diffusion and cultural diffusion represent two contrasting views that have received widespread attention in the literature. The demic diffusion hypothesis suggests the introduction of the new agro-pastoral technologies through movements of people: migrations of any kind; the cultural diffusion hypothesis suggests a technology shift through indigenous adaptations and inventions fostered by culture contact: information dispersal of any kind.

Demic diffusion, *i.e.* the spread of agro-pastoralism by migration of people has been put forward as one of the earliest hypotheses for explaining the spatio-

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temporal pattern of Neolithic arrival dates in Europe (*Clark 1965*); evidence for demic diffusions is accumulating with modern mtDNA and Y-chromosomal analyses, revealing matrilineal and patrilineal relationships in space and time (*Chikhi* et al. *2002; Deguilloux* et al. *2012; Fu* et al. *2012*) (although contrasting views have been presented by Vincenza Battaglia *et al.* (*2008*) and Wolfgang Haak *et al.* (*2010*)), and with earlier linguistic work (*Renfrew, Level 1987*).

Cultural diffusion is the spread of agro-pastoralism by information and material transmission in the absence of migrations. As both maternal and paternal genetic lines are continuous from the founder regions into Europe, approval for the cultural diffusion hypothesis depends on a temporal mismatch between the expansion of traits and knowledge and the expansion of people. Already Albert J. Ammerman and Luigi L. Cavalli-Sforza (*1973*) suggested that both demic and diffusive spread are active and that it is the relative contribution of each that needs to be investigated, rather than deciding on either demic or cultural diffusion. Furthermore, cultural diffusion theories have also been put forward as a reaction to processual diffusionist views and emphasise the agency and innovativeness of local populations (*Hodder 1990*) (but refuted again by *e.g.*, *Rowley-Conwy 2004*).

Mathematical models on the spread of agro-pastoralism have a long tradition in Europe and can be traced back to Childe's (*1925*) observations on the spatio-temporal distribution gradient of ceramics from south-eastern to North-western Europe. This pattern was replicated from Neolithic radiocarbon dates by Grahame Clark (*1965*), and subsequently mathematically formulated by Ammerman and Cavalli-Sforza (*1973*) as the 'wave of advance' model on which many subsequent formulations have been built (*Ackland* et al. *2007; Galeta* et al. *2011; Davison* et al. *2009*).

A common feature of diffusion models is concentric expansion from one or multiple centres of supposed origin, with modifications introduced to account for geographic bottlenecks, terrain, or rivers (*Davison* et al. *2006; Patterson* et al. *2010; Silva, Steele 2014*). Joaquim Fort (*2012; 2015*) attempted to disentangle demic and cultural diffusion from both a modelling as well as a data perspective. In a diffusion model, he found that both demic and cultural diffusion are important, with demic diffusion responsible for 60% (*vs.* 40% for cultural) of the spreading process. Similarly, our own investigation (*Lemmen* et al. *2011*) concluded that a mixed model produces a pattern of Neolithisation that best accords with the data.

Far fewer numerical studies have been performed for Eurasian regions outside Europe. The best investigated cases are probably South Asia and the Indian subcontinent. For this region Graeme J. Ackland *et al.* (*2007*) investigated the transition to agriculture as a diffusion process that emanates from a single founder region in Southwest Asia; in contrast, Mark A. Patterson *et al.* (*2010*) reported on a simulation of the Neolithic transition in India expanding from two centres, representing Chinese and Harappan migration streams. Our own simulations for the Indian subcontinent showed that the connection from the Indus region to the Levant was established only after the transition to agropastoralism (*Lemmen, Khan 2012*), consistent with the wheat/rice barrier identified by Graeme Barker (*2006*). The demic-cultural debate has not been investigated for greater Eurasia yet.

In the current study, I demonstrate with numerical simulations how the different assumptions about the diffusion process – interpreted as demic diffusion and cultural diffusion or a mixture thereof – may have played different roles in the spread of agropastoralism through Eurasia. Emanating from founder regions in North and South China, Central Asia, and the Levant about 9000 years ago, the entire continent (except Northern Eurasia) transitions to agropastoral life-styles by 3000 calBC, drawing a complex picture of cultural and demic diffusion.

The goal of this study is to investigate qualitatively the spatial and temporal predominance of either cultural or demic diffusion processes within Eurasia, and to provide a novel visualisation of the complexity of the interplay between these processes at a continental scale.

Methods

I employ the Global Land Use and technological Evolution Simulator (GLUES, *Lemmen* et al. *2011*) – a numerical model of prehistoric innovation, demography, and subsistence economy – to hindcast the regional transitions to agropastoralism and the diffusion of people and innovations across Eurasia for the period 7500–3500 calBC.

The model operates on 294 (country-like) spatial units within the domain –15°E to 135°E and 10°N to 60°N (Fig. 1). These regions represent ecozones that have been derived to represent homogenous net primary productivity (NPP) clusters based on a 3000 calBC 1° x 1° palaeo-productivity estimate (*Wirtz, Lemmen 2003*); this estimate was derived from a dynamic palaeovegetation simulation (*Brovkin* et al. *1997*) scaled down with the Mark New *et al.* (*2001*) climatology. By using NPP, many of the environmental factors taken into account by other expansion or predictive models, such as altitude, latitude, rainfall, or temperature (*e.g., Silva* et al. *2014b; Arıkan 2014*).

Within each region, a trait-based adaptive model describes regional societies with three characteristics: intrinsic innovations (technology), extrinsic (economic diversity), and subsistence style (*Lemmen* et al. *2011*). The evolution of these characteristic traits is interdependent and drives the growth of a regional population according to the gradient adaptive dynamics approach formulated by Kai W. Wirtz and Bruno Eckhardt (*1996*) for ecological systems. In his approach, the rate of change of the mean of each characteristic trait is calculated as the product of the trait's variability and its marginal growth benefit, *i.e.* the derivative of population growth rate with respect to the trait, evaluated at the mean growth rate. In Kai W. Wirtz and Carsten Lemmen (*2003*), we adopted this mathematical approach for social systems; as the approach is an aggregate formulation operating on the statistical moments of traits and growth rate, it requires large populations, and thus larger geographic areas. For further details on the trait-based model formulation, see Lemmen, Detlef Gronenborn, and Wirtz (*2011*) (their supplementary online material).

Exchange of characteristic traits and migration of people between regions is formulated with a diffusion-like approach, *i.e.* the flow of a quantity (technology, economic diversity, subsistence style) is directed from a region with higher influence (*i.e.* product of technology and population) to a region with lesser influence. The speed of the spread is proportional to the interregional difference of the respective quantity, and influence is proportional to the influential region's technology and proportional to common boundary length divided by interregional distance. Migration is furthermore dependent on acceptable living conditions (positive growth rate) in the influenced region. Equations for interregional interchange are given in the appendix. The size of the simulation regions (on average 300 000km^2) is insufficient for detailed local analyses, but appropriate for sub-continental and continental-scale simulations and necessary to allow for parameter space exploration.

We performed three different simulations, one with mixed diffusion, one with exclusively demic diffusion and one with exclusively cultural diffusion (see appendix for the different formulations). The global simulations (in total 685 regions) start at 8500 calBC, assuming equal initial conditions for all societies in all regions; we use the same set of parameters used by Lemmen, Gronenborn and Wirtz (*2011*): for the three diffusion scenarios, we obtained the diffusion coefficients by tuning each model to opti-

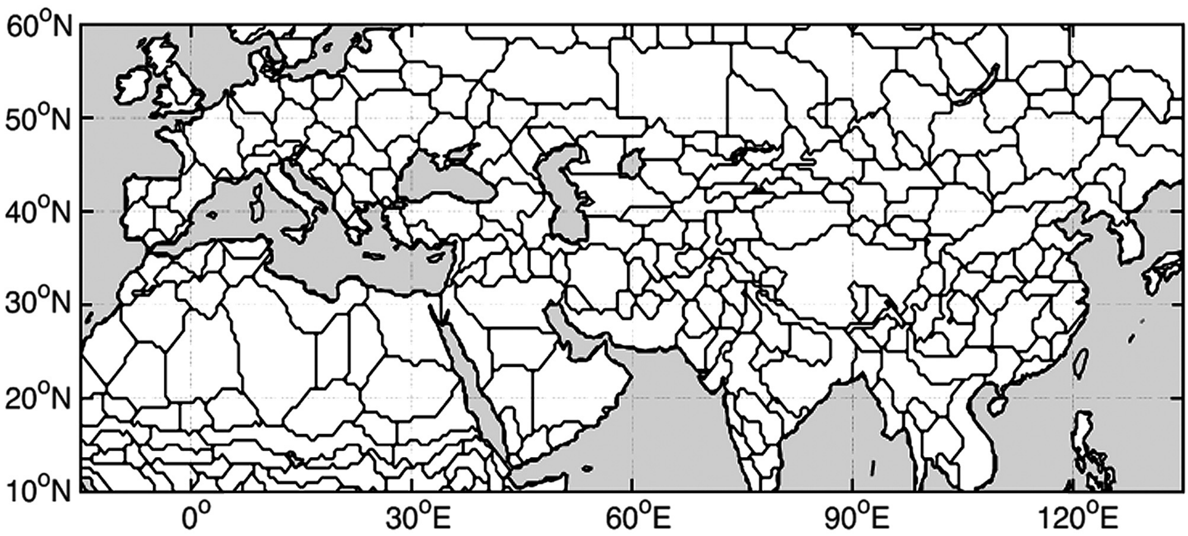

Fig. 1. Geographic setting of 294 Eurasian and North African simulation regions in the Global Land Use and technological Evolution Simulator. This is a subset of the full (global) simulation comprising 685 world regions.

mally represent the European arrival dates. Simulations were performed with GLUES version 1.1.20a; this version can be obtained as free and open source from http://sf.net/p/glues.

Despite tuning all scenarios to the radiocarbon record used in Lemmen, Gronenborn and Wirtz (*2011*), the highest correlation could only be obtained with the mixed (base) scenario. To disentangle cultural and demic diffusion processes, we compared the demic and cultural diffusion scenarios with each other after normalisation with the mixed scenario. Where the demic scenario predicted at least a 10% greater share of agro-pastoral life style, we diagnosed a predominantly demic diffusion. Where the cultural scenario predicted a greater share, we diagnosed a predominantly cultural diffusion. To estimate the overall influence of demic *versus* cultural diffusion, we averaged for each region the relative predominance of demic over cultural diffusion processes over time.

Results

The timing of the arrival of agro-pastoralism (Fig. 2) reveals its multicentric origin and spatio-temporal expansion, including the typical radiation from founder regions seen in all diffusive models.

By 6600 calBC, the transition to agro-pastoralism has occurred in five founder regions: (1) northern coastal China, (2) southern tropical inland China, (3) the Northern Indus region, (4) West Anatolia and Greece, and (5) the Zagros Mountains. At this time, emerging agro-pastoralism connects the Chinese regions with each other (Fig. 2). By 6300 calBC, agro-pastoralism is the dominant lifestyle in all founder regions; it has expanded west to the Balkans and Italy, and east to Korea. A broad band of agriculturalists is visible across China.

By 6100 calBC, the Levant and Anatolian founder regions connect and expand north and eastward, likewise the Chinese regions. The Indus regions extend towards the Ganges. These emerging life styles consolidate in the ensuing centuries. By 5500 calBC, the western Eurasian centre has continued to expand in all directions, reaching around the Black Sea and to the Caspian Sea. All of China has transitioned; emerging agro-pastoralism connects the Indus

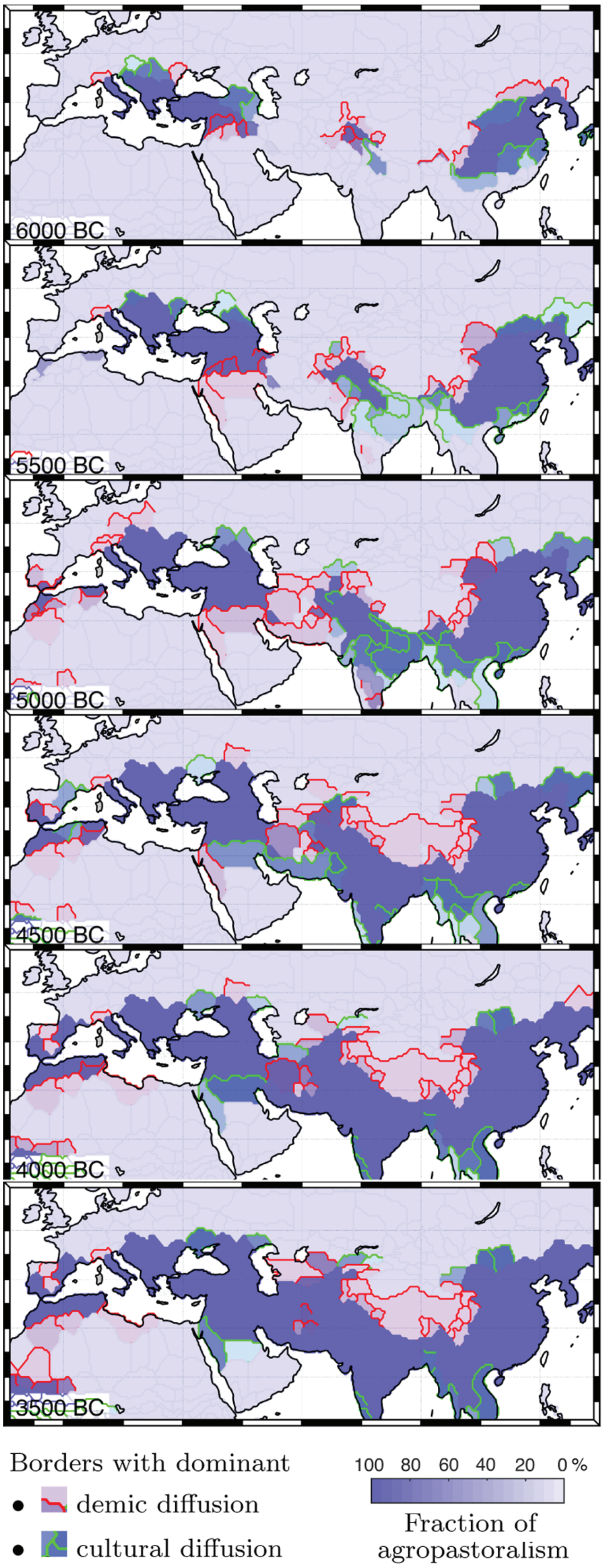

Fig. 2. Simulated transition to agriculture, 6000-3500 BC. The darker the shading, the higher the fraction of agropastoralists in the population. Red lines show regional borders with demic diffusion events, green lines show regional borders with cultural diffusion events.

to the Chinese region. By 5100 calBC, North African pastoralism emerges. There is now one large Asian agropastoralist region, also with emergent transitions throughout India.

By 4700 calBC the Western and Eastern Eurasian centre connect. Agro-pastoralism emerges in Southeast Asia and Western Europe. By 4000 calBC, one large belt of agro-pastoral lifestyle connects the Mediterranean with West Asia, South Asia, and East Asia.

Multiple, intermittent, recurrent, and predominantly demic or cultural diffusion processes are seen throughout the simulation for all regions. For example, exchange processes around the Central Asian plateau are dominated by demic diffusion at all times. At most times, North African and Southwest European exchange processes are dominated by demic diffusion. Cultural diffusion, on the other hand, is at all times dominant within East and South China, and in Southeast Asia. For most of the time it is dominant on the Indian subcontinent.

A more complex pattern of demic and cultural diffusion in space and time is observed in Western Asia and Southeast Europe. Diffusion from the Fertile Crescent is predominantly demic before 4900 calBC, and cultural thereafter. Just east of the Red Sea, it is demic until 4200 calBC, and cultural from 4000 calBC. The expansion of Southeastern and Anatolian agro-pastoralism northward is predominantly cultural at 5500 calBC, and predominantly demic 500 years later. At 5000 calBC, it is demic west of the Black Sea and cultural east of the Black Sea. At 4500 calBC, demic processes again take over part of the eastern Black Sea northward expansion.

Integrated over time, both demic and diffusive processes are equally relevant for most regions. No region, however, shows a demic contribution of less than 30%, and all regions have at least a cultural contribution of more than 15%. Ninety per cent of all regions show no dominance of either demic or cultural diffusion (Fig. 3). A dominance of demic diffusion is evident in the Sahara, and the Hindu Kush and other regions around the Central Asian Plateau. Cultural diffusion is persistent on the Arabian Peninsula, South and Southeast Asia, and several regions in southern Siberia and north of the Aral Sea.

Discussion

During each regional transition, both cultural and demic processes play a role, often even contribute sequentially to a regional agro-pastoral transition. In only very few regions, the simulated transition is best explained by either demic or cultural diffusion processes. Previous attempts to prove either demic or diffusion processes as solely responsible for regional agro-pastoral conditions seem too short-fetched, when the spatial and temporal interference of cultural and diffusive processes might have left a complex imprint on the genetic, linguistic and artefactual record.

In this respect, we confirm the suggestion of Ammerman and Cavalli-Sforza (*1973*) and Fort's analysis (*2012*) of a probably mixed process underlying the expansion of agropastoralism and herding. The new finding here is that for most regions within Eurasia, both processes were active, often contemporaneously, or subsequently, and that a time-integrated view

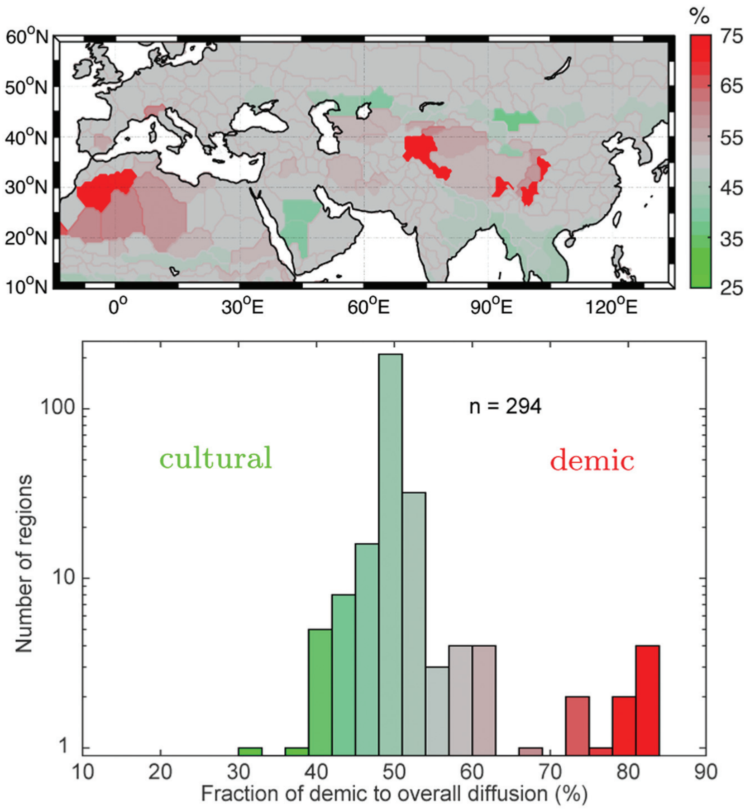

Fig. 3. Time integrated contribution of predominantly demic (red) and cultural (green) diffusion represented geographically (top panel) and as a histogram (bottom panel). For most regions, no predominance (grey) of either mechanism is found.

(such as population genetic or linguistic analyses) only picks out the few regions where either process dominates. For most regions, however, all of the complex interplay between cultural and demic diffusion is hidden in a time-integrated view.

This time-integrated view is, however, the only information that is accessible from radiocarbon arrival date compilations and most model simulations. Fort (*2015*), *e.g.*, analysed the variations in diffusion speeds and attributed these to predominant cultural, demic, or mixed diffusion for slow, intermediate, and fast apparent diffusion rates, respectively. Theirs and our analysis indicate potentially more demic exchange within Iberia and Northern Italy, separated by predominant cultural or mixed exchange in Southern France; at the coarse scale of the model regions, however, this comparison should not be expected to yield conclusive insights.

Based on this time-integrated view, ancient DNA work (*e.g., Bramanti* et al. *2009*) infers a demic signal throughout Europe. As time control is difficult in this record, the demic signal might have occurred before the expansion of agro-pastoralists by migrations of Mesolithic hunter-gatherers or horticulturalists, or even later. The Y-chromosomal and the mitochondrial DNA data show different expansion patterns and can be attributed to multiple migration events, including pre-Neolithic and post-Neolithic demic events (*Szécsényi-Nagy* et al. *2014*), although most of the introduced variability in the European gene pool was well established by the Bronze Age (*Ricaut 2012*).

Migration might have to be functionally disconnected from the spread of agro-pastoralism (*Gronenborn 2011*). Our simulations show that it was not necessarily only one migration wave and another cultural diffusion event that shaped the expansion of agro-pastoralism, but a multitude of combined events, sometimes more demic, sometimes more cultural, dominated. This two-faceted expansion process then explains both archaeogenetic data as well as cultural diffusion evidence, without requiring distinct migratory processes before the expansion of agro-pastoralism.

In GLUES, I did not consider maritime migration, because the Iberian arrival dates could largely be reconstructed without explicitly including this process in the model, as a secondary wave of advance enters Iberia from Gibraltar (there are land bridges connecting across the strait of Gibraltar, the Bosphorus and the English Channel to compensate for the lack of maritime transport), which possibly emulates the fast leap-frog maritime that has been proposed for that region (*Battaglia* et al. *2008*). For the purpose of investigating intra-continental diffusion processes in a compact land mass like Eurasia, an additional coastal or sea-mediated spread is not required.

The diachronic view of exchange processes presented here may help to identify individual migration and cultural exchange processes better than a time-integrated view. Thus, evidence of trade and exchange between two cultural layers with genetic continuity does not necessarily exclude demic diffusion during the entire period of interest, nor does a different genetic signal imply that cultural diffusion did not take place, or did not take place at other times.

Where do we see preferential cultural or demic diffusion in this study? Very roughly, mountainous regions seem to favour demic diffusion in the model simulation when integrated over time (Fig. 3). This is especially visible for the Central Asian plateau and its ridges. The Alps, the Pyrenees, the Iranian Plateau fit this pattern. Other important mountain regions, such as Anatolia or the Indian Ghats do not exhibit preferential demic diffusion.

Together with the apparent preferred demic diffusion in the western Sahara this possibly gives a hint that a lack of local adoption (due to environmental constraints) could be a reason for slower or lesser cultural diffusion. This does not explain, however, the preferential cultural diffusion in the (also environmentally marginal) Arabian Peninsula. Clearly, more work both in situ and in silico has to be done to explore the possibility of an environmental constraint selecting for a specific diffusion process.

These simulations were performed without being confronted with sufficient regional archaeological data for most parts of Eurasia, and the parameter values were tuned to best reproducing the origin locations and times of agro-pastoralism. Only European radiocarbon dates were used to estimate the diffusion coefficients for the demic, cultural and mixed diffusion scenarios (see appendix). One Eurasian region tested for model skill is the Indus region (*Lemmen, Khan 2012*), where the model appears slightly too fast compared to the (often very uncertain) dates; in a non-Eurasian study I found (*Lemmen 2013*) that radiocarbon dates for the transitory period 1000 BC-AD 1000 in Eastern North America were successfully simulated, again with a small model bias towards earlier dates.

The overall simulation for Eurasia is thus realistic in the sense of providing a consistent spatio-temporal view of one expectation of prehistoric developments (from a Eurocentric view) at a large scale. The results are not real in the sense that they provide the exact historical trajectory that has been found at the local scale (comp. *Ackland* et al. *2007*). The great challenge and promise arising from the simulation is thus to confront the expectation from the model with the realisation in the archaeological record: only when both disagree can we learn that either the model is not performing well enough, or that there is a process that is emancipated from the environmental and cultural context: then we have quantified human agency. The individual or society-level decision to migrate or to communicate should be expected to be at least as rich and complex as the cultural-demic diffusion picture appearing from a simulation.

Conclusion

I presented a numerical simulation study on the diffusion processes during Neolithisation in Eurasia, using an adaptive model of prehistoric societies in their environmental context that is able to resolve local innovation, cultural diffusion and demic diffusion. Although a mixed diffusion process was already suggested long ago, the analysis of simulations with either cultural or demic diffusion, and with mixed diffusion reveals an even more complex spatio-temporal pattern of the expansion of agro-pastoralism throughout Eurasia than has previously been found: demic and cultural processes occur contemporaneously, or multiple times iteratively or intermittently in most regions of Eurasia. There is no simple demic or cultural explanation, but a very complex and rich interplay of both processes in time and space. The polarised debate of either demic or cultural diffusion should give way to acknowledging again this more complex picture and to studying and appreciating the richness of mechanisms.

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Appendix

The diffusion process between a region i and another region in its neighbourhood $j \in N$ is realized with three diffusion equations, representing communication, trade, and migration. Diffusion depends on the influence difference (*Renfrew, Level 1979*), where influence is defined as the product of population density P and technology T. The diffusion flux f is proportional to the influence difference relative to the average influence of regions i, j times geographically determined conductance between the two regions.

The entries for $c_{i,j}$ in the conductance matrix C between two regions i, j are constructed from the common boundary length $L_{i,j}$ divided by the mean area of the regions $\sqrt{(A_i A_j)}$. As in Jacob Etten and Robert Hijmans (*2010*), geographically not connected regions have zero conductance; to connect across the Strait of Gibraltar, the English Channel, and the Bosporus, the respective entries in C were calculated as if a narrow land bridge connected them.

No additional account is made for increased connectivity along rivers (*Davison* et al. *2006; Silva, Steele 2014*), as the regional setup of the model is biased (through the use of net primary productivity (NPP) similarity clusters) toward elongating regions in the direction of rivers. Altitude and latitude effects are likewise implicitly accounted for by the NPP clustering in the region generation.

Finally, if the flux between i, j is negative, it is directed inward from j to i, else outward from i to j.

$$f_{i,j} = c_{i,j}\left(\frac{P_i T_i A_i + P_j T_j A_j}{A_i + A_j} - P_j T_j\right) \qquad (1)$$

Trade/information exchange: Trait value differences in all traits X between i and all its neighbours j are summed and added to region i's trait value.

$$\left.\frac{\mathrm{d}X_i}{\mathrm{d}t}\right|_{\mathrm{trade}} = \sigma_{\mathrm{trade}} \sum_{j \in N_i, f_{ij}>0} f_{ij} \cdot \left(X_j - X_i\right) \qquad (2)$$

The parameter σ_{trade} needs to be estimated (see below); trade is not mass-conserving.

Migration is composed of immigration or emigration, depending on the sign of the diffusion flux f.

$$\left.\frac{\mathrm{d}P_i}{\mathrm{d}t}\right|_{\mathrm{demic}} = \sigma_{\mathrm{demic}} \sum_{j \in N_i, f_{ij}>0} f_{ij} P_j \frac{A_j}{A_i} - \sum_{j \in N_i, f_{ij}<0} f_{ij} P_i \qquad (3)$$

The free parameter σ_{demic} can be chosen to adjust the speed of migration (see below). Population is redistributed by scaling with region area A, thus, migration is mass-conserving.

Hitchhiking traits: Whenever people move in a demic process, they carry along their traits to the receiving region:

$$\left.\frac{\mathrm{d}X_i}{\mathrm{d}t}\right|_{\text{demic}} = \sigma_{\text{demic}} \sum_{j \in N_i, f_{ij} > 0} f_{ij} X_j \frac{P_j A_j}{P_i A_i} \qquad (4)$$

Spread parameter estimation

Suitable values for the spread parameters are assessed after all other model parameters have been fixed (for the equations and parameters not directly relevant to the demic/diffusive analysis, see the supporting online material provided as a supplement to Lemmen, Gronenborn and Wirtz (*2011*)).

We initially assume that information travels two orders of magnitude faster than people, based on the typical size of exchange networks (1000km; *Mauvilly* et al. *2008; Gronenborn 1999*), the average active life time of a tradesperson (order 10 years), and the comparison with the typical demic front speed of the order 1km per year (*Ammerman, Cavalli-Sforza 1973*). Starting with this fixed relation between σ_{trade} and σ_{demic}, we vary both parameters such that we get the highest correlation with the dataset by Ron Pinhasi, Joaquim Fort and Albert Ammerman (*2005*) on European sites; with $\sigma_{\text{trade}} = 0.2$ and $\sigma_{\text{trade}} = 0.002$ the highest correlation achieved is $r^2 = 0.61$ ($n = 631$, $p < 0.01$). Analysis of the simulation confirms that this is a parameterisation that describes ***mixed diffusion*** (*Lemmen* et al. *2011.Fig. 6*).

For a purely ***demic diffusion*** model, trade was switched off ($\sigma_{\text{trade}} = 0$) and σ_{demic} was varied (systematically increased) to again obtain the best correlation with the data. The estimated parameter value is $\sigma_{\text{demic}} = 0.008$. The respective procedure was applied to estimate the parameter σ_{trade} for a purely ***cultural diffusion*** best-fitting model; its value was determined to be 0.3.

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Modelling the initial expansion of the Neolithic out of Anatolia

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ABSTRACT – *Using the space-time distribution of 1162 uniformly recalibrated dates from 71 sites in Asia Minor, the Aegean Basin, Southern Thrace and Macedonia, this article presents geostatistical (kriging) and graphical simulations of the Neolithic expansion out of Anatolia. How fast was the advance of the agricultural pioneer front? Did it proceed in a single wave, moving at a steady pace, or did it involve instead long periods of stasis, punctuated by rapid advances? The article suggests that the expansion was more arrhythmic than linear. The spread of farming halted in Central Anatolia for several hundred years, before quickly expanding into Europe.*

IZVLEČEK – *S pomočjo prostorsko-časovne distribucije 1162 rekalibriranih datumov z 71 najdišč v Mali Aziji, Egejskem bazenu, južni Trakiji in Makedoniji predstavljamo geostatistično ('kriging') in grafično simulacijo neolitske ekspanzije iz Anatolije. Kako hitro je bilo napredovanje meje pionirskih poljedelcev? Ali se je le-ta premikala v enem valu in enakomernem tempu, ali pa so bila pri premikanju meje vključena tudi dolga statična obdobja, ki so prekinjala hitro napredovanje? V članku predlagamo, da je bila ekspanzija bolj aritmična kot linearna. Širitev kmetijstva se je v osrednji Anatoliji najprej ustavila za več stoletij in zatem hitro nadaljevala v Evropo.*

KEY WORDS – *Neolithic; ^{14}C dating; kriging; Anatolia; Balkans*

Introduction

Computer-based simulations of the Neolithic expansion in Eurasia using the time-space distribution of ^{14}C dates have consistently highlighted a gradient from the Near East to the British Isles (*Gkiasta* et al. *2003; Pinhasi* et al. *2005; Bocquet-Appel* et al. *2009; Fort* et al. *2012*). The underlying assumption that agriculture swept across Europe following the advance of a pioneer front has (if anything) comforted Childe's and other diffusionists' accounts of a migration of early culture based on similarities in the pottery and other material remains (*Childe 1925; 1950; Elliot Smith 1915[1929]*). Clark is widely credited with the first explicit use of radiocarbon dates for modelling Neolithic expansion (*Clark 1965*). What has changed since Clark, as other authors have pointed out, is not so much the scope as the resolution of the model, which has improved dramatically thanks to the widespread use of ^{14}C dating (*Bocquet-Appel* et al. *2009.807*).

The sheer number of published radiocarbon dates is such that we advocate moving a step further, by drawing a regional simulation of the Neolithic dispersal, this time within a moderately small section of Eurasia (*c.* 1 000 000km^2), spanning from the Central Anatolian Plateau in the East to Thessaly in the West, and the Balkan Range in the North (Fig. 1). Sites in Northern Bulgaria and Serbia fall outside the scope of this paper and will not be considered further here. In the article, we use empirical Bayesian kriging to interpolate the advance of the Neolithic from the Anatolian heartland to Southeast Europe. The model relies upon a comprehensive dataset of 71 sites and 1162 uniformly recalibrated dates,

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falling within the interval 9000–5500 calBC at 2σ. Unlike other simulations of the Neolithic, which use the oldest observed ^{14}C date(s) as a proxy for the advance of a pioneer front (*e.g., Pinhasi* et al. *2005; Bocquet-Appel* et al. *2009; Fort* et al. *2012*), our simulation draws upon modelled dates, statistically constrained by prior information using Bayesian clustering. It goes without saying that this approach is feasible only with a small sample of sites, over which strict quality control can be maintained.

The central question being asked of the data is whether the spread of the Neolithic out of Anatolia was a linear process, or whether it consisted instead of standstills, punctuated by rapid advances. What is at stake is the potential identification of so-called farming 'frontiers' within the study region similar to the ones identified in the Great Hungarian Plain (*Whittle 1996; Zvelebil, Lillie 2000*), the southern Adriatic coast (*Forenbaher, Miracle 2006*), the circum-Baltic region (*Whittle 1996; Zvelebil 1998; 2001*) and the Low Countries (*Louwe Kooijmans 2007*). The traditional view, held by Ammerman and Cavalli-Sforza, is that farming expanded across Europe at a steady pace of approx. 1 km/year (*Ammerman, Cavalli-Sforza 1971; 1984.61, 135*). This estimate, which has been upheld in recent literature (*Pinhasi* et al. *2005*), is at odds with the archaeological picture outlined above and recent demographic work, which suggests an expansion in 'booms and busts' (*Shennan, Edinborough 2007; Shennan* et al. *2013*). The latter pattern of spread is usually captured under the concept of 'arrhythmic' expansion (*Guilaine 2000*).

By challenging the linear narrative of farming expansion within the study region, we hope to contribute to a growing body of literature which highlights the crucial role of Anatolia not just as a land bridge, but also as an independent centre of neolithisation (*Özdoğan, Başgelen 1999; 2007; Özdoğan* et al. *2012; Thissen 2000; Gérard, Thissen 2002; Lichter 2005; Gatsov, Schwarzberg 2006; Krauß 2011; Baird 2012; Çilingiroğlu 2012*). One of the key issues emerging over the years has been the distinction of two Neolithic traditions, one in Central Ana-

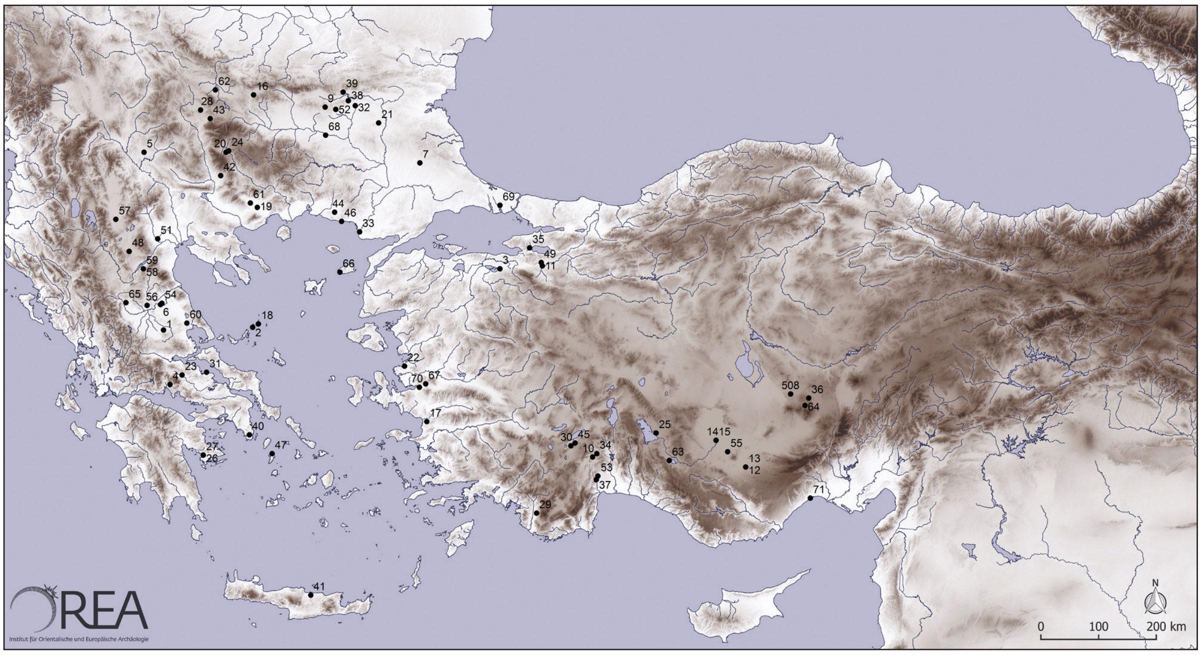

Fig. 1. Geographical distribution of 71 radiocarbon-dated sites in Anatolia and Southeast Europe. 1 Achilleion; 2 Agios Petros; 3 Aktopraklık; 4 Antre Corycien; 5 Anzabegovo; 6 Argissa; 7 Aşağı Pınar; 8 Aşıklı Höyük; 9 Azmak; 10 Bademağacı; 11 Barcın Höyük; 12 Can Hasan I; 13 Can Hasan III; 14 Çatalhöyük East; 15 Çatalhöyük West; 16 Čavdar; 17 Çukuriçi Höyük; 18 Cyclops Cave; 19 Dikili Tash; 20 Dobrinišče; 21 Drama-Gerena; 22 Ege Gübre; 23 Elateia; 24 Elešnica; 25 Erbaba; 26 Franchthi Cave; 27 Franchthi Koilada Bay; 28 Gălăbnik; 29 Girmeler; 30 Hacılar; 31 Halai; 32 Hlebozavoda; 33 Hoca Çeşme; 34 Höyücek; 35 Ilıpınar; 36 Kaletepe; 37 Karain B; 38 Karanovo; 39 Kazanlăk; 40 Kitsos Cave; 41 Knossos; 42 Kovačevo; 43 Kremenik; 44 Krovili; 45 Kuruçay; 46 Makri; 47 Maroulas; 48 Mavropigi; 49 Menteşe Höyük; 50 Musular; 51 Nea Nikomedeia; 52 Okražna Bolnica; 53 Ökü̈zini; 54 Otzaki Magoula; 55 Pınarbaşı; 56 Platia Magoula Zarkou; 57 Porodin; 58 Servia; 59 Servia-Varytimides; 60 Sesklo; 61 Sitagroi; 62 Slatina; 63 Suberde; 64 Tepecik-Çiftlik; 65 Theopetra Cave; 66 Uğurlu; 67 Ulucak Höyük; 68 Yabalkovo; 69 Yarimburgaz Cave; 70 Yeşilova Höyük; 71 Yumuktepe. Background map designed by M. Börner.

tolia, running broadly concurrent with Pre-Pottery Neolithic B societies in the Near East, and the other in Western Anatolia, coinciding or shortly pre-dating the widespread adoption of pottery in the Northern Levant (*Schoop 2005; Baird 2012; Düring 2013*). As this study demonstrates, the advent of farming in Western Anatolia was delayed by up to 2000 calibrated years and this lag in the dating needs to be properly accounted for in future.

Dataset and methods

A geostatistical (kriging) method was used to interpolate the spatiotemporal advance of the Neolithic from a set of known values. The first step was to obtain the known values from the sample data – a georeferenced dataset of 1162 calibrated radiocarbon dates from 71 sites (Electronic Supplementary Material 1). This number excludes duplicate entries and dates that fall outside the range 9000–5500 calBC at 2σ. For the period under review, 1057 dates were ascribed to Neolithic and Early Chalcolithic levels, 99 to Epipalaeolithic and Mesolithic levels; 6 came from mixed layers or could not be ascribed to a period in particular. A Bayesian model was built for each site where it is possible by using median estimators of phase boundaries in OxCal 4.2. Two versions of the kriging, one including virtually all modelled dates, regardless of quality, the other based on a strictly audited sample, were constructed. In turn, the intensity of the Neolithisation process was evaluated through summed probability distributions of calibrated radiocarbon dates.

^{14}C data collection, calibration and quality control

The radiocarbon database on which this study relies was collated from published literature and existing datasets, including the CalPal-database (*Weninger 2014*), the CONTEXT database (*Böhner, Schyle 2008*) and the CANeW (*Reingruber, Thissen 2005; Thissen 2006; Gérard, Thissen 2002*). Dates were uniformly recalibrated using the IntCal13 atmospheric curve (*Reimer* et al. *2013*) in Oxcal 4.2 (*Bronk Ramsey 2013*). The consistency of the database was checked for out-of-scope and duplicate entries. In attributing sites or phases to the 'Neolithic', we followed the assessment of the excavators, cross-checking (where possible) the validity of this attribution, based on such criteria as the adoption of food production, *e.g.*, domestic plants and/or animals (*Childe 1936*). On this basis, three of the 71 sites surveyed did not return any 'Neolithic' dates and were not processed any further. Subsequently, two different approaches were pursued. The first one involved limited pre-sorting, excluding only those radiocarbon determinations reported as problematic by the laboratories. The advantage of this method is that virtually all ^{14}C dates, regardless of quality, could be included in the model, thus pre-empting biases regarding the way in which the selection was made (see also *Brami 2015*). One potential problem, however, is that evaluating together dates with small and large error margins arising from several generations of radiocarbon dating places too much emphasis on the latter. As already pointed out elsewhere (*Brami, Heyd 2011.173*), dates of mainland Greece, which were mainly processed in the 1950s – 1970s, have two to four times larger standard deviations on average than dates of Western Turkey, making any comparison problematic at best.

The second approach thus incorporated a degree of chronometric hygiene to monitor the quality of the database. A cut-off value of 100 years BP was arbitrarily set for the standard deviation, meaning that ^{14}C dates with an uncertainty superior or equal to this minimum standard were excluded. Radiocarbon age uncertainty is linked to a variety of factors, not least the resolution of the dating equipment; larger standard deviations may indicate problems with the sample or with the laboratory treatment (*Flohr* et al. *2015*). The problem of 'old wood' effect in charcoal samples was addressed in the following way. First of all, bulk samples, in which carbon of unknown provenience from the sediment is mixed with carbon from the charcoal, were systematically excluded from the audited dataset. Similarly, unidentified charcoal samples which may stem from the inner rings of a tree in which ^{14}C has started to decay years before the tree was felled or burned were excluded (*Zilhão 2001.14181*). Finally, long-lived tree charcoal samples from structural timbers such as posts and roof beams which could be reused in successive buildings (*Cessford 2001*) were flagged out and the corresponding dates discarded.

As a result, short-lived materials such as cereal grains, hazelnut shells, bone/antler made up the essential part of the audited dataset. Bone was treated with caution: bone samples from before the introduction of AMS dating (*e.g.*, four UCLA dates from Argissa) were excluded; likewise, burnt bone and bone apatite (*Flohr* et al. *2015*). This approach is also not without problems. Human bones from coastal regions and river valleys may still have a reservoir effect due to human consumption of marine resources. Seeds, on the other hand, are prone to move across the sediment and, conversely, may be too young. Another consequence is that the dataset on which the second kriging simulation was based was significantly reduced, to 280 dates from 26 sites, leading entire regions such as Greece to be interpolated from only a few known sites. In conclusion, each of the two methods of sampling, selective and non-selective has advantages and limitations, but we argue that, taken together, they provide a valuable snapshot of early agricultural expansion out of Anatolia.

With regard to the input data that was fed into the kriging, it consisted of exact calendar dates (Tab. 1). Since calibrated dates are always expressed as a possible range between two values, not as a specific point in time, a protocol was followed to artificially determine the most statistically probable starting date of each site (Fig. 2). The method of median estimators of phase boundaries was used (*Bronk Ramsey 2009a*; see *Thissen 2010* for a practical application). In short, a Bayesian model was created for each site in which sufficient stratigraphic and contextual information was available for the units sampled (*e.g.*, chronometric phases based on ceramic evidence). Bayesian modelling narrowed down the statistical interval of the dates using prior information about, *inter alia*, the relationship of the dates, for instance their belonging to the same stratigraphic phase, or their coming 'before' or 'after' one another. In practice, this was done using the boundary function in OxCal 4.2 (*Bronk Ramsey 2013*). Outliers' dates, showing poor individual agreement (A< 60%) between the observed data and the model, were identified and down-weighted using the outlier analysis approach described by Bronk Ramsey (*2009b*). A uniform prior probability of 0.05, corresponding to a 1 in 20 probability of each sample being an outlier, was selected (*Bronk Ramsey 2009b.5*; see also *French, Collins 2015.125*). Finally, the median was used as the point estimator for the start phase (*Thissen 2010*).

Kriging interpolation

The dispersal of early farming from Central Anatolia to the Southern Balkans was modelled using the kriging technique of spatial interpolation and the ^{14}C values derived above. The principle of kriging is that, knowing the value of a set of points in space, it is possible to estimate the value of other points for which data is absent. This is based on the measure of spatial autocorrelation, expressed through a variogram. The variogram is a function describing the degree of spatial dependence of a spatial stochastic process (*Wackernagel 2003*). Its calculation is based on the distances among the available paired observations. A mathematical model can hence be fitted to the experimental variogram and the coeffi-

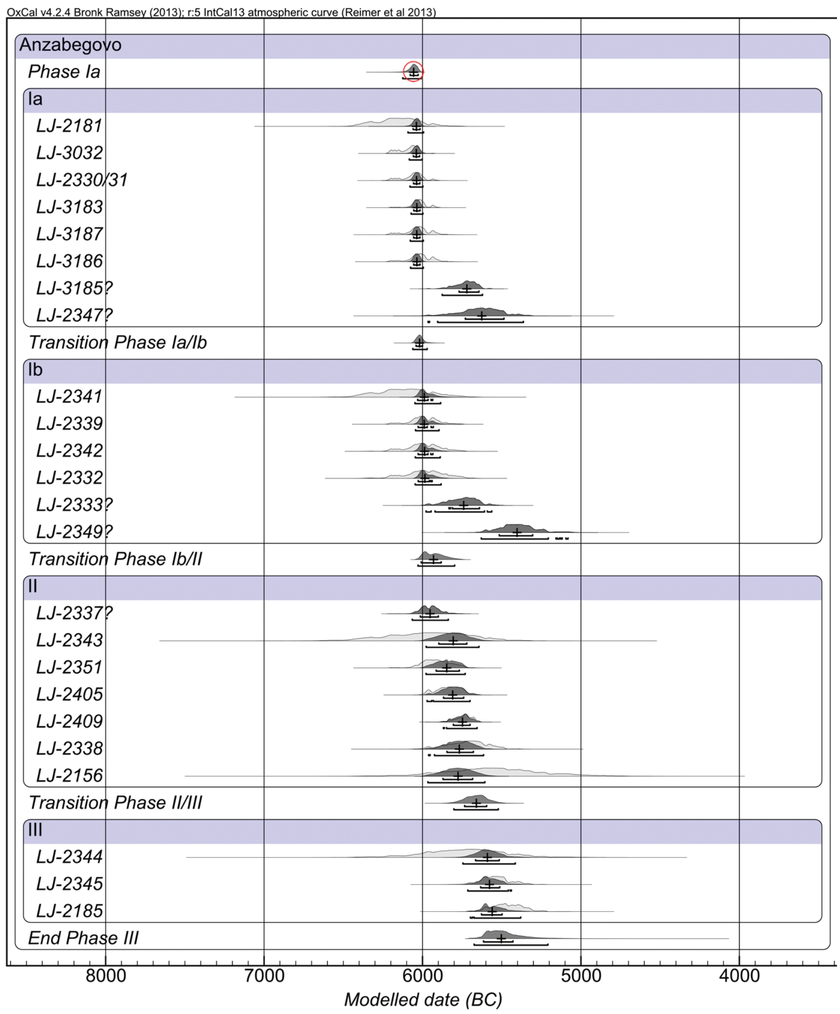

Fig. 2. Example of contiguous boundary model for the site of Anzabegovo. Modelled dates are shown in bold. The median used as point estimator for the start phase is circled. For illustration only, outlier dates (*e.g.*, LJ-3185?) are excluded from the model; in the final simulation, outliers were down-weighted. See dataset and methods for further explanation.

cients of this model can be used for the estimation through the kriging regression (for more information regarding the statistical process, see *Cressie, Wikle 2011*). Bocquet-Appel and Demars (*2000; Bocquet-Appel* et al. *2009*) applied this method based on the known distribution of ^{14}C dates on a uniform grid, in order to estimate the advance of a pioneer front within the context of a colonisation process. This method has some limitations; in particular, it is based on an assumption of spatial homogeneity (*Krivoruchko 2012; Pilz, Spock 2007*). In other words, this technique appears to be very effective when a subjacent trend is found. Fitting the variogram model to the observed data is a delicate process, which influences the parameters of the regression; if a spatial correlation is not evident, the risk of using an unsuitable variogram model is high.

For the present research, it is not clear from the outset whether or not the data has a linear distribution, so it is hard to find a good predictor for it with ordinary kriging. However, in many cases, the best predictor can be non-linear: empirical Bayesian kriging is a method for predicting non-linear distributions (*Krivoruchko 2012*). Empirical Bayesian kriging accounts for the error introduced by automatically drawing the variogram trend from a range of individual trends. The new variogram models are estimated on the basis of the previously simulated data; a weight for each variogram is given using the Bayes' rule, showing how likely the observed data could be generated from this variogram. The result of this procedure is the creation of a spectrum of variograms. The predictive density can be calculated by averaging transformed Gaussian distributions (*Pilz, Spock 2007*).

The variogram for the comprehensive dataset is shown in Figure 3. In order to make the calculation of distances the most accurate possible, the sites are in a metric projection (Universal Transverse Mercator). The values on the x-axis are expressed in metres raised to 10^5 (1 = 100 000m = 100km) and show the distances among the observed points; the y-axis, in turn, shows their semi-variance. The very high variance near the origin indicates a local heterogeneity, added to unavoidable issues related to the ^{14}C dates themselves (*e.g.*, data quality, dates not belonging to the earliest Neolithic horizon in the region). The low slope of the estimated variograms shows a very low spatial correlation. The variograms for the audited dataset is represented in Figure 4. In this case, the variance at the origin is much lower, and the trend of the simulated variograms shows a higher spatial correlation. Therefore, this dataset appears more appropriate to represent the spread of Neolithic farming. These variograms are inputted in the kriging interpolation model, providing a graphical representation of the possible timing and path of the spread through the use of isochrones, which are boundaries that contain homogenous dates.

Summed probability distributions

In addition to the kriging, the calibrated probability distributions of all ^{14}C dates were summed in order to gain an insight into regional population fluctuations. This approach rests on the assumption that the density of radiocarbon dates in the dataset is directly proportional to human activity (*Steele 2010*). In fact, both research and taphonomic biases are likely to affect the shape of the ^{14}C frequency distribution. To avoid sites being over-represented in the dataset (*e.g.*, Çatalhöyük East alone accounts for over 19.4% of all accepted ^{14}C dates in the study region), multiple radiocarbon dates for each site were first summed to a single distribution. These distributions were then summed across four target regions (Fig. 5).

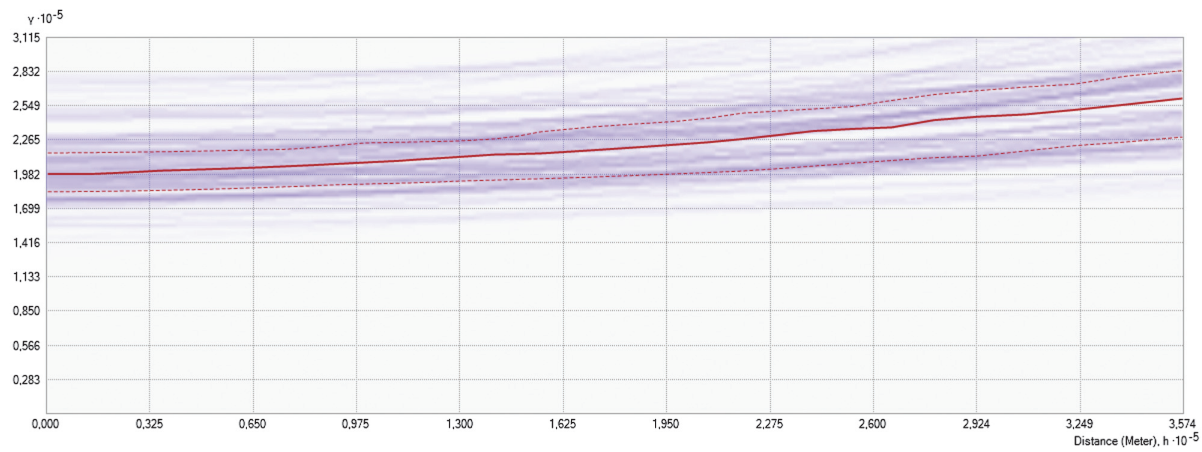

Fig. 3. Spectrum of the semivariogram models produced by empirical Bayesian kriging for the comprehensive dataset.

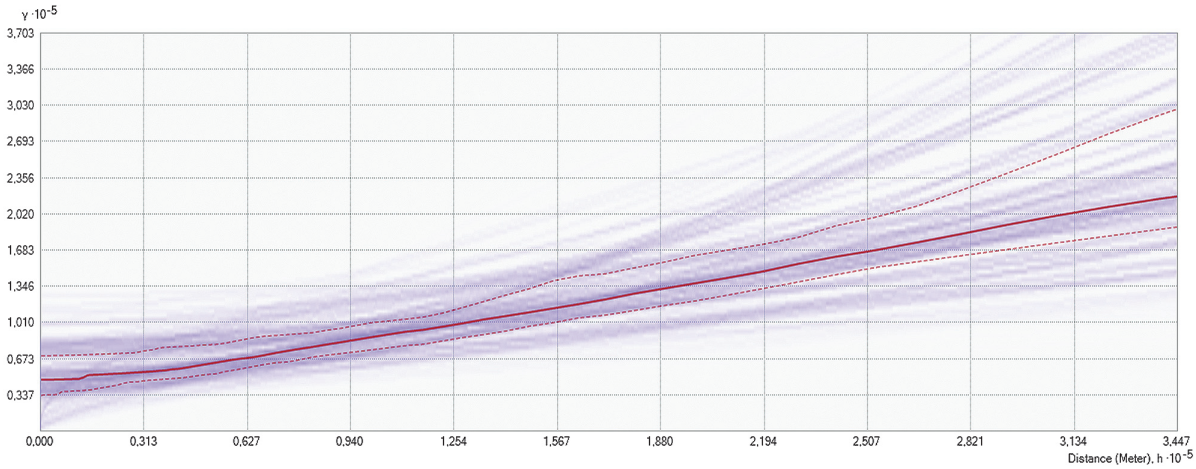

Fig. 4. Spectrum of the semivariogram models produced by empirical Bayesian kriging for the audited dataset.

Summed probability distributions in this case may not be used as accurate demographic proxies, given that the number of radiocarbon determinations in each region is below the 500-date minimum threshold quoted in the literature (*Williams 2012*). This approach, we admit, leaves open many issues; in particular, peaks and troughs in the distribution may not necessarily reflect population expansion and decline, but instead the plateaus and wiggles of the calibration curve (*Williams 2012.581*). The aim here was to detect major regional discrepancies in the dating, in the order of several hundred years; summed probability distributions provide a valuable medium to show just how well certain periods are represented in terms of ^{14}C date distribution. They provide an additional control layer, showing not just when farming initially took off, but also how this process was sustained over time, once all the dates are taken into consideration.

Results

The kriging interpolation of the space-time distribution of ^{14}C dates, whether based on the entire dataset or only a sample thereof, indicates a westward regression of the onset of farming from the Central Anatolian Plateau to the Aegean Basin, followed by a northward shift to inland Thrace and Macedonia. The incremental way in which the isochrones ripple out of Central Anatolia may, we argue, be an artefact of the kriging. Multiple isochrones, at short distances from each other, presumably indicate a standstill or very slow progression. In turn, summed probability distributions of calibrated radiocarbon dates indicate that the advent of farming in Western Anatolia was delayed by up to 2000 calibrated years, supporting the identification of a major chronometric lag between the start of the Neolithic in this region and in Central Anatolia.

Modelling the advance of the agricultural pioneer front

Figure 6 shows the expansion of the Neolithic, in 250-year isochrones, based on a comprehensive dataset of modelled radiocarbon dates. Compare with Figure 7, which draws on the modelled values of the audited dataset, while sharing the same simulation environment. Both simulations highlight the remarkably early uptake of agricultural production on the Central Anatolian Plateau, which was presumably a major centre of food-plant and animal domestication (*Buitenhuis 1997; Asouti, Fairbairn 2002; Martin* et al. *2002; Pearson* et al. *2007; Arbuckle* et al. *2012*). Surprisingly, the Pisidian Lake District, which is located at the western end of the Anatolian Plateau, already reflects a much younger tradition. The interpolation shows between two (Fig. 6) and six (Fig. 7) 250-year isochrones between Cappadocia and the Lake District, that is, a little over 200km, in a region which is not characterised by any major topographic boundary. If there was an expansion of the Neolithic towards the west, across the Anatolian Plateau, it was extremely slow-motion, possibly lasting hundreds if not thousands of years. The second kriging simulation, in particular, struggles to interpolate this advance, marked out by not too distant sites showing major discrepancies in corrected start date value, *e.g.*, Aşıklı (7934 calBC) and Höyücek (6353 calBC). The kriging produces artificial contour lines to span what is essentially a major lag between two Neolithic regions. In any case, the pattern suggests that agriculture was initially held off in Cappadocia and the Konya Plain, with the 'bond' finally

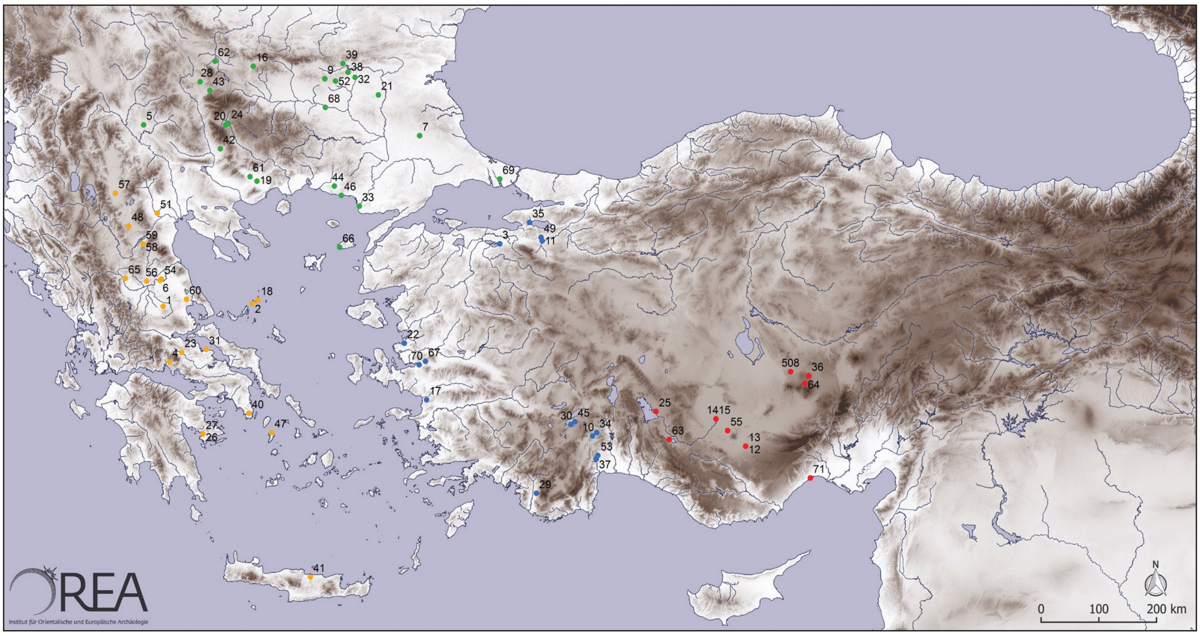

Fig. 5. Location of the four target regions: A: Central Anatolia (red); B: Western Anatolia (blue); C: Greece (orange); D: Thrace (green). Background map designed by M. Börner.

breaking sometime in the 7th millennium calBC (*Düring 2013*).

This above-outlined view is further supported by the subsequent change in direction of the isochrones, from south to north, rather than from east to west, in the Aegean Basin. Here, the two simulations differ significantly. The first kriging simulation based on the non-audited dataset suggests that the Lake District, together with Knossos in Crete, provided a starting point for the initial spread of the Neolithic into Europe. Once the older dates from Hacılar and Bademağacı are excluded from the dataset, due to their poor quality, the Lake District becomes a potential crossroad between a land-way, from the west across the Anatolian Plateau, and a sea-way to the west, spearheaded by slightly older sites like Çukuriçi Höyük and Ulucak. At present, the chronological differences between the Lake District and the Aegean coast of Anatolia are too small to draw firm conclusions about the existence of this second route.

The first kriging simulation highlights a fairly synchronous adoption of agriculture on both sides of the Aegean Basin (Fig. 6). If true, the Aegean Sea probably acted more as a bridge than as a frontier, as also indicated by early dates on the islands of Crete (Knossos), Kythnos (Maroulas) and Gökçeada (Uğurlu). Southern Aegean sites appear to be slightly older than those in the north on average by between *c.* 500–750 years depending on the simulation, but the distance to cover is much greater, approx. 600km from one end of the Aegean Basin to the other. Once again, differences in the dating are significant but not drastic; they may be explained by other factors, such as a plateau in the calibration curve in the first half of the 7th millennium calBC, which may influence the simulation (*Reingruber, Thissen 2009; Weninger* et al. *2014*). On the other hand, radiocarbon dates for the Aegean seaboard sites and adjacent regions, like the Thessalian plains, are significantly older than those encountered further inland, particularly in Thrace. Upriver sites in the Struma and Maritsa valleys demonstrate at least one further chronological step in the advance of the Neolithic, with the resulting expansion potentially being driven from west to east rather than from east to west (*Lichter 2006*).

The Central/Western Anatolian farming frontier

The rapid and incremental manner in which the interpolated isochrones succeed each other across the Central Anatolian Plateau (Fig. 7) lends support to the idea that agriculture was initially contained within this region, spreading internally to multiple sites and communities before radiating outward (*Düring 2013*). A regional stasis at the onset of the Neolithic in Anatolia can be represented graphically using summed probability plots (Fig. 8A-D). Notice in Figure 8A the calibrated probability distribution of ^{14}C dates in Central Anatolia during the interval 8500–7000 calBC. Remarkably, this period is almost entirely unaccounted for in Western Anatolia (Fig. 8B), suggesting that the Neolithic started there between 1500–2000 years later (*Brami 2015*). The peak in distribution after *c.* 6500 calBC perhaps marks the initial explosion of the Neolithic in the region. As it is barely noticeable in the other graphs, this peak is unlikely to have been artificially created by the calibration process.

Within the current dataset, there is no indication that Neolithic expansion in Western Anatolia was preceded by a population crash in Central Anatolia. On the contrary, the two distributions run largely concurrent during the interval 6500–6000 calBC. Further west, the question can be raised as to whether the abandonment of sites in Western Anatolia post *c.* 5800 calBC coincided with a renewed expansion of the Neolithic into Greece and Thrace. The summed probability distribution for the Greek Neolithic is skewed towards a slightly later horizon (Fig. 8C). Dates spanning between *c.* 7600–7000 calBC are statistical outliers, which can be firmly discounted (*Perlès 2001; Brami, Heyd 2011*). They show the inherent risk involved in keeping dates with large standard deviations from old excavations generating background noise, as in this case. Thrace represents a further step in time, with the greater part of the distribution presumably falling outside the study period (Fig. 8D).

For reference only, the rate of expansion of the Neolithic for the region under review was measured using the technique described by Ammerman and Cavalli-Sforza (*1971*). A regression to calculate the rate of expansion, as per the cited article, was performed, using Aşıklı as a potential centre of diffusion. The speed implied by the distance-versus-time regression was 0.32 ± 0.11km/year (the range of 0.11 corresponds to the 95% confidence interval), while the time-versus-distance regression returned a much faster diffusion rate, 1.07 ± 0.36km/year (Fig. 9A). The first regression (distance-versus-time) would be preferable if most of the error were due to the dating, while the second (time-versus-distance) if the error were due to the distances. In this case, the distances are exact, so the first regression is of more direct relevance. This approach assumes a linear fit of the regression coefficient. For the present dataset, the correlation coefficient was low, *i.e.* 0.58 (compare with >0.80 in *Pinhasi* et al. *2005*). This relatively low spatio-temporal correlation is illustrated in figure 9B, where the data distribution appears to be divided into two clusters. Data clusters show the potential lag in Neolithic occupation between Central and Western Anatolia, further undermining the relevance of a linear fit.

Discussion

The case for an arrhythmic model of Neolithic expansion

If we assume a linear regression from a hypothetical origin in Aşıklı, the rate of expansion of the Neolithic within the study region was very low, 0.32km/year on average (Fig. 9). It was much lower, for instance,

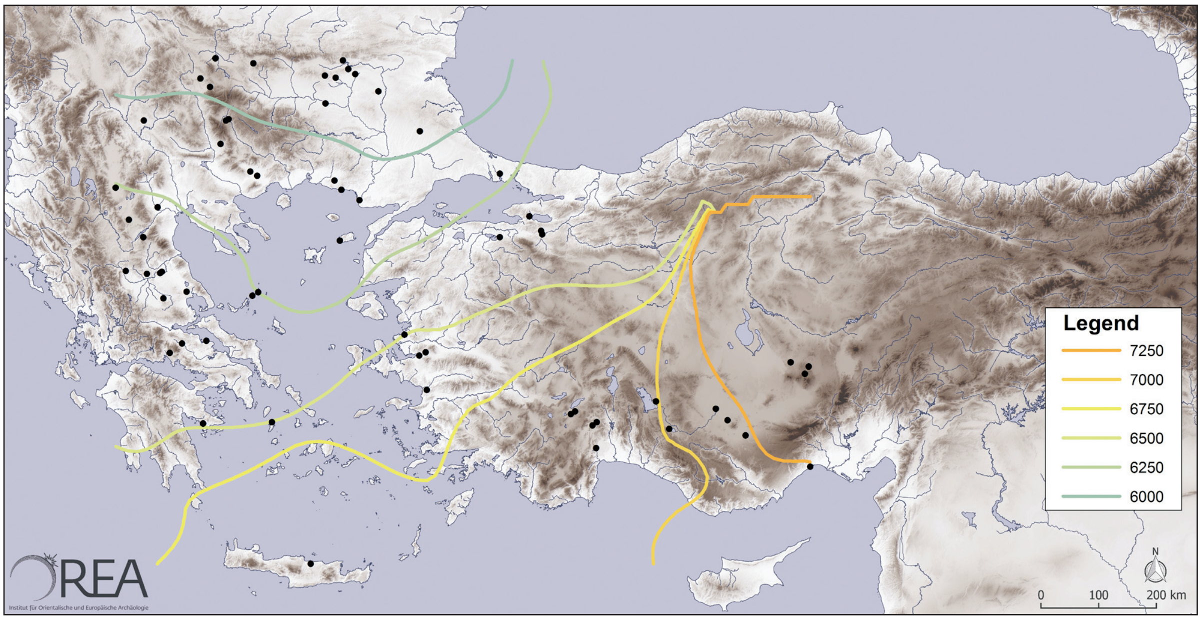

Fig. 6. Empirical Bayesian kriging interpolation of the advance of early farming, based on the comprehensive dataset (*cf.* Table 1: median 1). Where two sites share the same coordinates, the oldest modelled date was computed. Background map designed by M. Börner.

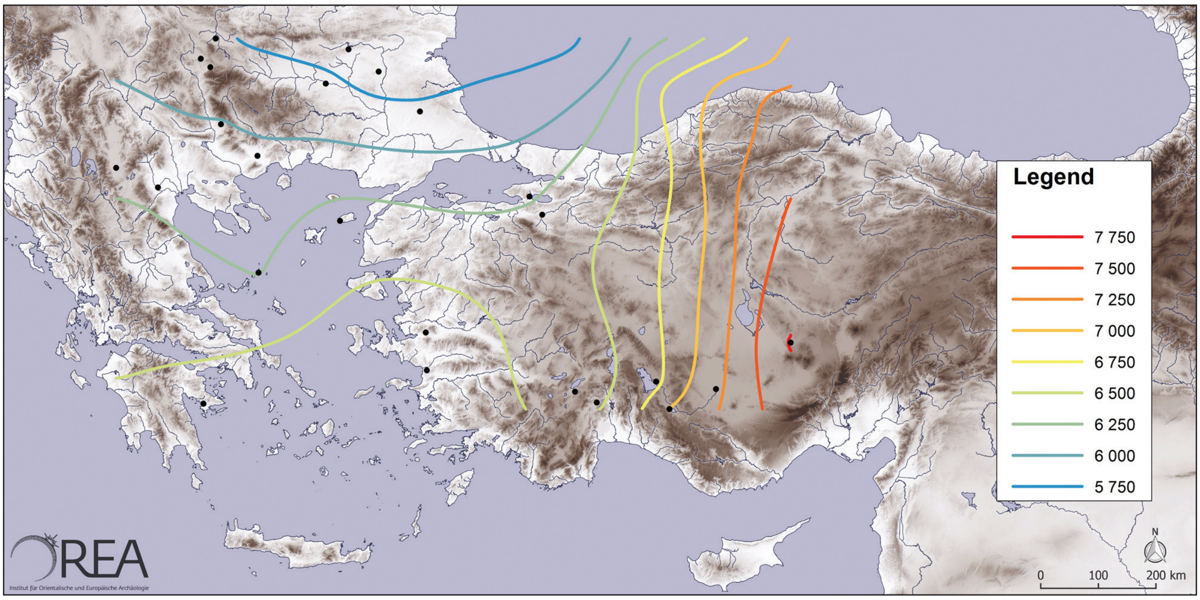

Fig. 7. Empirical Bayesian kriging interpolation of the advance of early farming, based on the audited dataset (*cf. *Table 1: median 2). Where two sites share the same coordinates, the oldest modelled date was computed. Background map designed by M. Börner.

than previous estimates for Eurasia, which returned values of *c.* 1km/year (*Ammerman, Cavalli-Sforza 1971.681; 1984; Pinhasi* et al. *2005*). Marina Gkiasta *et al.* have already pointed out that Ammerman and Cavalli-Sforza's average concealed wide regional variations: only 0.7km/year in the Balkans, but a record 5.6km/year in Central Europe (*Gkiasta* et al. *2003.45*; see *Ammerman, Cavalli-Sforza 1971.684*). In what follows, we suggest that calculating a mean rate of expansion for the study region is potentially misleading, because it assumes a linear wave-dispersal model, which is not consistent with the evidence (*Weninger* et al. *2014*). From a regional perspective, one indeed observes that linear regression models unduly normalise highly particularised sets of values.

Several arguments can be made in support of an arrhythmic model of Neolithic expansion. First of all, the non-uniform distribution of the isochrones in the two kriging simulations and their change of direction over time (east-to-west then south-to-north) are strong indications that farming did not expand in a linear manner, spreading in fits and starts (Figs. 6–7). Furthermore, the incremental way in which the isochrones ripple out of Central Anatolia in the second simulation (Fig. 7) suggests that farming expansion in this region was extremely slow or halted. A long stasis at the outset of the Neolithic on the central Anatolian Plateau has been represented graphically using summed probability distributions (Fig. 8). Data clusters in the age-distance graphs further demonstrate the existence of a chronometric lag between Central Anatolia and regions further afield (>400km; Fig. 9).

The results outlined in this paper are consistent with a previous identification of a 2000-year lag in Neolithic occupation between the central Anatolian Plateau and the Aegean Basin (*Brami 2015*). Farmers appear to have been initially held off in this region. On account of the summed probability plots, there is no indication that a 'bust' preceded the 'boom', as in other regions of Europe (*Shennan* et al. *2013*). No regional population collapse can be detected in Central Anatolia before *c.* 6000 calBC (Fig. 8A). On the face of the evidence presented, the idea of a farming frontier crystallising as a result of either a loss of momentum in the Neolithic core or an encounter of resistance in Western Anatolia appears more likely. The 'bond' was finally breached *c.* 6500 calBC, with a subsequent explosion of sites recorded throughout Western Anatolia (*Düring 2013*).

Limitations of the study

Kriging is arguably a powerful technique to interpolate the spread of early farming across Eurasia (*Bocquet-Appel* et al. *2009*). One issue that this paper has sought to address is the assumed linearity of ordinary kriging, which makes the computation of non-linear expansion behaviour, such as an arrhythmic spread in fits and starts, problematic. Where sites on either side of a 'frontier' display widely different values, ordinary kriging breaks down the gap be-

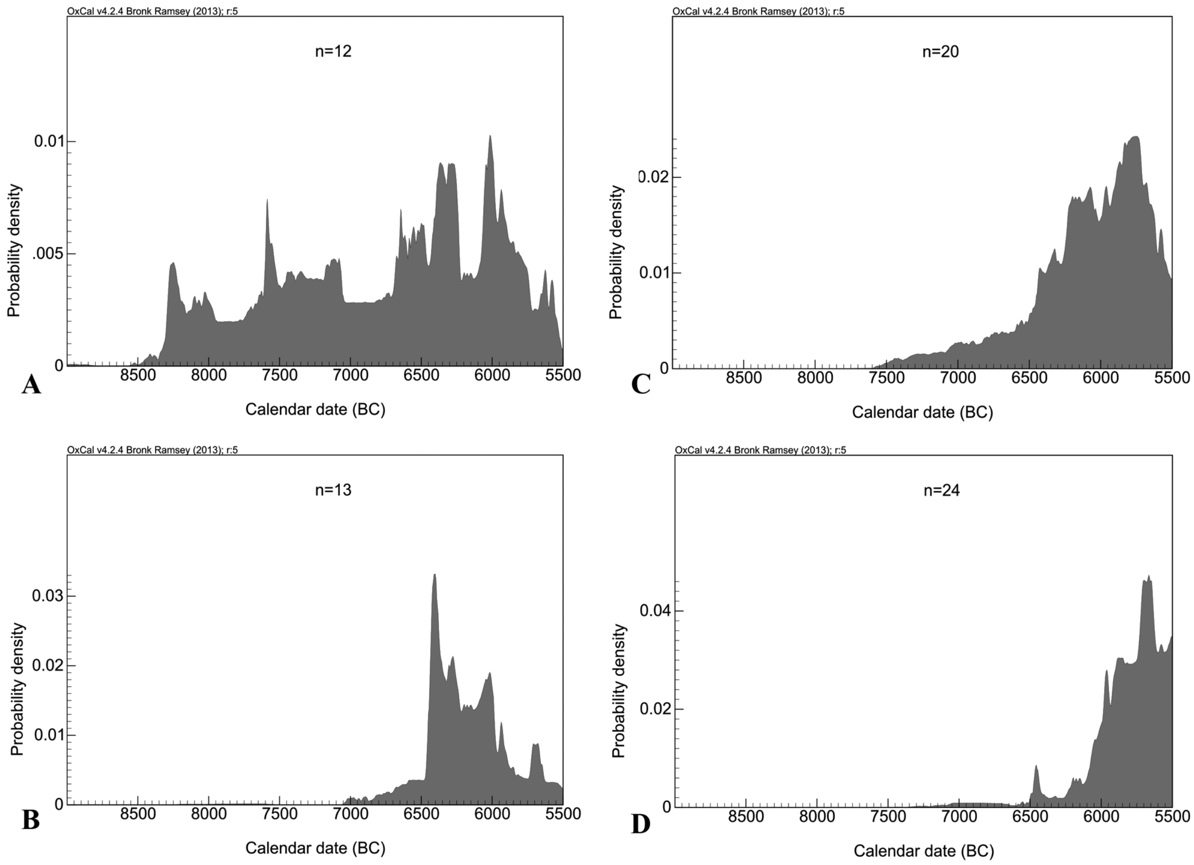

Fig. 8A–D. Summed probability distributions of calibrated radiocarbon dates in each of four target regions. A: Central Anatolia; B: Western Anatolia; C: Greece; D: Thrace (see Figure 4 for geographical coverage); n = Number of dated sites.

tween them into a series of isochrones, essentially imposing linearity where there is none. The method of kriging which was used here, empirical Bayesian kriging addresses this issue by adjusting the simulation at each of the input data locations (*Krivoruchko 2012*). Although the results obtained with this method indicate an improvement in kriging data with non-stationary covariance structure, the second interpolated map (Fig. 7) still displays an incremental pattern of expansion out of the Central Anatolian Plateau ('ripple' effect). One potential issue with this simulation lies in the number of plotted sites, which at 26 is not high enough to generate an accurate isochrone map. The second kriging simulation possibly lacks in resolution what it makes up for in data quality.

Another limitation of the kriging method of interpolation as it has been pursued here is that it operates in a spatially neutral environment, where every section of the map is given equal weighting regardless of its geographic context, *i.e.* valley bottom, mountain top, sea, *etc.* This is consistent with previous applications of kriging for modelling the expansion of the Neolithic in Eurasia (*Bocquet-Appel* et al. *2009*). One way forward would be to use the 'best patch' variable (*e.g., Bocquet-Appel* et al. *2014.63–64*). This amounts to grading land according to their agricultural potential. Approaches based on the spatiotemporal distribution of ^{14}C dates are helpful to describe a geographic spread, less so to analyse or explain it. The models presented in this paper do not take into account a multitude of variables which may have influenced early farmers. A different approach, which estimates climatic variables and their effect on the landscape as well as the socio-economic systems and demographic structure, is agent-based modelling. This holistic approach, which brings in data from different disciplines (economy, anthropology, ethnography, paleo-climatology), has been recently introduced in archaeology, allowing one to test scenarios that could not be inferred from purely archaeological observations (*Axtell* et al. *2002; Kohler* et al. *2007; Janssen 2009; Bocquet-Appel* et al. *2015*).

Conclusion

This article has established, through a suite of geostatistical and graphical simulations, that the advance

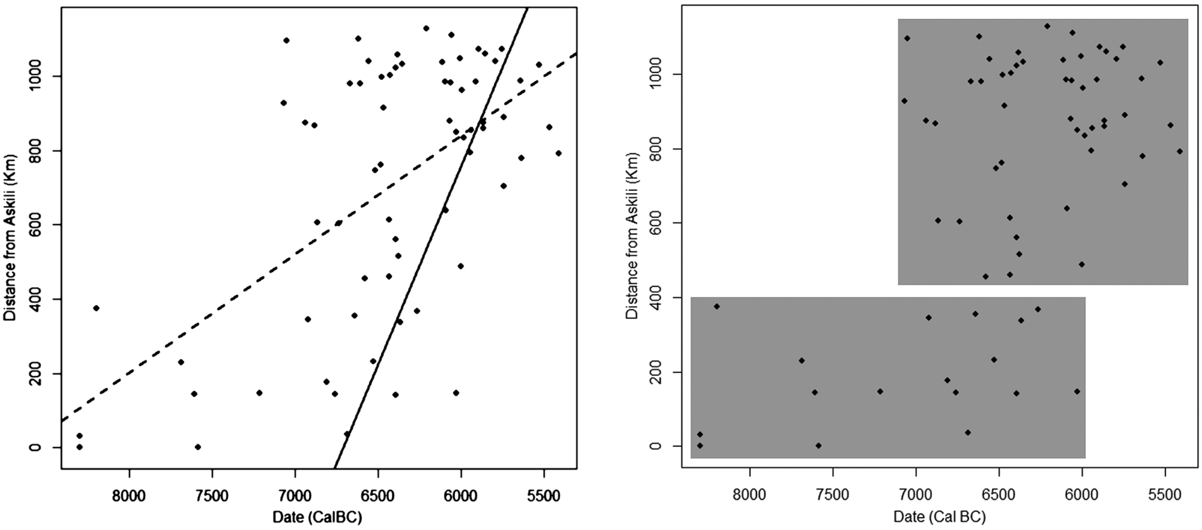

Fig. 9A–B. Age-distance graphs from Aşıklı using the comprehensive dataset. Method adapted from Pinhasi **et al. *(*2005.Fig. 2*); Weninger*** **et al. *(*2014.Fig. 2*). A: Linear regression fits to the data for calibrated date BC and distance of sites from Aşıklı. The speed implied by the distance-versus-time regression is 0.32 ± 0.11km/year (dashed line), while the speed implied by the time-versus-distance regression is 1.07 ± 0.36km/year (continuous line). B: Data clusters showing the lag in Neolithic occupation between Central and Western Anatolia.***

of the Neolithic from the Anatolian heartland to Southeast Europe involved at least two distinct stages. Farming was initially held off on the central Anatolian Plateau. Up to 2000 calibrated years were necessary to bridge the chronometric lag between Central and Western Anatolia (*Brami 2015*). Once early farming finally spread into the Southwest Anatolian Lakes Region and the Aegean Basin, shortly before *c.* 6500 calBC, it rapidly made its way north, reaching Eastern Thrace *c.* 6000 calBC. The pattern of spread described in this paper is consistent with an arrhythmic model of diffusion, involving major standstills (or 'arrhythmic phases') – *i.e.* the Central/Western Anatolian farming frontier – punctuated by rapid and/or regular advances in the Aegean Basin and the Southern Balkans (*Guilaine 2000.268–270*).

Moreover, this paper has demonstrated that linear regression models, such as the 'wave of advance' (*Ammerman, Cavalli Sforza 1971; 1984*), virtually conceal strong regional variations in the data by normalising them. While these approaches may be useful on the scale of Eurasia to describe the overall pattern and direction of spread, moving one scale down, the reader can see that they fail to reflect the fits and starts of the process, in this case the crystallization of boundary or frontier zones, which preceded the ultimate explosion of farming communities *c.* 6500 calBC. The use of Bayesian clustering alongside the kriging helped to further sharpen the resolution of the model. Two kriging simulations were presented, one based on virtually all calibrated ^{14}C dates, the other on a strictly audited sample. Together they provided a valuable picture of the Neolithic expansion out of Anatolia, as evidenced by the time-space distribution of ^{14}C dates. Finally, summed probability plots were used to show regional population fluctuations past the initial expansion of the Neolithic.

All ^{14}C dates used in this paper are available from: http://revije.ff.uni-lj.si/DocumentaPraehistorica/article/view/42.6

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The origins of agriculture in Iberia: a computational model

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ABSTRACT – *Here we discuss the importance of using the rich and growing database of high-precision, audited radiocarbon dates for high-resolution bottom-up modelling to focus on problems concerning the spread of the Neolithic in the Iberia. We also compare the spread of the Late Mesolithic (so-called Geometric) and the Early Neolithic using our modelling environment. Our results suggest that the source of radiocarbon data used to evaluate alternative hypotheses plays an important role in the results and open up new lines of research for the future.*

IZVLEČEK – *V članku poudarjamo pomen bogate in še vedno rastoče podatkovne zbirke natančnih in revidiranih radioakarbonskih datumov pri pojasnjevanju širjenja neolitika na Iberskem polotoku s pomočjo 'visoko ločljivega modeliranja od spodaj navzgor'. Z njegovo pomočjo primerjamo tudi širitev poznega mezolitika (to je 'geometričnega' mezolitika) in zgodnjega neolitika. Rezultati kažejo, da izvor radioakarbonskih datumov, ki jih uporabljamo pri vrednotenju alternativnih hipotez, vpliva na rezultate in odpira nove možnosti raziskav v prihodnosti.*

KEY WORDS – *simulation; Neolithic; Iberian Peninsula; radiocarbon; agent-based model*

Introduction: the computational approach to testing the spread of the Neolithic

The absence of local wild ancestors for the earliest domestic plants and animals, and recent DNA analyses of domestic animals confirm that they were introduced into Europe from the Near East and Anatolia in the early to mid-Holocene. For Europe, then, the origins of agricultural society involved the geographic and temporal spread of domestic species, technologies, and social practices. Considerable debate continues, however, over the mechanisms by which agriculture spread across Europe. Did this involve the movement of farming peoples who displaced or mixed with indigenous hunter-gathers, or was it the transmission of information and materials and knowledge of their use (*i.e.* the 'Neolithic Package') that brought this new way of life to Europe? The latter is sometimes referred to as cultural, and the former as demic, diffusion.

The mechanisms that drove this process (*e.g.*, demographic pressure or climatic events) are also debated. To respond to these questions, new methods and theoretical approaches have been recently applied

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in research on the spread of agriculture. In this context, computer simulation has become one of the techniques most frequently used to explore the space/time of Neolithic dispersal and its subsequent evolution.

The introduction of computer applications in archaeological research can be dated roughly to the 1950s. The first work focusing on simulation *per se* was Doran's short essay on cybernetics and its application as a useful tool for generating explanations of the archaeological record (*Doran 1970.296–298*). Subsequently, computer simulation applied to the problem of the dispersal of the Neolithic can been found throughout the archaeological literature for over 40 years. The first and most influential work was framed by Albert J. Ammerman and Luigi L. Cavalli-Sforza (*1971; 1973; 1979; 1984*), which was based on an adaptation of Fisher's reaction-diffusion model applied to the spread of agricultural groups driven by constant population pressure, so-called *logistic growth*. They evaluated this model for the diffusion of agriculture across different areas of western Eurasia (*1984.134–135*) by comparing the timing of the initial arrival of agriculture predicted by their model with then-available radiocarbon dates from the archaeological record. They concluded that the predictions of their model and the archaeological information strongly correlated (R ~ 0.8). They also suggested a southeast-northwest gradient for the spread of agriculture across Europe, validating the theory of a Near Eastern origin for the Neolithic as promulgated by Grahame Clark (*1965*). Although we are discussing the Neolithic expansion in Europe here, other simulation work has focused on the spread of rice in Asia (*Silva* et al. *2015*), and the expansion of Paleolithic populations (*Fort* et al. *2004*) or languages, such as Bantu (*e.g., Grollemund* et al. *2015; Russell* et al. *2014*).

In the past 15 years, the availability of inexpensive, high-speed computer processing and a greatly expanded radiocarbon database has led to a number of studies revisiting the empirical comparisons and demic diffusion models of Ammerman and Cavalli-Sforza, using different approaches such as time-delay, the role of waterways, effects of boundaries and cultural practices (*e.g., Ackland* et al. *2007; Davison* et al. *2006; Fort* et al. *2012; Fort, Méndez 1999*). In other research, we conducted a detailed review of some of the most notable such work (*e.g., Bocquet-Appel* et al. *2009; Davison* et al. *2009; Gkiasta* et al. *2003; Pinhasi* et al. *2005*), concluding that new radiometric information from the Iberian peninsula has not yet been fully utilised in computer models for Neolithic dispersal at continental scales (*Pardo Gordó* et al. *in press*). This large body of new radiocarbon dates only has been used in local spreading models (*Bernabeu* et al. *2015; Isern* et al. *2014*).

Since the 2000s we are now in a position to highlight the growing interest in examining different theoretical frameworks by means of archaeological simulation, and the corresponding increase in the number of papers focused on modelling work (*Costopoulos 2010; Lake 2014*). Computational modelling has become a more common and sophisticated tool in the archaeological analytic toolbox (*Barton 2013a; 2013b*), although the use of computers to support social theory more generally is hardly actu-

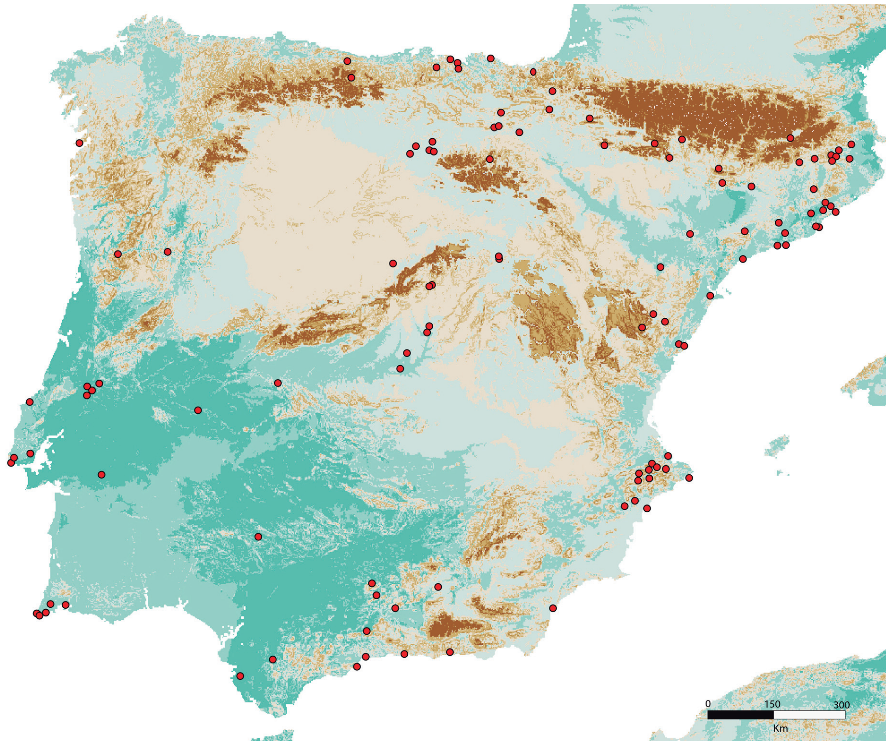

Fig. 1. Map of the Iberian Peninsula with Early Neolithic sites with radiocarbon dates used for the model evaluation.

ally a new concept (*Hägerstrand 1965*). In this paper, we investigate the spread of agriculture in Iberia using by means of simulation methods, and compare results with the preliminary models for the spread of the Late Mesolithic, the so-called *Geometric Mesolithic*. We focus on the Iberian Peninsula because it is a particularly good region in which to study the process of agricultural dispersal. It has evidence of populations of foragers during the final Mesolithic, *post quem* 6000 BC (*Bernabeu* et al. *2014*). It is situated at the western extreme of the Mediterranean Basin and serves as a bridge between Africa and Europe. For these reasons, Iberia can be considered a sub-continent where it is possible to examine a number of processes related to the Neolithic transition. For example, this area is the best place to evaluate the possibility of duel expansion routes (South-eastern France and Northern Africa) of the first groups of farmers. This has become a topic of interest recently, although there are different views on its impact on the process of Neolithic expansion (see *Cortés Sánches* et al. *2012; García Borja* et al. *2014; Zilhão 2014* for references).

Computational model

We use computer simulation models, more specifically in Agent-based Model (ABM), to investigate the spread of agriculture in Iberia. This methodological approach is one of the most active applications of simulation in archaeology (*Lake 2015*) despite its lack of use in studies of the spread of farming (*Parisi* et al. *2008*). Briefly, ABM is a kind of computational model with agents that are discrete and autonomous entities that differ from others in space and time, and usually interact with others or with their environment locally (*Bonabeau 2002; Railsback, Grimm 2012*).

Our spread model (*Bergin* et al. *2015*) was implemented the Netlogo modeling platform (*Wilensky 1999*) because it allows us to import and use geo-referenced datasets within the modelling environment, including radiocarbon dates and other kinds of information (in our case, ecological). For this reason, our model takes the form of a spatially explicit cellular automaton in a gridded landscape in which agriculture can spread on the basis of rules of dispersal. Our approach is based on "*modelling as experiment*" (*Bankes* et al. *2002*) as this allows us to use computational model environments to explore the effects of different variables and compare hypotheses to existing datasets (*Grimm* et al. *2005*).

Virtual world

Currently, the emphasis on the importance of environmental conditions is a triggering factor for the dispersal of Neolithic groups (*Gronenborn 2009; 2010*). Although it is widely recognised that ecological contexts are more or less suitable for early Neolithic agriculture, this has not been considered explicitly – with a few exceptions – in the modeling work (*e.g., Ackland* et al. *2007; Banks* et al. *2013*).

We classified landscape cells based on their suitability for cereal agriculture, using a combination of terrain and climate parameters[1] (*Bevan, Conolly 2004; López Bellido 1991*). We focused on wheat, because it has the most stringent climatic requirements of the different species of early Eurasian cereals. Maps for minimum temperatures for March, maximum temperatures for the spring months of March through May, and total precipitation for spring months were combined to create an index map of suitability for cereal agriculture; these are summarised in Table 1. A combined ecological suitability index was created by summing the three climate index maps and slope index map. The resulting map was scaled to a 5 x 5km resolution and uploaded to NetLogo. Each patch in the models then has a suitability index value based on a combination of the variables described above.

Parameter	Values	Index Value
Slope	16°–100°	1
	11°–15°	2
	6°–10°	3
	0°–5°	4
	cell is ocean	NULL
Mean Maximum Spring Temperature (degrees C for March, April, and May)	< 18° or > 30°	0
	25°–30°	1
	18°–24°	2
Minimum March Temperature	< 0°	NULL
	0°–4°	1
	≥ 5°	2
Total Spring Precipitation (mm for March, April, and May)	< 100mm or > 600mm	0
	100mm–149mm	1
	301mm–600mm	1
	150mm–300mm	2

Tab. 1. Environmental parameters used to calculate Ecological Suitability Index.

1 Climate parameters were derived from the WorldClim database (http://www.worldclim.org) (*Hijmans* et al. *2005*).

Spread movement, demographic effects and starting points for agriculture dispersal

The three modes of Neolithic dispersal tested in our model are neighbourhood, leapfrog and the Ideal Despotic Distribution (IDD) model (Fig. 2). The first corresponds to the classical wave-of-advance movement promulgated by Fischer (*1937*) and applied to population expansion by many researchers (see *Steele 2009* for references). The model is straightforward: agriculture spreads from one cell to neighbouring cells that lack agriculture as long as they are suitable for it (*i.e.* have a sufficiently high ecological suitability index value).

The second corresponds to the leapfrog model described by Tjeerd Van Andel and Curtis Runnels (*1995*). This algorithm simulates the dispersal of agriculture from any cell that has agriculture to another randomly selected cell within a given distance (specified by the user) which does not yet have agriculture and that is suitable. This punctuated spread is also the kind of movement proposed in the *maritime pioneers* models (*e.g., Dawson 2011; Zilhão 2001*). Two related types are "*neighbourhood with no ecological constraints*" and "*leapfrog with no ecological constraints*". These work like the constrained versions already described, but without taking into account the suitability of cells for agriculture.

The third process is the IDD model from Human Behavior Ecology (*Kennett, Winterhalder 2006; Smith 1992; Smith, Winterhalder 2003*), it was implemented as a follow-up on suggestions by Stephen Shennan (*2008*) and Sarah B. McClure *et al.* (*2006*) about the potential impacts of socially mediated access to resources during the Neolithic. In this case, agriculture spreads to the neighbouring cells with the highest suitability values, but this suitability is affected by the number of farmers already occupying the cell. That is, values decline whenever agriculture 'spreads' to a cell in which it is already present, and agriculture will spread only to neighbouring cells with the highest suitability values.

Finally, in this model, we explored 17 different potential starting points for the spread of the Neolithic

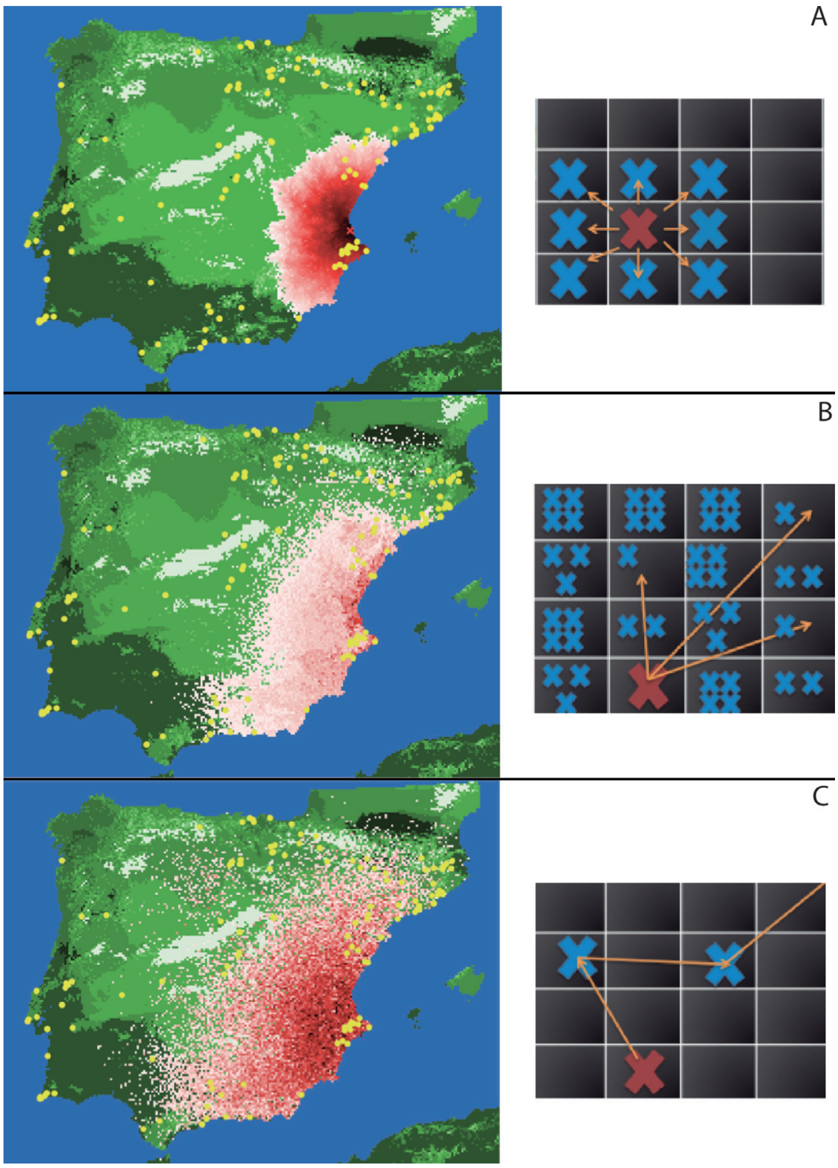

Fig. 2. Examples of spread models in action. A: shows wave-of-advance dispersal; B: shows the IDD spread algorithm; C: shows leapfrog dispersal with the maximum leap distance set to 5 cells.
On the maps, an 'X' marks the starting point for the spread; yellow dots show the locations of Neolithic sites. The colours indicate the relative time of arrival of agriculture: the darkest red is the oldest arrival time, and lightest pink the most recent arrival time. Underlying green shades show the ecological suitability of cereal farming.

across Iberia. We chose the mouths of various rivers or areas near of them (*e.g.*, Málaga and Gibraltar) around the perimeter of the Iberian Peninsula, with one of them in the centre as a null case (Madrid).

Previous results

To estimate a chronological range sufficient to encompass the spread of agriculture over much of the Peninsula, we first identified the oldest acceptable unquestionable date for the use of domesticates: a date of 7569±48 calBP (all dates used here are expressed as calibrated years BP.) We then extended this range up to 6000 calBP to encompass the earliest evidence for agro-pastoral systems across the Peninsula. This range permits us to cover a total time span of between 7800–6000 calBP, with the last 500 years for sites located only in northern Spain. For any region in the Iberian Peninsula, we selected sites representing the earliest dated evidence for domestic plants and/or animals. The radiocarbon dataset (*Bernabeu* et al. *2015.Tab. 2 SI*) includes only dates clearly associated with archaeological remains of domestic taxa (plants or animals). In total, we have 134 radiocarbon dates associated with 115 archaeological sites. Their distribution can be seen in Figure 1. In total, 53 refer to long-lived taxa, 39 to short-lived taxa and 42 to domestic taxa (Fig. 3). We grouped this radiocarbon information into four subsets (the mean radiocarbon age is used in all groups):

❶ Best: includes a mix of dates made on domestic taxa where available, non-domestic short-lived taxa when directly dated domestic taxa are not available, and non-domestic long-lived taxa when this is the only kind of radiocarbon sample available. In other words, this is the best radiocarbon date for each site.
❷ Oldest: the oldest date for each site regardless of the kind of sample.
❸ Short-lived: dates are limited to those from animals (domestic and non-domestic) and human bones, shrubs (like rosemary), grasses and herbs, and domestic and non-domestic fruits
❹ Domestic: dates are limited to radiocarbon dates of domestic plant and animal remains.

Before reviewing previous results (*Bernabeu* et al. *2015; Pardo Gordó* et al. *in press*), we first describe how we compare the model results with the archaeological information. This involves establishing a temporary equivalence between the model and the empirical record. In our case, this was not problematic because calculating the Pearson correlation coefficient between model time arrival (ticks) and the average of the calibrated radiocarbon dates (agents) is sufficient to evaluate different modelled scenarios. Since we are comparing simulation time-steps, which increase through time, and radiocarbon dates, which decrease in value from oldest to youngest, negative correlations indicate good results.

Our first work (*Bernabeu* et al. *2015*) focused on exploring the radiometric dating sample, points of origin for the Iberian Neolithic and exploration of parameters such as movement, distance, ecology and occupation costs. In the first experiment, we evaluated archaeological samples and initial expansion points, keeping the values of movement, distance and cost of occupation fixed (*Bernabeu* et al. *2015.Tab. 1*). The results show that the samples used influence the results, and the best starting points are systematically located in eastern Spain, confirming the Mediterranean origin of the Neolithic. In the second experiment, we evaluated whether the fit between the model and the empirical data improves with multiple origin points instead of a single origin point. This experiment allowed us to test a possible double entry route for the Iberian Neolithic. The results of this experiment allowed us to discard the idea that simply increasing the number of origin points increases the correlation results.

We concluded that 9 of the 10 strongest correlations are associated with a dual entry route of the Neolithic into Iberia (one of them located in the northeast

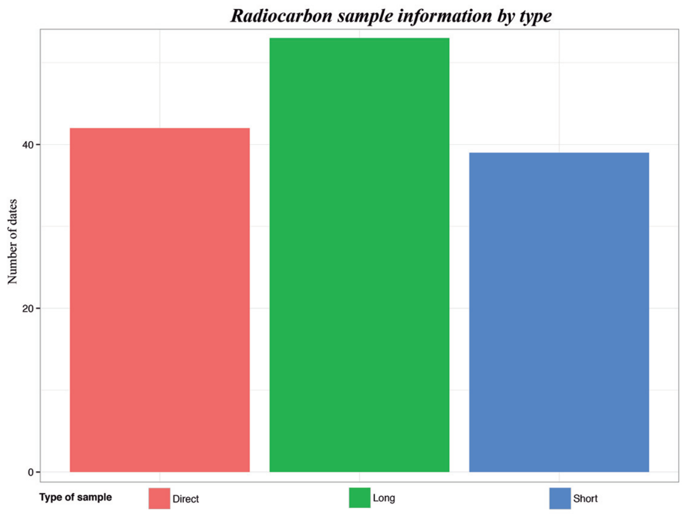

Fig. 3. Bar chart with the number of radiocarbon dates made on long-lived taxa, short-lived taxa and direct taxa. See the online version to identify the colours of each category.

and the other in the southeast) and a complex, multi-spreading process.

Finally, using the best correlations of the previous experiments, we explore movement, distance, ecology threshold and the costs of existing occupation by farming groups. We observed the best correlations are associated with leapfrog dispersal, with a distance between 25–50km, medium-high impacts of prior agricultural occupation (demographic aspects) and a preference for places with high potential cereal productivity (ecological threshold between 5 and 6). This allowed us to conclude that the expansion of Neolithic into Iberia can be characterised by pioneer colonisation, whereby farmers travelled relatively long distances looking for places with no or few people already farming, and an attractive environment for wheat.

Finally, in other work (*Pardo Gordó* et al. *in press*), we explored in more detail the radiocarbon data and its influence on our model results with several experiments. The first compared different groups (above) from the radiocarbon dataset, with a single origin point, and more specifically the best and oldest sub-sets. We observed that that 15 of the 20 strongest correlations are associated with the best sub-set, suggesting that different selections of the radiocarbon information can produce quite different results. Next, we compared the best sub-set with short-lived dates. Again, we looked at the 20 strongest correlations, with unexpected results. The more 'reliable' short-lived radiocarbon dataset generated correlation coefficients considerably worse than the larger, mixed best dates set. Why? We conducted a sub-experiment to test whether dated shell that had potentially been affected by the reservoir effect (*Ascough* et al. *2005; Soares, Dias 2006*) could have had an impact on the results. We again selected one starting point (the Segura River, eastern Iberia) for each of the 5 configurations and removed those dates for shells in the short-lived data set. Removing shell dates from this sub-set significantly improved its match with model results. It is worth remembering that the use of samples made on shells can be problematic when used to evaluate model results if the reservoir effect is not taken into consideration. In the last experiment, we compared the short-lived dates with the smaller group of dates from domestic taxa. Of the 25 best correlations, better Pearson correlations coefficient were produced from the more reliable dates of domestic taxa only dates than the larger short-lived dataset, even without dates for shell.

In short, our previous work suggests that the quality of the radiocarbon information used needs to be considered carefully when using a body of dates to evaluate the results of computational modelling of the spread of farming (empirical evidence for this new economy). The importance of using careful and rigorous criteria for the selection of radiocarbon dates noted by other archaeologists (*e.g., Bernabeu 2006; Zilhão 2001; 1993; 2011; Bernabeu* et al. *2001; Bernabeu, Martí 2014; Rojo* et al. *2008*) is firmly reflected in the results of our modelling experiments. Nevertheless, the poor results obtained from samples made on short-lived taxa associated with domestication economies were surprising.

New experiments

Auditing radiocarbon problems, new modelling results

As we observed in the section above, the best correlations obtained from previous experiments made on remains of domestic and dates on short taxa (including domestic and non-domestic plants and animals), generated Pearson correlation coefficients considerably worse than other subsets including the oldest and the best. We suggested that these poor correlations could relate to the reservoir effect (on shells and bones). Consequently, we need to calculate the reservoir effect and its impact on spatio-temporal variations (for details see *Ascough* et al. *2005*). As we pointed out (*Bernabeu* et al. *2014*), these problems are especially visible in Portugal, where a significant number of dates derive from shells and human bones.

Also, as recently pointed out by Rachel Wood (*2015*) and Karl-Göran Sjögren (*2011*), problems linked with the sampling criteria can also affect different treatment procedures in the laboratory. At the same time, the ratio of nitrogen to carbon in bone collagen has been proposed as a good indicator for testing the quality of radiocarbon results (*Van Klinken 1999*). Unfortunately, the details of the N/C ratio are not usually available for the published radiocarbon dates, adding uncertainty about the possible importance that this kind of problem in radiocarbon assays of bones. Finally, Haidé Martins and colleagues (*2015*) demonstrated that distinguishing some domestic taxa in animal bones (especially *Ovis* sp. in the Iberian Peninsula) can be difficult, with consequences for dating the beginning of farming. Bearing in mind the potential effect in the radiocarbon outputs, we designed a new experiment that considers only charred samples such as seeds, fruits and charcoals identified as short taxa (shrubs) and we add domestic bones only when the N/C ratio is known and adequate for dating. A total of 34 radiocarbon dates meet these criteria and were used for the experiments reported here (Tab. 2). Figure 4 shows a comparison of our previous results obtained with domestic taxa (for details see *Bernabeu* et al. *2015. Tab. 1*) and the results using the same model parameters obtained using the new audited radiocarbon data set. As shown in the graph, the correlation obtained increases significantly.

To further illustrate this point, if we look at the results associated with the point of origin set to the *Rio Segura* and using the wave-of-advance spread algorithm with ecology considered, the use of domestic taxa shows only a value of R = –0.39, while the use of a database with the filtered information increases its correlation to R = –0.50.

In sum, these results suggest again that the radiocarbon samples used have significant effects on the correlations obtained, and consequently on the evaluation of different model scenarios. If we want to be sure about the evaluation of our models (including mathematical, agent-based or cellular automata) to analyse Neolithic dispersals (and, of course, other similar phenomena) using radiocarbon dates, then we need to carefully audit the samples, a task on which we are working now in order to reexamine our previous conclusions (*Bernabeu* et al. *2015; Pardo Gordó* et al. *in press*).

Geometric spread as a null hypothesis

Mesolithic bladelet technology, including trapezoidal forms appeared in the 9th millennium calBP as a European phenomenon which included the appearance of new techniques and tools in lithic industries. A millennium later, agriculture expanded around Western Europe. The Mesolithic dispersal has been considered by several authors, such as Clark (*1958*), who compares this expansion with the posterior Neolithic advance. Despite an interest in exploring the mechanisms behind this dispersal (demic *versus* cultural), only a few works have highlighted this potential line of research, without developing it further (*Binder* et al. *2012*). Instead, most authors focus on the geographical origin of the Mesolithic, arguing over the different potential starting points (*Biagi, Kiosak 2010; Binder* et al. *2012; Marchand, Perrin 2015*). Although there is broad spatial variability in Mesolithic technology across Europe, it is generally thought to indicate a major shift in blade technology and the production of compound arrowheads (geometric tools). This involves knapping techniques to obtain regular blades and bladelets using indirect percussion or pressure as a distinctive characteristic in order to make regular blades for geometric forms (trapezes) with symmetric or asymmetric shapes (*Binder* et al. *2012*). Other tools, such as notched blades, are also common, and were probably used for processing plant materials (*Gassin* et al. *2013*). In the Western Mediterranean, this cultural complex is known as the *Tardenosien* tradition, or referred to as the Late Mesolithic. This encompasses the re-

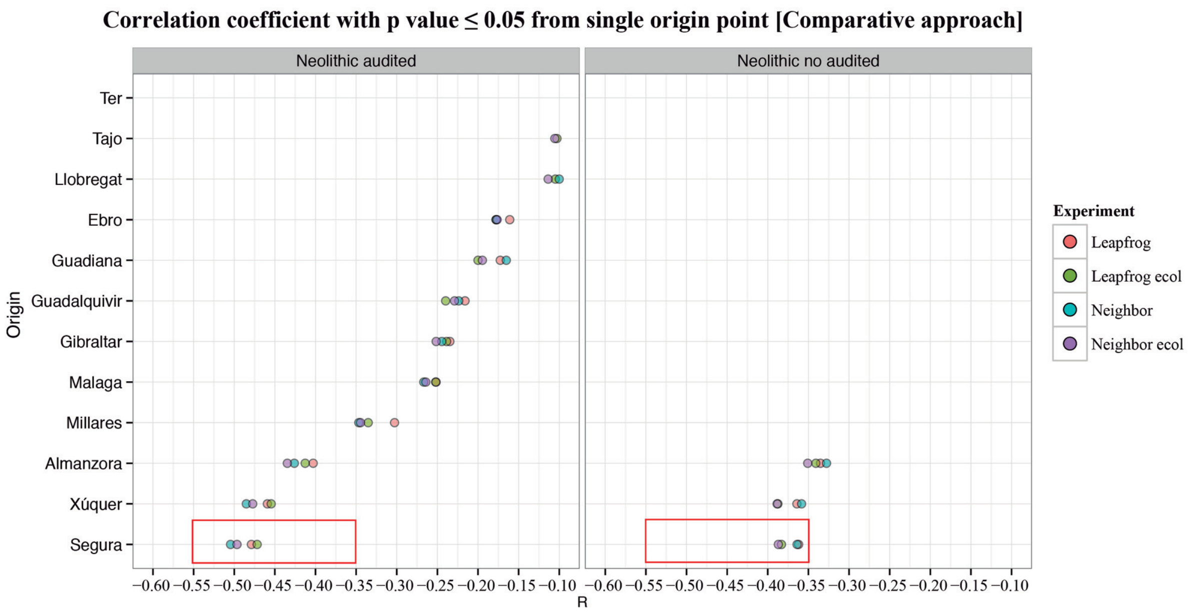

Fig. 4. Correlation coefficients for the results of the Neolithic audited and not audited for individual starting points for agricultural dispersals. The colours indicate the different strategies employed by agents. Positive correlations and models are excluded.

gionally named industries of the Castelnovien Complex (or Second Mesolithic in France and Italy), the Upper Capsian in North Africa (*Rahmani 2003*) and Geometric Mesolithic in Mediterranean Iberia and Portugal (*Fortea 1973; Utrilla, Montes 2009*). With some regional particularities, this Mesolithic phenomenon has been considered to have across spread Europe in some kind or diffusion process (*Kozłowski 2009*).

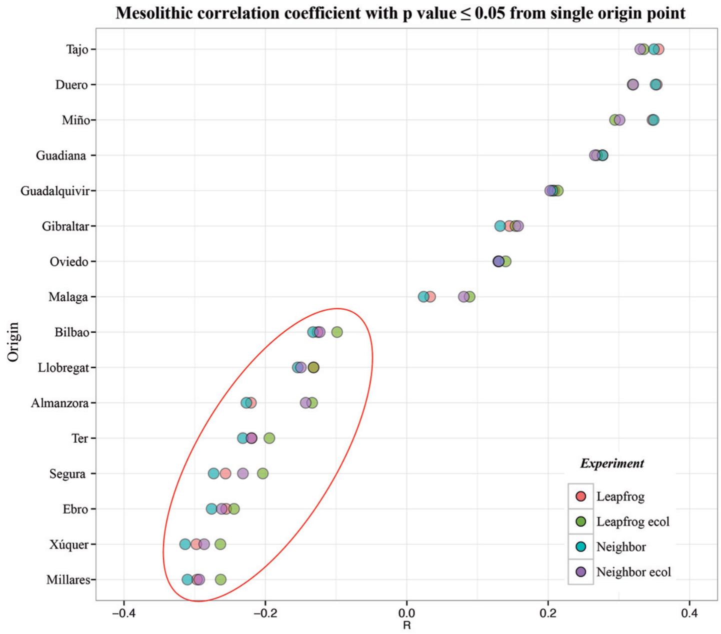

Fig. 5. Correlation coefficients for the results of the Late Mesolithic for individual starting points for agricultural dispersals. The colours indicate the different strategies employed by agents. A red circle indicates negative correlations.

Building on our prior work, we selected radiocarbon dates corresponding to the first Geometric Mesolithic in order to compare some parameters related to Mesolithic and Neolithic dispersals. Current information shows that the Late Mesolithic is well documented in eastern Iberia and the Ebro valley (Mediterranean region), and central and southern Portugal (Atlantic coast). While several authors consider some settlements in the Cantabrian region as Mesolithic with geometrics (*Arias, Fano 2009*), these settlements did do not include all of the technological elements of the well-defined Late Mesolithic of the Castelnovien tradition, so they were eliminated from our database for this preliminary assessment. Other areas (northeastern Iberia in Catalonia and the inner territories of the Meseta) lack archaeological data on this period.

We compiled a total of 21 dates associated with Mesolithic contexts, considering only audited short-lived samples as described above (Tab. 2). The criteria followed the protocols used in our previous work (*Bernabeu* et al. *2015*), considering the most ancient date for each site provided by short-lived samples and comparing them with the modeling results. A particularity in relation to the nature of the samples affects Portuguese Mesolithic contexts, where human skeletons constitute the main material dated. For this, we used the radiocarbon dates compiled by António Faustino Carvalho (*2010*).

In this experiment, we compare different starting points for the spread of the geometric tools around the perimeter of Iberia and evaluate the modelling results against radiocarbon dates made on short-lived taxa. The parameters for this experiment were set as follows: threshold for ecological suitability (*i.e.* for wheat cultivation) 0 and 3, costs of prior occupation 5% and leapfrog radius distance of 5 cells (25km). As we can see in Figure 5 that the best correlation between the model result and dated Late Mesolithic sites occurs when the ecological threshold is limited to 0 with R = –0.32 in the best case.

Regarding the best correlations (those that have negative values), we note several results. First, most of the points of origin with negative correlations (except Bilbao) are located on the Mediterranean coast of the Iberian Peninsula. These results parallel the proposed expansion of the Mesolithic complex throughout Europe (*e.g., Clark 1958*). The best fitting spread algorithm in all cases is the wave-of-advance (spreading to neighbouring cells only), and when ecological suitability is not considered.

However, are there any similarities between these results and those related to the first groups of farmers? Figure 6 shows the comparison between the Mesolithic and Neolithic (using only dates from domestic taxa). The graph shows that the correlations associated with the Neolithic are higher than those for the Mesolithic, and that the best Neolithic correlations ($R \geq -0.3$) are associated with scenarios where ecological suitability is taken into consideration. These results do not seem unreasonable, because the base map used was drafted following ecological parameters for cultivating wheat (see section 2.1), which should not be relevant to Mesolithic foragers. Nevertheless, this first attempt to model the

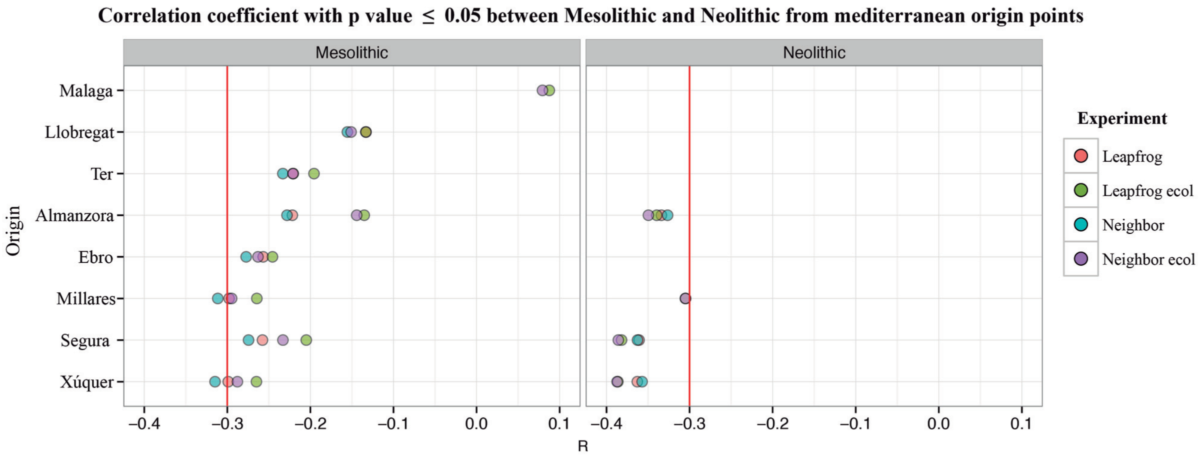

Fig. 6. Correlation coefficients for the results of Late Mesolithic and Neolithic results (only dates on domestic taxa used for comparison) for individual starting points for agricultural dispersals. The colours indicate the different strategies employed by agents. A red line indicates negative correlations > –0.3.

spread of the Mesolithic in the Iberian Peninsula is interesting, as we can detect the Mediterranean character of this expansion. It demonstrates the potential for a new direction of research in which modelling can be a useful tool for understanding the emergence and expansion of pan-European phenomena in general.

Concluding remarks

In this paper, we illustrate the potential of bottom-up modelling for investigating the dispersal of agro-pastoral economies and life ways in Europe, focusing on the Iberian Peninsula as a case study. Additionally, we use computational modelling approach as a method of formalising and testing multiple (and complex) hypotheses about local-scale decision rules, rather than as a means of quantitatively characterising agricultural dispersals at the continental scale (so-called top-down models). Agent-based models and mathematical models are complementary approaches to formalising hypotheses about the dynamics of human societies. Top-down modelling allows us to describe general trends and to aggregate behaviour(s) in societies at large scales and over extended periods. On the other hand, bottom-up modelling is particularly well suited to understanding individual behaviour and its interactions with others and its environment, which generated the general trends observed. We believe that the formalisation in both kinds of modelling approaches is an essential step for the ability to systematically compare and test hypotheses about spatiotemporal dynamics of past human societies against a poor, fragmentary and incomplete archaeological record. In short, this paper is a good example of methods useful for understanding a complex problem (the Neolithic spread) with a promising new approach (agent-based models).

Finally, this work demonstrates the importance of carefully auditing the radiocarbon information used to evaluate quantitative models of Neolithic (and others) dispersals. This is essential if we aim to test the reliability of models of human dynamics against the empirical record.

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Appendix

Tab. 2. Sites and radiocarbon dates used to evaluate model experiment results. All dates are given as calibrated BP. N: Neolithic; M: Mesolithic; S: short taxa; D: domestic taxa.
***** Radiocarbon dates used in the audited experiment in this work.***

Site	Period	Code lab	Type	Sample	Level	BP	SD	CalBP smean	Reference
Abric de la Falguera**	N	Beta142289	D	Seed (*Tritucum*)	UE 2051b	6510	80	7407	*Bernabeu* et al. 2015
Almonda	N	OxA9288	S	Bone (Stag)	I	6445	45	7373	*Bernabeu* et al. 2015
Alto de Rodilla	N	CSIC1967	S	Bone (Human)	II	6171	55	7082	*Bernabeu* et al. 2015
Arenaza	N	OxA7157	D	Bone (*Bos taurus*)	IC2	6040	75	6889	*Bernabeu* et al. 2015
Atxoste	N	GrA9789	S	Bone	III b	6220	60	7132	*Bernabeu* et al. 2015
Balma Margineda**	N	Beta352681	S	Fruit (Hazelnut)	III b	6630	80	7518	*Martins* et al. 2015
Benàmer	N	CNA539	S	Pollen	II	6575	50	7491	*Bernabeu* et al. 2015
Ca l'Estrada	N	Poz10391	S	Bone (human)	SF501	5740	40	6555	*Bernabeu* et al. 2015
Cabranosa	N	Sac1321	S	Shell (*Mytilus*)	fireplace	6550	70	7490	*Bernabeu* et al. 2015
Caldeirao	N	OxA1035	D	Bone (*Ovis*)	NA II	6330	80	7290	*Bernabeu* et al. 2015
Camp Colomer de Juberri**	N	Beta325686	D	Seed (*Hordeum*)	Pit FS 29	5630	40	6409	*Martins* et al. 2015
Can Roqueta	N	CR	S	Bone	CRII-173	6400	50	7345	*Bernabeu* et al. 2015
Can Sadurní **	N	OxA15488	D	Seed (*Tritucum*)	Layer 18	6421	34	7367	*Bernabeu* et al. 2015
Cariguela	N	Pta9163	S	Bone (Human)	CIV II 2	6260	20	7207	*Bernabeu* et al. 2015
Carrascal	N	Beta276401	D	Bone (*Bos taurus*)	NA level	6280	40	7214	*Bernabeu* et al. 2015
Casa da Moura	N	TO953	S	Bone (Human)	Ia	5990	60	6820	*Bernabeu* et al. 2015
Casa Montero	N	Beta295152	D	Bone (*Ovis*)	Pit 15267	6200	40	7093	*Bernabeu* et al. 2015
Castelo Belinho	N	Sac2031	S	Bone (Human)	Structure 1	5790	70	6582	*Bernabeu* et al. 2015
Cerro Virtud	N	OxA6714	S	Bone (Human)	Lev. 6 (B3.30)	6030	55	6870	*Bernabeu* et al. 2015
Chaves	N	GrA38022	D	Bone (*Ovis*)	Ib	6580	35	7468	*Bernabeu* et al. 2015
Chaves **	N	GrA28341	S	Fruit (Acorn)	Ib	6380	40	7315	*Baldellou* 2011
Cingle del Mas Cremat **	N	Beta232340	S	Seed (*Sorbus* sp.)	IIIb	6020	50	6862	*Bernabeu* et al. 2015
Codella	N	Beta221900	D	Bone (*Ovis*)	–	5720	60	6530	*Bernabeu* et al. 2015

Site	Period	Code lab	Type	Sample	Level	BP	SD	CalBP smean	Reference
Costamar	N	OxA23578	D	Bone (*Bos*)	UE 40102	5995	38	6838	*Bernabeu* et al. *2015*
Costamar **	N	UCIAMS60738	D	Seed (*Tritucum*)	UE 13002	5965	25	6792	*Flors 2009*
Cova Avellaner	N	UBAR109	S	Bone (Human)	3A	5830	100	6622	*Bernabeu* et al. *2015*
Cova Colomera **	N	OxA-23634	D	Seed (*Tritucum*)	CE 14	6170	30	7086	*Bernabeu* et al. *2015*
Cova de la Sarsa **	N	OxA26076	D	Bone (*Ovis*)	-	6506	32	7402	*Bernabeu* et al. *2015*
Cova de les Cendres	N	Beta239377	D	Bone (*Ovis*)	H19	6510	40	7406	*Bernabeu* et al. *2015*
Cova de les Cendres **	N	GifA101360	D	Seed (*Tritucum*)	H19	6490	90	7396	*Bernbabeu, Molina 2009*
Cova de l''Or	N	UCIAMS66316	D	Bone (*Ovis*)	VI a	6475	25	7381	*Bernabeu* et al. *2015*
Cova de l''Or **	N	OxA10191	D	Seed (*Tritucum*)	VI a	6310	70	7239	*Martí 2011*
Cova de Sant Llorenç **	N	Beta299597	D	Seed (*Tritucum*)	II	6160	40	7067	*Oms 2014*
Cova del Toll **	N	OxA26070	D	Bone (*Ovis*)	IIb	6425	35	7368	*Bernabeu* et al. *2015*
Cova dels Trocs **	N	OxA26070	D	Seed (*Tritucum*)	I	6080	40	6942	*Rojo* et al. *2013*
Cova den Pardo	N	Beta231879	D	Bone (*Ovis-Capra*)	VIII	6610	40	7513	*Bernabeu* et al. *2015*
Cova Font Major	N	Beta317705	D	Bone (*Ovis*)	Ig	6310	40	7224	*Bernabeu* et al. *2015*
Cova Foradada	N	Beta248524	D	Bone (*Ovis*)	Ic	6200	40	7093	*Bernabeu* et al. *2015*
Cova Fosca d'Ebo **	N	OxA26047	D	Bone (*Ovis*)	II z	6413	33	7364	*Bernabeu* et al. *2015*
Cova Gran **	N	Beta265982	S	Seed (acorn)	E9	6020	50	6862	*Bernabeu* et al. *2015*
Cova Sant Martí	N	Beta166467	S	Bone (Human)	UE206	5740	40	6555	*Bernabeu* et al. *2015*
Cueva del Toro **	N	Beta341132	D	Seed (*Tritucum*)	IV	6150	30	7063	*Socas, Camalich 2013*
Cueva de la Higuera	N	Beta166230	S	Bone	II	6250	60	7144	*Bernabeu* et al. *2015*
Cueva de los Mármoles **	N	Wk25171	D	Seed (*Hordeum*)	N1 D2	6198	31	7094	*Bernabeu* et al. *2015*
C. Murciélagos (Alb.) **	N	CSIC1133	S	Charcoal (Stipa)	–	6086	45	7013	*Bernabeu* et al. *2015*
C. Murciélagos (Zuh.) **	N	GrN6639	D	Seed (*Cereal* sp.)	C	6025	45	6865	*Bernabeu* et al. *2015*
Cueva de Nerja	N	Beta131577	D	Bone (*Ovis*)	IV	6590	40	7496	*Bernabeu* et al. *2015*
El Barranquet	N	Beta221431	D	Bone (*Ovis*)	UE 79	6510	50	7406	*Bernabeu* et al. *2015*
El Cavet **	N	OxA26061	D	Seed (*Triticum*)	UE 2014	6536	36	7451	*Oms 2014*
El Congosto	N	KIA27582	S	Bone (Human)	–	6015	50	6860	*Bernabeu* et al. *2015*
El Mirador **	N	Beta208134	D	Seed (*Triticum*)	MIR 23	6300	50	7220	*Bernabeu* et al. *2015*
El Mirón **	N	GX309010	D	Seed (*Cereal* sp.)	Trench 303.3	5550	40	6348	*Bernabeu* et al. *2015*
El Tonto	N	Beta317251	D	Bone (*Ovis*)	–	6230	30	7138	*Bernabeu* et al. *2015*
Fuente Celada	N	UGA75665	S	Bone (Human)	H62-UE622	6120	30	7048	*Bernabeu* et al. *2015*
Gruta do Correio-Mor	N	Sac1717	S	Bone (Human)	–	6330	60	7246	*Bernabeu* et al. *2015*
Hostal Guadalupe	N	Wk25167	D	Bone (*Ovis-Capra*)	–	6249	30	7205	*Bernabeu* et al. *2015*
Hostal Guadalupe	N	Wk25169	S	Bone (Human)	–	6298	30	7220	*Bernabeu* et al. *2015*
Kobaederra **	N	AA29110	D	Seed (*Cereal* sp.)	IV	5375	90	6150	*Bernabeu* et al. *2015*
La Draga	N	Beta278255	D	Bone (*Ovis-Capra*)	I	6270	40	7210	*Bernabeu* et al. *2015*
La Draga **	N	OxA20233	D	Seed (*Triticum*)	I	6179	33	7080	*Bosh, Tarrús 2011*
La Lampara **	N	UtC13346	D	Seed (*Triticum*)	Structure 1	6280	50	7214	*Bernabeu* et al. *2015*
La Lampara	N	KIA21347	S	Bone	Structure 18	6407	34	7360	*Bernabeu* et al. *2015*
La Paleta	N	Beta223091	D	Bone (*Ovis*)	Structure 175	5850	40	6685	*Bernabeu* et al. *2015*
La Paleta	N	Beta223092	D	Seed (Cerealia)	Structure 219	6660	60	7535	*Bernabeu* et al. *2015*
La Revilla del Campo	N	KIA21356	D	Bone (*Ovis-Capra*)	Structure 4	6355	30	7286	*Bernabeu* et al. *2015*
La Revilla del Campo	N	KIA21358	S	Bone	Structure 14	6365	36	7333	*Bernabeu* et al. *2015*
La Revilla del Campo **	N	UtC13295	D	Seed (*Triticum*)	Structure 12	6313	48	7242	*Rojo* et al. *2008*
La Vaquera **	N	GrA8241	S	Fruit (acorn)	UE 98	6080	70	6976	*Bernabeu* et al. *2015*
Les Guixeres **	N	OxA26068	D	Bone (*Ovis*)	A	6655	45	7538	*Bernabeu* et al. *2015*
Los Cascajos **	N	Ua24427	D	Seed (*Cereal* sp.)	Structure 516	6250	50	7145	*Bernabeu* et al. *2015*
Los Castillejos **	N	Ua36215	D	Seed (*Cereal* sp.)	I	6310	45	7223	*Bernabeu* et al. *2015*
Los Gitanos	N	AA29113	S	Bone	A3	5945	55	6764	*Bernabeu* et al. *2015*
Los Husos I	N	Beta161182	S	Bone	XVI	6240	60	7141	*Bernabeu* et al. *2015*

Site	Period	Code lab	Type	Sample	Level	BP	SD	CalBP smean	Reference
Los Husos II	N	Beta221640	S	Bone	VII	6050	40	6878	*Bernabeu* et al. *2015*
Marizulo	N	Ua-4818	S	Bone (Human)	I	5285	65	6067	*Bernabeu* et al. *2015*
Mas d'Is **	N	Beta162092	D	Seed (*Hordeum*)	House 2	6600	50	7500	*Bernabeu* et al. *2015*
Molino de Arriba	N	KIA41450	S	Bone (Human)	UE 202	6120	30	7048	*Bernabeu* et al. *2015*
Peña Larga	N	Beta242783	D	Bone (Ovis/Capra)	IV	6720	40	7570	*Bernabeu* et al. *2015*
Pico Ramos **	N	Ua3051	D	Seed (*Hordeum*)	IV	5370	40	6151	*Bernabeu* et al. *2015*
Plaza Vila de Madrid	N	Beta18271	S	Bone (Human)	–	6440	40	7373	*Bernabeu* et al. *2015*
Portalón	N	Beta222339	S	Bone	N9 north	6100	50	7021	*Bernabeu* et al. *2015*
Prazo	N	GrN26404	S	Charcoal (*Arbustus* u.)	SVII-UE 3	5630	25	6400	*Bernabeu* et al. *2015*
Roca Chica	N	Wk27462	D	Bone (*Ovis*)	–	6234	30	7140	*Bernabeu* et al. *2015*
Sant Pau del Camp	N	Beta236174	S	Bone	Trench 1	6290	50	7216	*Bernabeu* et al. *2015*
Senhora das Lapas	N	ICEN805	S	Bone (Human)	Layer 3	6100	70	7020	*Bernabeu* et al. *2015*
Serrat del Pont	N	Beta172521	S	Bone (*Sus scrofa*)	III	6470	40	7379	*Bernabeu* et al. *2015*
Tossal de les Basses	N	Beta232484	D	Seed	UE34	5950	50	6787	*Bernabeu* et al. *2015*
Vale Boi	N	OxA13445	D	Bone (*Ovis-Capra*)	C II	6042	34	6875	*Bernabeu* et al. *2015*
Vale Boi	N	Wk17842	S	Bone (wildlife)	C II	6095	40	7016	*Bernabeu* et al. *2015*
Ventana	N	Beta166232	D	Bone (*Ovis*)	II lower	6350	40	7328	*Bernabeu* et al. *2015*
Abric de la Falguera	M	AA59519	S	Charcoal (bract)	VIII	7526	44	8352	*Martí* et al. *2009*
Aizpea	M	GrN16620	S	Bone	I (b base)	7790	70	8571	*Utrilla* et al. *2009*
Atxoste	M	GrA13469	S	Bone	IV	7480	50	8299	*Utrilla* et al. *2009*
Benámer	M	CNA680	S	Pollen	UE2213	7490	50	8310	*Torregrosa* et al. *2011*
Botiquería dels Moros	M	GrA13265	S	Bone (*Cervus elaphus*)	2	7600	50	8403	*Utrilla* et al. *2009*
Cabeço da Amoreira	M	TO11819R	S	Bone (Human)	Burial CAM 00 01	7300	80	8113	*Bicho* et al. *2011*
Cabeço da Arruda	M	Beta127451	S	Bone (Human)	Skeleton 6	7550	100	8355	*Carvalho 2010*
Cabeço das Amoreiras	M	Beta125110	S	Bone (Human)	Skeleton 5	7230	40	8042	*Carvalho 2010*
Costa do Pereiro	M	Wk17026	S	Bone (Deer)	c1b	7327	42	8118	*Carvalho 2010*
Cpva da Onça	M	Beta127448	S	Bone (Human)	–	7140	40	7966	*Carvalho 2010*
Cueva de la Cocina	M	UCIAMS145348	S	Bone (*Capra pyrenaica*)	Sector 1941 c16	7905	40	8720	In this work
Cueva de Nerja	M	GifA102010	S	Seed (pine nut)	NV3 (IIIc)	7610	90	8417	*Aura* et al. *2013*
Esplugón	M	Beta306725	S	Bone	Prof 189	7860	40	8645	*Utrilla, Domingo 2012*
Mendandia	M	GrN22743	S	Bone	III inferior	7620	50	8418	*Utrilla* et al. *2009*
Forcas II	M	Beta250944	S	Bone	II	7150	40	7973	*Utrilla* et al. *2009*
Casa Corona	M	OxAV239292	S	Bone (Human)	Burial 2	7116	32	7949	*Fernández López de Pablo* et al. *2011*
Moita da Sebastiao	M	TO131	S	Bone (Human)	Skeleton 22	7240	70	8066	*Carvalho 2010*
Rambla Legunova	M	GrA61768	S	Bone	2	7260	45	8085	*Montes* et al. *2015*
Tossal de la Roca	M	Gif6898	S	Bone	I ext.	7660	80	8464	*Martí* et al. *2009*
Vale Boi	M	TO12197	S	Bone (Human)	Layer 2 (base)	7500	90	8307	*Carvalho* et al. *2010*
Valcervera	M	GrA45763	S	Bone	b	7035	45	7875	*Montes* et al. *2015*

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Farmers' spatial behaviour, demographic density dependence and the spread of Neolithic agriculture in Central Europe

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ABSTRACT – *Since the early 1970s, the demic diffusion model has been the cornerstone of the migrationist approach to European Neolithisation. It considers the latter as a slow, gradual and haphazard process. During the last decade, its relevance has been challenged by the observed variability of the expansion, such as the extreme example exhibited by LBK expansion in Central Europe. To account for it, migration – which is usually explained by exogenous push-pull factors – must rather be viewed as the result of farmers' spatial behaviour. We adopt this approach and highlight the influence of agglomeration effects and the Allee effect in settled areas on farmers' choice of location, an influence which also leads to defining migration as endogenous. Both effects – which find support in archaeological records – exhibit demographic density dependence and help to explain an observed but counter-intuitive result. Indeed, high demographic density is associated with a slower rate of expansion of farming; this may result from strong agglomeration and Allee effects, which hinder – or even prevent – the migratory spread of agriculture. Farmers' cooperation with indigenous populations leads to the acculturation of the latter and, therefore, may reduce the influence of both effects, fostering farmers' migration.*

IZVLEČEK – *Že od začetka sedemdesetih let prejšnjega stoletja je model demske difuzije eden od temeljev migracijskih pristopov k neolitizaciji Evrope. Koncipiran je kot počasen, postopen in neorganiziran proces. V zadnjem desetletju so njegovo relevantnost spodkopale opažene razlike v hitrosti širjenja, kot recimo ekstremni primer širitve LTK v srednji Evropi. Da bi jo ustrezno upoštevali, moramo migracije, ki so običajno razložene z zunanjimi 'push' in 'pull' faktorji, razumeti kot odraz prostorskega vedenja kmetovalcev. V prispevku uporabimo ta pristop in osvetlimo vpliv učinka aglomeracije in Alleejevega učinka v izbranih kmetijskih poselitvenih območjih. Ti vplivi gibalo migracij postavljajo med notranje vzroke. Oba učinka, za katera lahko najdemo dokaze v arheološkem zapisu, sta odvisna od demografske gostote in pomagata razumeti opažene rezultate, ki niso intuitivno jasni. Izkaže se, da je večja demografska gostota povezana s počasnejšim razširjanjem kmetovanja; to je najbrž rezultat močnega aglomeracijskega in Allejevega učinka, ki zavira – ali celo preprečuje – migracijsko širjenje kmetijstva. Sodelovanje kmetovalcev z domorodnimi skupnostmi vodi k akulturaciji domorodcev in omejuje vpliv obeh učinkov, kar spodbuja migracije kmetovalcev.*

KEY WORDS – *agglomeration economies; Allee effect; demographic density; LBK culture; migration; palaeo-economy*

Introduction

Since Gordon V. Childe's (*1936*) original conceptualisation, the introduction of agriculture into Europe has been thought to reflect the spread of incoming farmers bringing the so-called 'Neolithic package', *i.e.* animals and domestic plants, ceramic containers, storage facilities, new architecture and elaborate burials rituals. Indeed, based on similarities at early Neolithic sites across Europe, Childe first proposed that the patterns exhibited were not consistent with the diffusion of Neolithic practices from southwest Asia, but rather the movement of agriculturalists. In Europe, agriculture spread in approximately 2500

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years from South-East Europe (Thessaly, 6500 BC)[1] to Scandinavia, Britain and Ireland (around 4000 BC). The apparent regularity of this spread, along with the monotonic cline in dates for the earliest Neolithic across Europe from the southeast to northwest, has led subsequent researchers to adopt a view similar to Childe's. Among these contributions, the most famous is the demic diffusion model (*Ammerman, Cavalli-Sforza 1971; 1984*) and its associated '*wave of advance*'. Demic diffusion is in fact a kind of cumulative short-distance movement requiring no human motivation, intentionality, or agency at the macro level, or as Albert J. Ammerman and Luigi L. Cavalli-Sforza themselves put it (*1984.68*), 'a form of colonization without colonists'. The demic diffusion model is based on Ronald Fisher's (*1937*) reaction-diffusion equation. According to this model, the entire diffusion process, from Greece to the British Isles, took place in about 2500 years, *i.e.* it proposes that agriculture spread in Europe at an average speed of one kilometre per year, or 25 kilometres per generation.[2] However, when Ammerman and Cavalli-Sforza (*1971*) derived the rate of spread to be 1km/year on average in Europe, they also noted very significant regional variations in the rate. This is not surprising when the heterogeneity of the spatial domain, Europe, is considered. For example, unfavourable ecological and geographical factors caused a retardation of the spread to the Alps; similarly retarded movement occurs at latitudes above 54° North due to the unsuitable climatic conditions. Unlike the previous slow speed, in Central Europe the propagation path of the LBK[3] culture had an increased propagation speed along the Danube and Rhine valleys, as did the spread of the Cardial-Impressa cultures along the Mediterranean coast. According to various estimates, the speeds of propagation of the wave front in these diverse areas are as follows: 1km/yr on average in Europe, 4–6km/yr for the Danube-Rhine valleys, 10km/yr in Mediterranean coastal regions (*Zilhão 2001*).

The regional variability of the spread

It is thus clear that farmers' migration into Europe[4] did not occur in a uniform way; indeed, spatial variations in the propagation speed of the land farmers have been noted in many publications (*Price 2000; Gkiasta* et al. *2003; Rowley-Conwy 2011; Fort 2015*). While demic diffusion may describe the overall patterning of the European dataset particularly well, when viewed at a regional scale very few regions appear to be the result of merging communities and the slow expansion of a wave of agriculturalists. When looking at site patterning for the earliest Neolithic in many regions of Europe, a more stochastic pattern of agricultural spread emerges (*Price 2000*). As stated by Rowley-Conwy (*2011.S443*), "*We must replace the monolithic 'wave of advance' concept with a series of local and disparate 'lurches of advance*".

When the spread of agriculture is measured at a spatial and temporal micro scale, its observed variability may even be very important. For instance, Detlef Gronenborn (*2003.81*) argues for an LBK migration covering 800km in 100 years, between Transdanubia and western Central Europe. At the other extreme of the spectrum is the fact that, while LBK materials spread from Hungary to southern Holland and northern Germany within a hundred years, its explosive movement stopped before it reached the Atlantic and Baltic coasts. In these regions, the period from first contact between indigenous hunter-gatherers (Ertebølle)[5] and agricultural groups (LBK and subsequent cultures to TRB[6]) to the full adoption of agricultural practices in Northern Europe extends over more than 1500 years. There is thus a disparity between artefacts and agriculture: 1500 years of artefact exchange led to no economic Neolithisation. The first evidence for the Neolithic in Scandinavia appears around 4000 BC in the form of the TRB culture (*Svizzero 2015*). Such observed extreme

1 Dates listed as BC are in calibrated years.

2 It should be noted that in their initial work, Ammerman and Cavalli-Sforza (*1971*) studied 53 early Neolithic sites and derived a speed range of 0.6-1.1 km/yr. More recent studies using a larger sample of radiocarbon dates have confirmed this initial result: *e.g.*, Pinhasi *et al.* (*2005*) consider 753 early Neolithic sites and derive a speed range of 0.6-1.3 km/yr.

3 Many archaeologists continue to use the German name *Linearbandkeramik* (LBK) or *Linienbandkeramik* or sometimes simply *Bandkeramik*. The English translation, also frequently seen in archaeological literature, is Linear Pottery culture.

4 This view also includes the recognition of local and regional variability in the LBK package (*Bentley 2007*) which was, until recently, considered as particularly homogeneous.

5 The Mesolithic Ertebølle culture is found 5400–3950 BC in the western Baltic area (southern Sweden, Denmark, and northern Germany between the Elbe and the Oder Rivers) and is contemporary with the LBK.

6 The LBK disappeared from Central Europe at the beginning of the 5th millennium and various Neolithic groups developed in the areas previously occupied by LBK populations. Among these various Neolithic groups the Funnel Beaker Culture, also called TRB (TRB for the abbreviation of its German name, *Tricherrandbecher* or *Trichterbecher*) appeared around 4000 BC. People of the TRB culture were the first farmers of much of Northern Europe.

variability leads some authors (*Bogucki 2000; Fiedel, Anthony 2003; Shennan 2007; 2009; Kind 2010*) to reject commonly used models to explain the Neolithisation of Central Europe. The demic diffusion model as well as agriculture diffusion by leapfrog[7] colonisation has been excluded because they are not consistent with rapid colonisation. Similarly, massive or 'folk' migration as well as long-distance migration are rejected because such migrations require an important logistic and tend to cross an ecological or cultural boundary and involve extensive planning and the risk of permanently breaking ties with the homeland population, all of which hinders the rate of expansion (*Fiedel, Anthony 2003*).

From demic diffusion to farmers' spatial behaviour

The rapid colonisation of some areas implies a major change in the framework used by scholars to study the spread of agriculture. Since farmers' migrate rapidly, they must have done so before their population came close to its absolute local carrying capacity. Therefore, farmers' migration was probably not the result of a combination of negative stresses – the so-called 'push factors' used in migration theory – such as population growth and resource depletion in areas under domestication, but more likely triggered by positive attractions – pull factors – in the immigration area, such as the search for uninhabited and arable land. In other words, the link between human migration and the spread of agriculture should not be only viewed at the macro-scale – *e.g.* the entire European continent – as the demic diffusion model assumes. On the contrary, it should also be viewed at a more restricted or local scale, *e.g.* the 'site level'. According to this latter approach, migration is now viewed as the result of farmers' spatial behaviour[8] (*Bogucki 2000; Fiedel, Anthony 2003; Shennan 2007; 2009; Kind 2010*). Thus, even for early farming groups, decisions on where to settle were highly selective rather than proceeding from a random-walk process, as described by the wave of advance model. Early farmers chose to settle only in optimal areas, with high soil fertility and moisture content. Consequently, the initial spread of farming was not uniform, with early farmers 'leap-frogging' from one niche environment to another, *i.e.* involving instead the infilling of optimal areas within a region through the spread of the daughter settlements to sites comparable to those occupied by their mother settlements (*van Andel, Runnels 1995*).

It should be noted that this approach also finds support in spatial aspects of migratory theory. Among the theoretical characteristics of migration, Everett S. Lee (*1966*) considers that the most influential is the concept that migration is selective. Moreover, it would be expected traditionally that the probability of migration decreases as the distance between two places increases, as a result of the greater risk involved in migrating over larger distances. Gareth J. Lewis (*1982*) recognised that the majority of modern migration events, and presumably in prehistory, were over short distances within a local area.[9] This belief is reinforced by the fact that social connections between migrants and populations in the homeland form an essential component of the migration process, *i.e.* they are thought to influence the spatial limits of migration.

The purpose of this paper is thus to study the spatial behaviour of farmers and the resulting migratory movements. More precisely, we try to identify the main factors which influence farmers' decision about whether to migrate or not, and which therefore are able to explain the regional and temporal variability in the rate of expansion of the farming system. We identify three factors, related respectively to soils fertility, agglomeration effects – *i.e.* economic forces affecting geographical concentration – and the conditions of farmers' reproduction and survival. These three factors have a common thread: their influence on farmers' spatial behaviour is mediated by demographic density (defined at the site level). While a high demographic density fosters migration through the first factor, it hinders it (or may even prevent it) throughout the two other factors. While the first factor is quite common in the literature related to agriculture diffusion, the two others are not. Since they lead to a negative correlation between the rate of farming expansion and demographic density, they contribute to explaining this counter-intuitive correlation exhibited for instance by Jean-Pierre Bocquet-Appel *et al.* (*2012*).

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7 It should be noted that other scholars consider that the colonization of Central Europe by farmers occurred through 'leapfrog colonization'; see *e.g.*, Marek Zvelebil (*2001.5*).

8 Human Behavioural Ecology provides tools and concepts suited to analyze optimal behavior related to, for instance, location or foraging (see *Winterhalder, Kennett 2006*).

9 This observation has formed the basis of many 'friction of distance' migration models.

The initial spread of farming in Central Europe: the LBK culture

Fundamental to the debate about the spread of agriculture is the Central European LBK culture, which has been dated from 5700 to 5000 BC, and is the earliest agro-pastoralist phenomenon outside the Balkans. Since the first LBK farmers of central Europe were clearly not the direct descendants of local hunter-gatherers, they must have emigrated from another region. As yet, no palaeogenetic data are available to indicate the most probable region of origin of the early LBK farmers (*Burger, Thomas 2011. 378*). From an archaeological perspective, the most plausible region is around the area of Lake Balaton in present-day Hungary, where the LBK first developed from the predecessor Starčevo culture. The LBK period is typically divided into four chronological phases based on the evolution of ceramic decoration: oldest (5700–5500 BC), older (5500–5300 BC), younger, and youngest (*Keeley, Golitko 2004*). However, more precise regional chronologies have been developed for most areas of LBK distribution, *e.g.*, Krisztián Oross and Eszter Bànffy (*2009*) consider three successive waves of Neolithisation in Transdanubia. Much LBK material culture (pottery, lithics, groundstone, ceramic figurines) and the economy have clear ties to the northern Balkan Early Neolithic, while other aspects, most notably the LBK longhouse, are novel. The LBK economy is based almost entirely on domesticated plants and animals and its settlements (ger. *Siedlungskammern*) are concentrated on fertile loess soils along streams. The LBK culture brought the first farming settlements to central Europe through a movement of farming peoples from the Danube Valley to the north and west and to the central European uplands, as well as to parts of the North European Plain along the Oder and Vistula Rivers. The westernmost sites did not appear until 4900 BC, which would indicate that, on average, the LBK culture spread into Europe at a rate of 3.5–5 kilometres per year. By using strontium isotope measurements of human skeletal material from two cemeteries, Douglas Price *et al.* (*2001*) demonstrated a high incidence of migration, *i.e.* LBK farmers were highly migratory and interacted with surrounding communities. Initially, it was believed that LBK communities practiced swidden agriculture or shifting cultivation and that the constant need for new land fuelled the rapid dispersal of LBK peoples into central Europe (*Childe 1929*). It has since become clear that many LBK sites were settled continuously for several hundred years, *i.e.* their farming practices were sustainable for hundreds of years on heavy, loess-derived soils (*Saqalli* et al. *2014*). For the most part, the expansion of LBK peoples seems to have halted at the boundaries of the North European Plain (except in Poland), where for as long as a millennium they were in contact with complex hunter-gatherers to the north. After 4800 BC, the LBK culture disappeared, but several related 'daughter' cultures emerged, such as the Rössen in western Germany and the Netherlands, the Villeneuve/Saint Germain in France, the Blicquy in Belgium, the Stichbandkeramik (Stroke-Ornamented Pottery culture) in eastern Germany, and the Lengyel in much of the eastern LBK region. The latter culture gave rise to the earliest Funnel Beaker communities (or TRB) in the Polish lowlands, continuing the expansion of agriculture onto the North European Plain and into southern Scandinavia.

LBK archaeological assemblages (domesticated animals and plants, longhouses, pottery) appeared suddenly from the Hungarian plain, near Budapest, to eastern France in a relatively short period in the 6th millennium. Within 700 to 800 years, these peoples had spread through most of central Europe and to the boundary of the North European Plain. With the largest area of the LBK region being about 1500km (from Transdanubia to the Paris Basin) and the time taken to spread over that area of about 360 years, the average propagation rate of the LBK could not have been less than 4km/year (*Dolukhanov* et al. *2005*). Gronenborn (*2003.81*) even argues for a migration covering 800km, from Transdanubia to the Rhine valley, within less than 150 years, which is a viable hypothesis through riverine colonisation, since many central European rivers form a nexus to facilitate this (*Davison* et al. *2006; Rowley-Conwy 2011; Henderson* et al. *2014*). Settlers thus covered an average distance of about 800km at a rate of at least 5.6km/year. The actual propagation speed could have been even higher, as only loess regions were settled.

Traditionally, scholars have made assumptions about the overall uniformity of the LBK culture, which therefore was interpreted as reflecting colonisation events as the one explained by demic diffusion, which in the present case indicated the rapid east-west orientation of the spread of agro-pastoralist populations. However, this uniformity has increasingly come to be doubted, with the recognition of local and regional variability in the LBK package (*Bentley 2007*). The latter includes lithic, ceramic, burial and dietary habits *etc.*; its variability suggests more continuity and the passage of traditions from indigenous hunter-gatherer populations to farmers. Therefore, it remains to explore the mosaic of regional variation within the once uniform LBK culture.

Farmers' spatial behaviour and the differential of soil fertility

When farmers' migration is – fully or partially – considered as responsible for the spread of farming – as it is for instance in the demic diffusion model – it is assumed, implicitly or not, that the spread of farming presupposes that spatial expansion would not have been triggered until local populations approached an absolute local carrying capacity. However, this view has been challenged by the variability in the diffusion of agriculture, such as the speed of agricultural expansion into Central Europe.[10] Indeed, in certain areas, we can see that new places were colonised before others had reached any sort of carrying capacity.

Farmers' spatial behaviour

The basis for understanding why further expansion does not necessarily presuppose demographic saturation is provided by principles related to decision making concerning spatial behaviour (*Fiedel, Anthony 2003; Shennan 2007; 2009*). For this purpose, we refer to concepts such as marginal valuation, opportunity cost, discounting, and risk sensitive analysis of microeconomic analysis and human behavioural ecology (*Winterhalder, Kennett 2006*) which are used in an attempt to assess the costs and benefits of alternative courses of action under a range of environmental conditions. It seems obvious that agricultural communities would choose to settle in areas of high productivity. Less desirable areas (due to economic, climatic, ecologic,[11] geographic or social barriers) are bypassed in favour of more optimal locations. As these favourable areas become colonised, subsequent colonisation events will take place in the immediate vicinity of the initial colony. Therefore, the radial spread of sites continues outward from the earliest agricultural site in an area. This expands on Ammerman and Cavalli-Sforza's model in that it accounts for differential agricultural productivity in the study region and the desire of emigrants to choose specific locales suited for agriculture. However the variability of agriculture diffusion observed in different regions means that this pattern appears much closer to directed colonisation events than the random short-distance dispersal of daughter communities assumed in the demic diffusion model.

Farmers' access to land under contest competition

In order to express farmers' spatial behaviour, we first describe what is required for cultivation, in addition to cultigens and labour force, *i.e.* land. Since our analysis is conducted at a micro or local level, we start by considering a site[12] (as it is usually defined by archaeologists). This site consists of many patches, and each patch encompasses several territories. In a given patch, the territories are not identical. They differ with respect to soil fertility and thus may be ranked from the best territory (the one with the highest soil fertility) to the worst (where soil fertility is at its lowest level). In a given patch, land is a resource available in limited quantities. Then, its distribution among farmers is consistent with two alternative scenarios concerning competition[13] among farmers coming into that patch.

The first scenario involves simultaneous common exploitation of land. Depending on the approach considered (economics, population ecology, and demography), such a situation is called 'scramble competition' or 'ideal free distribution'. We may simply define it as a situation of open access to land. When farmers move into a new patch, they will occupy first the territories that give them the best returns. As more farmers occupy the patch, the returns to each farmer decline, to the point that the returns to farmers from the best territory are no better than those from the best territory of the next patch, which at this point has no occupants. The returns from both territories are then equal, and they will be occupied indiscriminately until additional incoming farmers are introduced to the point at which there is an equal benefit to be gained from occupying still worse territory, and the process is repeated. Thus, under scramble competition, new incoming farmers reduce the mean return for everybody, including those who arrived first.

If scramble competition may be appropriate to describe competition for access to resources among some species, it is not appropriate to describe land

10 As well as in Southeast and Mediterranean Europe.

11 See *e.g.*, Robert Kertész, Pál Sümegi (*2001*).

12 Site: a distinct spatial clustering of artifacts, features, structures, and organics and environmental remains – the residue of human activity (*Renfrew, Bahn 2012.583*).

13 Both scenarios are detailed by Clem Tisdell (*2013.Ch. 7*).

competition among farmers; a second scenario must be considered. Indeed, open access to land is relevant to describing a foraging economy. While foraging is associated – most of the time – with an immediate-return economy (*Woodburn 1982*), farming necessitates many 'investments' (such as ploughing, sowing, weeding, irrigating ...) before crops can be harvested. Farming is thus intrinsically associated with a delayed-return economy. Therefore, any farmer will have incentives to incur the investments previously described if, and only if, he owns in the future the output resulting from these investments. This condition is fulfilled if there is territoriality, or contest competition. It results in individuals staking out rights to the limiting resource (land in our case) and defending these usually by aggression. In most cases, this involves creating exclusive territories where the incumbent has exclusive rights to the limiting resources within his territory.

In our present case study, contest competition means that property rights related to land ownership are introduced. Indeed, such introduction is completely consistent with – and even necessary to – the transition from foraging to farming, since as stated by Douglass C. North and Robert P. Thomas (*1977. 230*), "*The key to our explanation (of the transition from foraging to farming) is that the development of exclusive property rights over the resource base provided a change in incentives sufficient to encourage the development of cultivation and domestication*".

Under contest competition, even if all farmers of a given patch are working the same amount of time every day, their labour productivity will differ as well as income. This results from the combination of the difference of soil fertility between territories, and the introduction of territoriality. In other words, contest competition among farmers is naturally associated with economic (and social) inequalities. Based on archaeological evidence[14] related to LBK settlements and cemeteries located in the western Rhineland, Stephen Shennan (*2009.347*) observes that "*Over time these local LBK societies do indeed seem to have become more unequal*", a situation which can result from contest competition among farmers concerning access to land. A similar conclusion is reached by Alexander R. Bentley *et al.* (*2012*). Indeed, from isotopic analysis of human skeletons, these authors derive evidence concerning forms of social organisation and differentiation at the population scale from across the LBK distribution.

The differential of soil fertility and farmers' migration

Under contest competition – also called ideal despotic distribution – the first incoming farmer into an unoccupied patch is able to select the best territory. Since the latter has the best soil fertility, it is in this territory that the marginal productivity of labour (and thus the farmer's income) will be at its highest level. The second incoming farmer will select the second best territory; as a result, his income will be lower than the one earned by the first incoming farmer. The same logic applies to subsequent incoming farmers who decide to remain in the initial patch. From this, we may deduce a general principle associated with contest competition: in contrast to what happens in scramble competition, in contest competition, the farmers' returns depend on their order of settlement in the patch. Indeed, subsequent incoming farmers settling there do not affect the income of incumbent farmers. Since each additional incoming farmer has to take the next best territory, and therefore earns less than the previous incomer, there comes a critical point at which the next settler will do just as well by taking the best territory in the next patch. At this critical point, the farmer's spatial optimal behaviour means a shift from the initial patch to the next patch, *i.e.* it leads to migration. Indeed, at any moment, any incoming farmer takes his decision about spatial location by comparing:

- on the one hand, the return associated with a territory of the initial patch, the latter being partially occupied by incumbent farmers. It should be noted that this return is decreasing with increasing demographic density in the initial patch;
- on the other hand, the return provided by the best territory of the next patch, which is unoccupied.

As long as the differential between both returns is exceeded by the cost of transportation from the initial patch to the next patch, the farmer remains in the initial patch, *i.e.* he does not migrate. Symmetrically, when this differential is larger than the cost of transportation, the farmer decides to migrate to the next patch.

It is thus possible to derive a general result from the previous statement: the higher the demographic

14 For example, the site of LW8 in the Merzbachtal in the Aldenhovener Platte region of western Rhineland, which was established in the 52nd century BC and was occupied throughout the approx. 400 years of the local LBK sequence.

density in the initial patch, the lower will be the return of the marginal farmer coming into that patch, and the more this farmer will be willing to migrate to the next patch. In other words, throughout the influence of the differential of soils fertility, demographic density fosters migration, *i.e.* the spread of agriculture. This result is in fact the simple transposition at the local level of the belief that at a macro level population growth constitutes a push factor of migration (and then also of the spread of agriculture).

As a remark, we have assumed that the differential of returns reflects the differential in soil fertility between territories. Implicitly, this means that other factors, such as technology, ecological conditions or climate, do not have an influence on agricultural returns. Indeed, without loss of generality, we may assume that at the local level, all farmers have the same technology. Furthermore, we may also assume that at the local level, ecological conditions and climate have the same influence on the various patches of the site. In other words, the only difference – at the local level – in agriculture productivity results from differences in soil fertility.

Agglomeration economies and cumulative causation

We have previously demonstrated that the higher demographic density may imply migration, since it reduces the income provided by agriculture production of any incoming farmer. However, a higher demographic density should have an opposite effect on the farmer's income since it induces agglomeration economies in the initial patch. Such agglomeration economies are associated with geographical concentration of activities and have been studied in economics for several decades.

The New Economic Geography

In the 1950s, some development economists used a variety of concepts – such as Gunnar Myrdal's (*1957*) 'circular and cumulative causation', or Albert O. Hirschman's (*1958*) 'forward and backward linkages' – to emphasise that large markets are those where more firms and workers locate. From the early 1990s, New Economic Geography (hereinafter NEG) – an economic approach mainly lead by Paul Krugman (*1991*) – has formalised this kind of cumulative causation mechanism, to show that regions which are similar or even identical in underlying structure can endogenously differentiate into rich 'core' regions and poor 'peripheral' regions. Thus, and as stated by Masahisa Fujita and Paul Krugman (*2004. 140*), NEG is a body of research which fundamentally attempts "*to explain the formation of a large variety of economic agglomeration (or concentration) in geographical space*". Most of the concepts and tools employed by NEG, as well as the ambiguous impact of economic integration on development, were well-known before NEG's appearance. In fact, the innovative contribution of NEG consists of the rigorous formalisation of such concepts, which basically allows us to account for the dynamics of spatial clustering (and dispersal) of economic activity. Since there are several mechanisms through which cumulative causation may arise, we may successively consider all of them in our framework devoted to farmers' spatial behaviour.

As highlighted in the previous section, transport costs – which of course are included in NEG – are a crucial element influencing location choices. The impact of transport costs on farmers' location choices clearly depends on the level of such costs. As a consequence, any farmer decides whether it is more convenient to concentrate in just a single location, the initial patch, or alternatively to incur additional cost in order to migrate in a different location, the next patch. In other words, the level of transport costs constitutes a crucial force towards agglomeration (or dispersal) in farmers' location behaviour.

Marshallian sources of external economies

NEG incorporates external economies; in doing this, NEG essentially recalls Alfred Marshall's (*1890*) insights about externalities. Several sources of external economies can be identified in a farming context.

Firstly, any economic concentration supports a concentrated local labour market, especially for specialised skills, so that employees find it easier to find employers and vice versa. Therefore, farmers that cluster in a single location take advantage of the availability of a pooled labour force endowed with agricultural-specific skills. In fact, the labour for most cultivation-related tasks is organised within two forms: the household and kin, and community work groups. Household labour by itself suffices for very few plot-related tasks, the most significant of which is watching the crops. Community-level labour is the main form of labour deployment, which can ensure the successful completion of the cycle, from clearing forest to harvest. Thus, the agglomeration of farmers connected with a local pooled labour market leads to an increase in efficiency in farming activities.

Secondly, there are some market-size effects. Hence, when farmers concentrate production in a given patch they also take advantage of the presence of specialised suppliers of intermediate goods and inputs such as tools (*e.g.*, digging stick, hoe, ard, stone axe, mortar and pestle ...). These are so-called 'forward linkages', because a large local market supports the local production of intermediate goods, lowering costs for downstream farmers. One may also note that the development of the agrarian economy leads to a more intensive division of labour among farmers. This has two consequences: it increases specialisation and thus farmers' productivity, and leads to the release of labour from food production. The latter means that many job opportunities appear, which in turn implies the emergence of non-food specialists (such as craft specialists, bureaucrats, priests, soldiers and chiefs). According to Jacob L. Weisdorf (*2003.19*), "*If the adoption of more productive food procurement methods went hand in hand with the emergence of non-food specialists, the rise of agriculture bore the seeds for the later process of industrialisation and thus for economic growth*".

Thirdly, a local concentration of economic activity may create more or less pure external economies via information spillovers and technological externalities. Thus, clustered farmers are supposed to benefit from technological spillovers consisting of unintentional flows of knowledge arising from proximity to one another and benefitting all farmers located on the same patch. As a result, farmers are encouraged to localise in a single place to benefit from external knowledge arising from other farmers' activities.

It should be noted that such technological externalities were more likely to occur during the early stages of agricultural expansion into Central Europe. Indeed, the continental climate and the ecosystem of Central Europe are very different from the Mediterranean climate and biome, where agriculture first originated (the Fertile Crescent) and then spread (Greece and the Balkan Peninsula). Moreover, geographic and biogeographic conditions do not have a separate, but combined, influence on plants and animals. Indeed, every plant or animal has certain habitat and environmental preferences. As such, they can only be cultivated and bred within their tolerance limits.[15] Therefore, the climatic and ecological adaptation of cultigens and domesticated animals was a great task for the first farmers migrating into Central Europe. Thus, the success of this adaptation is due to a large extent to information spillovers and technological externalities between farmers belonging to a same cultural group, such as the LBK culture.

Clustering and migration

Even if land, which is an immobile factor of production, militates against concentrations of production, we have identified several sources of external economies in a farming context, such as labour market pooling, availability of the specialised intermediate products and technological spillover effects. All these sources of external economies may be viewed as possible reasons why farmers tend to cluster together[16] in a given patch, *i.e.* why they do not migrate. More deeply, any of these external economies is positively correlated with the number of farmers remaining in the initial patch, *i.e.* with demographic density. In other words, when agglomeration economies or external economies related to clustering are taken into account, demographic density hinders migration.

Agriculture and increasing returns

It is well known that increasing returns to scale are acknowledged to be fundamental for NEG when accounting for the spatial unevenness of economic activity, since by definition they stimulate the spatial clustering of economic production. Thus, conventional economists would argue that there is a problem in our previous statement, since agricultural systems are usually subject to diminishing returns caused by limited amounts of fertile land. However, this claim can be challenged for early Neolithic agricultural systems. Indeed, we may assume, as Weisdorf (*2005. 570*) did, that "*farming exhibits constant returns to labour, a fair assumption given the abundance of suitable land at that time*".

Since fertile land was obviously unlimited at the beginning of the Neolithic in Central Europe, we may even go further, as Peter Bogucki (*2000*) did. This author considers that, after a demanding initial investment, with the adaptation of cultigens and livestock to central European habitats, accumulated experience led to a progressively greater understanding of soils, climate, landforms, plants, and animals. Therefore, the introduction of agriculture to Central

15 This phenomenon is called the minimum limiting factor (*Liebig 1840*).

16 Sergei Fedotov *et al.* (*2008*) develop a model for population migration and the growth of human settlements during the Neolithic transition; the numerical results show that the individual farmers have a tendency for aggregation and clustering.

Europe was very much a knowledge-based process, and such processes are usually largely subject to increasing returns. Thus, we may even assume that during the early ages of agricultural diffusion, farming was associated with increasing returns, the latter increasing the magnitude of the external economies related to geographical concentration, as described above.

Demographic density dependence of reproduction and survival conditions

Under contest competition among farmers, we have demonstrated in a section above a general and quite intuitive result: throughout, the influence of the differential of soils fertility, demographic density fosters migration, *i.e.* the spread of agriculture. This result is in fact the simple transposition at the local level of the macro-level mechanism, which states that population growth, constitutes a migration push factor. We assumed as well that a farmer who migrated from the initial patch to the next (unsettled) patch would not incur additional costs, except for transport. Here, we release this strong assumption. Indeed, any migrant takes the risk of finding and settling a new top-quality territory in the next patch, which may be located some distance away. More precisely, the first migrants, and especially the first one, will be the first occupants of the next patch that has not been settled. Thus, the first migrant-occupant may have some disadvantages, such as limited access to reproductive partners or lack of local support if crops fail. In other words, for the first migrants into the next patch, demographic density will be extremely low (and even nil for the first migrant), implying many disadvantages related to their reproduction and survival. This positive correlation between population density and individual fitness is the so-called Allee effect.

The Allee effect

The classical view of population dynamics states that, due to competition for resources, a population will experience a reduced overall growth rate at higher density and increased growth rate at lower density: this is the so-called 'logistic growth'. Such a view is implicitly associated with Charles Darwin and his concept of the 'struggle for survival'. However, even Darwin was worried that his notions of 'struggle' and intense competition for survival would obscure the importance of cooperation[17] (*Lidicker 2010.72*). In the early 1930s and through experimental studies (on fish populations), Warder C. Allee (*1931*) demonstrated the positive correlation between population density and individual fitness, *i.e.* a result opposite to Darwin's struggle for life. Allee concluded that aggregation can improve the survival rate of individuals, and that cooperation may be crucial in the overall evolution of social structure. Then, he defined effects that are classified by the nature of density dependence at low densities. There is a weak Allee effect if the per capita growth rate is positive and increasing and a strong Allee effect if the population shrinks for low densities, *i.e.* when per-capita growth rate is negative below a threshold density.

Since Allee's (*1931*) seminal work, the presence and the role of his effect have been widely studied in population ecology, from which numerous evidence of its existence are provided (see for instance *Kramer* et al. *2009*) and also with respect to individual behaviour (*Sutherland 1996*). It is thus possible to consider the existence and the role of the Allee effect related to farmer's spatial behaviour.

The mechanisms underlying the Allee effect

Due to its definition as a positive correlation between population density and average fitness, the mechanisms which cause the Allee effect are therefore inherently tied to survival and reproduction. These Allee effect mechanisms arise from a lack of cooperation or facilitation among farmers at low demographic density.

Firstly, the first migrants into the next (unsettled) patch could encounter difficulties related to their reproduction due to mate limitation. The latter refers to the difficulty of finding a compatible and receptive mate for sexual reproduction at lower population size or density, and thus to avoid inbreeding, *i.e.* the production of offspring from the mating or breeding of individuals that are closely related genetically.

Secondly, the first migrants into the next (unsettled) patch could encounter difficulties related to their survival due to their exposures to serious risks. For instance, the first migrants could be in a precarious situation due to the lack of local support if their crops failed. Indeed, simpler, traditional and small-scale societies – such as the farming society prevailing in the initial patch – are usually characte-

17 This led Darwin to ponder the evolution of sociality in insects.

rised by 'mechanical solidarity'.[18] In a society exhibiting mechanical solidarity, its cohesion and integration comes from the homogeneity of individuals, since people feel connected through similar work, religion and beliefs, and lifestyle. When it exists, such solidarity is based on kinship ties of familial networks; however, when demographic density is too low in the next patch, we may conjecture that these ties become too weak, whereupon the solidarity among migrants disappears. Such a situation may even lead to site abandonment by early farming communities.[19]

Another possible problem for the first migrants is protecting themselves against invasion by group anti-invader behaviour. Mark Golitko and Lawrence H. Keeley (*2007.333*) recall that a number of well-known LBK contexts demonstrate that violence was often quite severe during the early Neolithic of Central Europe. In addition to evidence of traumatic injuries and massacres, these authors provide evidence of group defence behaviour against invaders, such as the existence of enclosed LBK settlements, which they interpret as fortifications.[20] They finally show that there is a clear association between enclosed sites and remains that can be taken as immediate evidence of conflict. Whether this resulted from direct competition between local hunter-gatherers and competing LBK groups is under investigation; this kind of evidence can only be partly helpful. Indeed, the burials and the traumatic injuries can be considered as evidence of ritual behaviour rather than of inter-group warfare. They can also be the result of warfare within a group or between groups of hunter-gatherers, or between hunter-gatherers and farmers. Neus Isern *et al.* (*2012*) explain that the slowdown in the Neolithic rate of spread in Northern Europe can be related to a high indigenous population density hindering the advance as a result of competition for space between the two populations. However, and as pointed out by Golitko and Keeley (*2007.340*), "*... much of this violence seems to have involved LBK communities fighting each other, as indicated by the mass graves at Talheim and Schletz-Asparn ...*" In other words, most of the evidence of LBK violence is related to the late phase and therefore conflicts between hunter-gatherers and LBK people are not likely to be the reason for fortification efforts or the evidence of traumatic injuries.

Thus, farmers not only face high risks, but they also need to spend time, energy and resources defending themselves, building walls, manning watchtowers, guarding herds and patrolling fields. This means less time and energy and fewer resources devoted to food production. It could even happen that the greater productivity of the hours they spend growing and raising food is outweighed by the greater time they must spend defending themselves and the food they have grown, meaning that they produce less food in total. But, as stated by Robert Rowthorn and Paul Seabright (*2010.3*), despite these drawbacks, "*What makes the difference (...) is a crucial externality in the technology of defense*". However, we believe that such externality exists only when the demographic density of farmers is sufficiently high, which is not the case in the next patch when the first migrants are incoming. Therefore, and to cope with this problem of defence, incoming farmers may increase their vigilance, but the latter will result in less time and energy spent on farming, thus reducing the fitness of farmers living in smaller groups.

Allee effect and migration

For the first migrants, the demographic density in their patch will be very low. Therefore, there will be, as explained above, an Allee effect related to their reproduction and their survival. Any farmer from the initial patch who intends to migrate into the next patch will expect the existence of these disadvantages. It is thus possible to derive a general result: the higher the differential of demographic density between patches, the higher the Allee effect in the next patch, and fewer farmers on the initial patch will be willing to migrate. In other words, when Allee effects are taken into account by farmers in their spatial behaviour, high demographic density at home hinders migration (weak Allee effect) or may even stop it (strong Allee effect).

Coordination failure between farmers and cooperation with indigenous populations

We have previously demonstrated that, even when it is derived from farmers' optimal spatial behaviour, migration could be hindered and even stopped. The latter occurs when for a high demographic den-

18 A concept defined by Emile Durkheim.

19 Bogucki (*1996*) provides evidence of sites abandonment in post LBK North Poland between 4300 and 4000 BC and presents the various explanations provided in the archaeological literature.

20 They also highlight (*Golitko, Keeley 2007.337*) several features of LBK settlements for which only a military function is appropriate: V- or Y-sectioned enclosure ditches, and complex forms of gates: baffled, offset, crab-claw, labyrinthine or screened.

sity in the initial patch, there are a low differential of soils fertility between patches, strong agglomeration effects and a strong Allee effect.

Coordination failure and multiple equilibria

In such a situation, any farmer from the initial patch decides not to migrate. At the site level, the distribution of farmers between the two patches can thus be described by a 'status quo equilibrium', *i.e.* all farmers remain in the initial patch and the next patch remains empty. However, others' equilibrium exists, due to strong spill-over effects between patches, which Pareto-dominate the status quo equilibrium. Indeed, if spill-overs are strong enough, multiple equilibrium outcomes may occur, some of which are better for every farmer than the alternatives, but with no tendency for market forces to lead from the worse to the better state of affairs; thus a problem of coordination failure exists (*Hoff 2001*). For instance, we may consider, without loss of generality, that an equilibrium associated with an iso-distribution of the farmer population between the two patches provides a higher level of welfare to all farmers.

Massive colonisation

In order to avoid the problem of coordination failure presented above, and thus to recover a positive rate of expansion when migration stops, the solution consists in avoiding low demographic density in the next patch. Such an intriguing solution may, however, be the result of two different processes.

The first is a massive movement of farmers from the initial patch to the next patch. If it occurs, since the first migrants will be immediately numerous, they will benefit from agglomeration effects and good conditions regarding their reproduction and survival. It could be argued, however, that massive migrations were less likely to occur in the early Neolithic, since colonisation by farmers required substantial logistical planning and harnessing of resources to move a viable population not only of people, but also animals and seed-corn (*Fiedel, Anthony 2003*). Indeed, evidence of planed massive colonisation occurs only from the Bronze Age, with the early Greek civilisation, for instance.

Acculturation of indigenous populations

The second process consists of farmers' cooperative strategy with hunter-gatherers. Such a process can indeed lead to the acculturation of hunter-gatherers, *i.e.* can ease the transition of the latter from foraging to farming. Therefore, the number of settled farmers in the next patch could increase considerably very fast, including 'true' farmers migrating from the initial patch and former hunter-gatherers who were previously foraging in the surrounding area.

Acculturation can result from various contacts between farming and foraging communities, such as intermarriage, the exchange of information or trade (*Dennell 1985*). For instance, Galeta and Bruzek (*2009*) demonstrate that the demographic conditions necessary for colonisation were beyond the potential of the Neolithic population and thus support the integrationists' view of the Neolithic transition in Central Europe. In other words, they consider that the establishment of LBK farming communities in Central Europe without an admixture with foragers was highly improbable. In their 'availability model', Marek Zvelebil and Peter Rowley-Conwy (*1984*) describe a process of acculturation in three phases. Exchange of prestigious goods characterises the first, or availability, phase. More intensive trade characterises the second, the substitution phase. In the third, the consolidation phase, these authors consider that the acculturation process is completed.

While the spread of farming had traditionally been accepted as an example of agricultural colonisation by LBK farmers, it has recently become increasingly apparent[21] – from evidence of contact and interaction between local hunter-gatherers and the earliest farming communities (*Gronenborn 1999; Price* et al. *2001*) – that a scenario such as the one described above provides a plausible explanation for the situation in some areas of Central Europe. For instance, concerning the LBK formation in Transdanubia, Oross and Bánffy (*2009*), there is evidence that the late Mesolithic settlements and their occupants played a major role in the transformation of the terminal Starčevo culture. In addition, molecular approaches using non-recombining genetic marker systems (mitochondrial DNA and Y-chromosome) have indicated a contribution of Neolithic Near-Eastern lineages to the gene pool of modern Europeans of around a quarter or less (*Richards 2003*). According to this analysis, even the highest Neolithic impact, this was on southeast Europe, central Europe, and northwest and northeast Europe, is between 15% and 22% of Neolithic lineages.

21 For an overview, see *e.g.*, Michaela Divišová (*2012*).

Conclusion

The migrationist approach to the spread of agriculture can be divided into two different points of view. For the first, the spread is considered on a macro-scale, such as the European continent, and over a long period (the period associated with the complete Neolithisation of Europe). In such approach, the demic diffusion model seems to provide a convincing explanation. According to this model, the spread was a slow, regular and haphazard process. The motives of migration (soil depletion, conflict or warfare, population pressure) are assumed to have been exogenous to farmers. Similarly, factors which hinder the spread of agriculture – *e.g.*, ecological, geographical or cultural barriers – are also considered exogenous.

In this paper, we favour a second view in which the spread is considered at a spatial micro scale. At the regional level, as illustrated by the spread of LBK in Central Europe, archaeological records provide evidence of extreme variability in the rate of farming expansion. Since environmental conditions are quite homogeneous at this regional level – and above all, homogeneous at the site level – migration must be considered as a deliberate process resulting from farmers' spatial behaviour. We highlight two effects – agglomeration effects and the Allee effect – which endogenously influence farmers' decision making and therefore the rate of farming expansion. When both effects are weak, they contribute to the rapid expansion of agriculture, as experienced by the LBK culture from Transdanubia to the Rhine valley, when 800km were covered in approx. 150 years. On the contrary, when both effects are strong, they may hinder or even stop the migration process, as experienced by the LBK culture in Northern Europe, where, despite contacts with indigenous populations, the expansion stopped for 1500 years. The magnitude of both effects exhibits demographic density dependence. When at a given site settled by farmers, the demographic density is low (respectively high), both effects are weak (respectively strong). Therefore, when both effects are taken into account, they help to explain the counter-intuitive, but observed, negative correlation between demographic density and the rate of expansion. Thus our view provides a significant contribution to understanding the spread of the Neolithic by bridging macro/micro approaches.

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Preceramic, Aceramic or Early Ceramic? The radiocarbon dated beginning of the Neolithic in the Aegean

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ABSTRACT – *The* Pre-Pottery-Neolithic *refers to a period in the Eastern Mediterranean when ceramic containers were not yet in use (although small objects made of clay were already being created). This concept, which reflects a specific and quite unique stage in the development of human history, was introduced to Aegean prehistory under the term of* Preceramic *during the 1950's (*e.g.*, in Argissa-Magoula and Sesklo). Shortly thereafter, a different term, the* Aceramic*, was applied in the Aegean (*e.g.*, in Knossos) for levels devoid of pottery, although ceramic products were supposedly used in the wider region. In some cases, the thin levels interpreted as* Preceramic *or as* Aceramic *contained sherds that were regarded as being intrusive from above (*e.g.*, Argissa-Magoula, Franchthi Cave). The new sequences of radiocarbon dates allow a more precise description of this early period and thereby contribute, not least, also to the clarification of terminological issues.*

IZVLEČEK – *Predkeramični neolitik označuje obdobje, ko v vzhodnem Sredozemlju keramične posode še niso bile v uporabi (čeprav so majhne predmete iz žgane gline že izdelovali). Koncept, ki se nanaša na določeno in precej posebno stopnjo v našem zgodovinskem razvoju, je bil z imenom 'predkeramični' vpeljan v egejsko prazgodovino v petdesetih letih prejšnjega stoletja (npr. v Argissa-Magouli in Sesklu). Kmalu za tem ga je nadomestil 'akeramični' neolitik (npr. v Knossosu), ki je označeval plasti brez keramičnih posod, čeprav so bile v širši regiji domnevno že poznane. V nekaterih primerih so tanke naselbinske plasti interpretirali kot 'predkeramične' ali 'keramične' s fragmenti lončenine, ki naj bi vanje prišli iz zgornjih plasti (npr. Argissa-Magoula, jama Franchthi). Nove sekvence radiokarbonskih datumov omogočajo še posebno natančne predstavitve teh zgodnjih obdobij, in nenazadnje tudi boljše terminološke pojasnitve.*

KEY WORDS – *Preceramic; Aceramic; Initial Neolithic; Meso-Neolithic interface; radiocarbon dates; Aegean*

The terminology: the impacts of Near Eastern and Anatolian research

Modern archaeology saw its beginnings around 1950 with the introduction of natural sciences into archaeological methodology. In 1947, when Robert and Linda Braidwood from the University of Chicago started their interdisciplinary project in Jarmo (Northern Iraq), for the first time they worked together with a palaeoethnobotanist (Hans Helbaek), a zoologist (Charles Reed), a geologist (Herbert Wright) and a radiocarbon expert (Fred Matson) (*Watson 2006. 10–11*). Braidwood was also among the first archaeologists to learn about the radiocarbon method. In 1947, he provided his Chicago colleague Williard F. Libby with some of the very first ancient samples to be tested by the new dating method. Soon after, in 1949, while a professor at the University of Chicago (1945–1954), Libby then published his revolutionary results on the radiocarbon dating method (*Arnold, Libby 1949; Libby 1952*), for which he received the Nobel-prize in 1960.

Again in 1949, Vladimir Milojčić published his influential book on chronological issues of the Neolithic

DOI: 10.4312/dp.42.9

in Central and Southeastern Europe, based on comparative stratigraphical observations (*Milojčić 1949*). Until his untimely death in 1978, Milojčić remained the most convinced advocate of this method, which depended on sound knowledge, a sharp observational spirit, and on the talent of archaeologists for identifying interrelations among distant sites and regions, in the end on subjective, qualitative analysis. At first, probably under the influence of Braidwood, Milojčić was not completely dismissive of the radiocarbon method. Between 1956 and 1958, he collected several charcoal samples from the sites of Argissa- and Otzaki-Magoula, not being shy of costs and efforts. In 1959, at the end of his *Thessalien-Projekt* and the beginning of his professorship in Heidelberg (*Hauptmann 1994.531–532*), he delivered 12 samples to the Heidelberg laboratory for radiocarbon dating. The results did not support Milojčić's chronological assessments, and from that time on, until late in his life, he became a harsh opponent of the method (*Milojčić 1973*). However, his critique was not completely unqualified, since, at the very beginning of radiocarbon dating, the need for tree-ring calibration was not understood. As Harald Hauptmann recollects (*personal communication, 21.03.2015*), it was only shortly before Milojčić's sudden death at the age of 60 that he admitted that ^{14}C-dates could be taken into consideration. Following in the footsteps of Braidwood, Milojčić worked with the zoologist Joachim Boessneck and the botanist Maria Hopf (*Milojčić 1962*).

However not only theoretical and methodological procedures were at issue; Milojčić met Braidwood at least twice in his lifetime: in 1958, at the international congress in Hamburg and the year after, when Braidwood visited Milojčić in Thessaly during his last excavation campaign in Otzaki (*Hauptmann 2008. 3*). This direct contact of the two researchers is important, since it resulted not only in an exchange of ideas, but also in the transfer of the Near Eastern terminology and vocabulary to the Aegean.

For example, when in 1952 Milojčić coined the German word *Präkeramikum* (*Milojčić 1952.315*), it is clear that he was not simply translating some few words (*e.g.*, *Pre-Pottery-Neolithic, PPN*) from English into German, but was actually very carefully transferring the corresponding archaeological notions and concepts from the Near East to the Aegean. The specific formulation *PPN* was in fact introduced by Kathleen Kenyon during her excavations at Jericho 1952–1958. To be precise, as a result of his excavations at the Tell es Sultan/Jericho layers X–XVII already in 1936, John Garstang had noted that the Early Neolithic was devoid of pottery, but did have a microlithic blade industry (*Garstang* et al. *1936. 69*). Yet, he did not give this period a specific name. Initially, Braidwood (*1957.76*) rejected the term *PPN* as meaningless, yet Kenyon justified its usage by the fact that the *PPN*-layers were separated from the PN-layers by a long temporal gap (*Kenyon 1957a. 83*). In Jericho, 3–4m high levels containing Neolithic pottery overlay meter-high levels devoid of ceramic containers (*Kenyon 1957b*). At least when speaking of the 'Old World', therefore, the term *PPN* defines the time before pottery was produced. In comparison, in the Eastern Asiatic Jōmon culture, pottery was in use since at least in the 10th millennium BC, and in the North Pontic steppe since the 8th millennium BC (*Piezonka 2014*).

As well as the exchange of ideas through the excavation leaders, the team members also brought new and first-hand knowledge from ongoing investigations in Anatolia to Greece. A good example is Hans Helbaek, who was initially part of Braidwood's team, but later also worked in Hacılar with James Mellaart and in Knossos with John D. Evans. Similarly, the archaeozoologist Sebastian Payne, who defined the *Aceramic* levels in Franchthi Cave, initially worked with David French in Can Hasan (1964–1967), but then with Ian Todd in Aşıklı, a site that was identified as *Aceramic* in 1964 (*Payne 1973; 1985*). Clearly, since a precise delimitation between the terms *Aceramic* used in Central and Southwestern Anatolia as opposed to the *PPN* used in the Levant and Zagros area had not yet been thoroughly discussed, the two terms were often used interchangeably. Understandably, therefore, what we observe is that whether the two different notions were introduced into Greek research strongly depended on the personal relationships between the archaeologists working in the Aegean with their specific colleagues, who could either be active in the Near East (Palestine and Zagros) or in Asia Minor (Central and Western Anatolia).

Yet the usage of the terms *Preceramic* and *Aceramic* should not be fortuitous. The *Preceramic*, in particular, is tied to a specific concept: it covers a period when ceramic products were not yet in use, and this reflects a certain stage in the development of mankind (*Nissen 2012.169–170*) prior to 7000 calBC. For Knossos in the Aegean, Evans proposed that *Aceramic* should refer to those levels that do not contain ceramic containers, even though pottery was actually in use in the wider region (*Evans 1964; Warren* et al. *1968.271*).

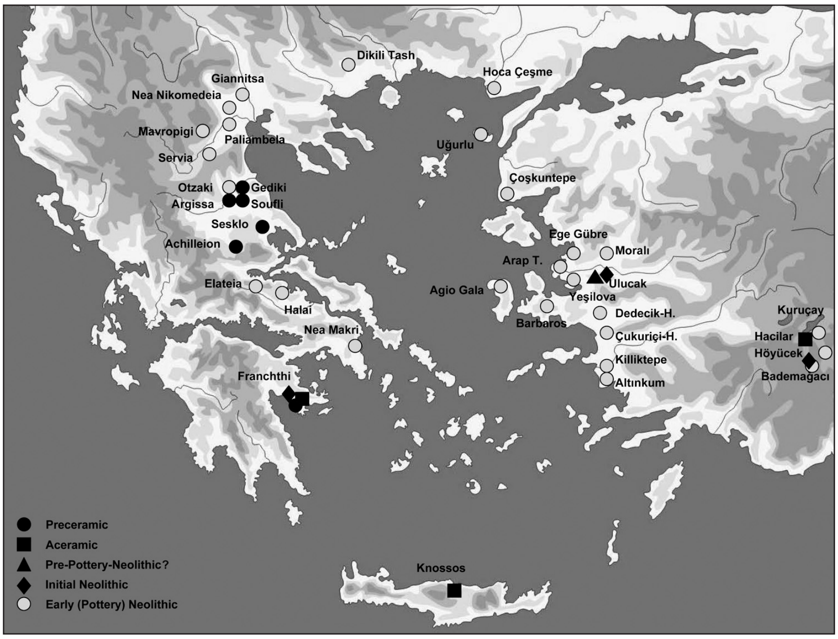

Fig. 1. Sites of the **Preceramic, Aceramic, Pre-Pottery-Neolithic, Initial Neolithic** *and of the* **Early Pottery Neolithic** *in the Aegean.*

In the present paper, we respect this distinction, but argue that a more precise definition of relevant words and concepts will strongly reinforce our understanding of the earliest sedentary communities in the entire Aegean sphere. Certainly, one could object that the concepts involving the production (or not) of ceramic containers cover by no means the complete range of social and cultural behaviour during the Meso-Neolithic interface, and indeed that pottery often appears to be more meaningful to prehistoric archaeologists than it may have done to prehistoric communities. Nevertheless, given that these terms are so widely applied, it does appear useful to study in detail the historical reasons for their initial introduction, and also to account for the alternative meanings given to these terms by different scholars in different regions.

The situation near the Aegean coasts: Thessaly, Crete, the Argolid, and Western Anatolia

The *Preceramic* layers of the Argissa-Magoula were excavated in 1956 and 1958 by Milojčić, at that time a professor at the University of Saarbrücken. Some 120 sherds were collected from these lowest levels, some 30cm thick (if we take into consideration the so-called pits β–ζ, then the height totals up to 50cm thickness in the deepest parts). The sherds were interpreted by the excavator as intrusive since they were comparable to the pottery from the above level, and were consequently excluded from discussion (*Milojčić 1962.14*). In 1957, at a time when Milojčić was pausing from the excavations in Argissa, Dimitrios Theocharis cleared the collapsed northern profile at Sesklo, where he confirmed Milojčić's appraisal that a *Preceramic* period existed at the start of the Neolithic in Thessaly (*Theocharis 1967*). Subsequently, Theocharis carried on this work at Soufli-Magoula and also at Achilleion. At both sites, excavations were also conducted thereafter, but no *Preceramic* levels were encountered. Sesklo and Gediki are therefore the only so-called *Preceramic* sites where re-investigations would be necessary to clarify the situation (for detailed appraisals of stratigraphic and contextual analysis of finds and ^{14}C-dates connected to the *Preceramic* levels, compare *Reingruber 2008*).

At the end of that decade, in 1957–1960, two new projects were initiated by the British Institute, one led by Mellaart (who had been working with Kenyon in Jericho in 1952: *Kenyon 1960.VI*) in Hacılar in the SW-Anatolian Lake District, the other by Evans in Knossos on Crete (Fig. 1). Both excavators interpreted the lowest levels of their sites that were found to be devoid of pottery as *Aceramic*. When Evans reached the 10–20cm thin lowest level at Knossos he preferred this label, because he presumed that pottery was not in use yet, but was already circulating in the larger area (*Warren* et al. *1968.271*). Evans later revised his interpretation of Knossos X as a temporary camp, but kept the label *Aceramic* (*Evans 1971.95–117*). As it appears, this specific concept of the *Aceramic* implies that pottery had already been invented, but was not in use on a specific site for various reasons.

In Franchthi Cave, the archaeozoologist Payne was the first to define the so-called 'gray clay-stratum' as pertaining to an early, even *Aceramic*, group of people (*Payne 1973.59–66*). In view of the very small number and the small size of the sherds found in this stratum Thomas Jacobsen termed it as "*possibly Aceramic Neolithic*" (*Jacobsen 1969.352*). This term is also used by Karen Vitelli (*1993*). Catherine Perlès variously speaks both of an *Aceramic* or of a *Preceramic* phase (*Perlès 2001.46, footnote 18*). In 2001,

Site	Lab. No.	BP	±	calBC 1σ	Sample material	Level	Provenance, Reference
Franchthi	**GifA-80049**	8025	45	7070–6830	Charcoal	Final Mesolithic	FAN 169 (*Perlès* et al. *2013*)
Franchthi	**GifA-80048**	7990	40	7050–6820	Charcoal	Final Mesolithic	FAN 166 (*Perlès* et al. *2013*)
Franchthi	**GifA-80046**	7935	40	7030–6690	Charcoal	Final Mesolithic	FAN 166 (*Perlès* et al. *2013*)
Franchthi	**GifA-80043**	7910	40	6910–6670	Charcoal	Initial Neolithic, Grey clay stratum	FAN 151, 33g of sherds (*Perlès* et al. *2013*)
Franchthi	**GifA-80045**	7875	40	6780–6640	Charcoal	Initial Neolithic, Grey clay stratum	FAN 159, no sherds (*Perlès* et al. *2013*)
Franchthi	*GifA-11016*	*7805*	*40*		*Seed*	*Final Mesol./ Initial Neolithic*	*FAN 163, no sherds* (*Perlès* et al. *2013*)
Franchthi	*GifA-11455*	*7740*	*50*		*Seed*	*Final Mesol./ Initial Neolithic*	*FAN 163, no sherds* (*Perlès* et al. *2013*)
Franchthi	R_Combine: **GifA-11016+** **GifA-11455**	7780	32	6650–6590	From same sample		
Franchthi	*GifA-11017*	*7780*	*40*		*Seed*	*Initial Neolithic, base of gray clay str.*	*FAN 162 [1], no sherds* (*Perlès* et al. *2013*)
Franchthi	*GifA-11456*	*7645*	*50*		*Seed*	*Initial Neolithic, base of gray clay str.*	*FAN 162 [2], no sherds* (*Perlès* et al. *2013*)
Franchthi	R_Combine: **GifA-11017+** **GifA-11456**	7728	32	6600–6500	From same sample	X-Test fails at 5%	X2-Test: df = 1 T = 4.428(5% 3.8)
Franchthi	**GifA-80044**	7555	40	6460–6400	Charcoal	Initial Neolithic, Grey clay stratum	FAN 158; 1 sherd (*Perlès* et al. *2013*)
Knossos	**OxA-9215**	7965	60	7040–6770	Charred seeds (Quercus evergreen)	Level 39/1	Trench II, depth 7.8 m (*Reingruber, Thissen 2009*)
Knossos X	*BM-124*	*8050*	*180*		*Charcoal* (Quercus)	*Stratum X; Area AC, level 27*	*Central Court, Pit F, Sample 1,* (*Barker, Mackey 1963.104*)
Knossos X	*BM-278*	*7910*	*140*		*Charcoal* (Quercus)	*Stratum X; Area AC, level 27*	*Central Court, Pit F, Sample 1,* (*Barker* et al. *1969.280*)
Knossos X	R_Combine: **BM-278+** **BM-124**	7964	111	7050–6700	From same sample		
Knossos X	**BM-436**	7740	140	6770–6430	Seed	Stratum X, Area AC, level 27	Central Court, Pit F, Sample 1, (*Barker* et al. *1969.280*)
Ulucak VI	**Beta-269727**	7950	50	7030–6710	Charcoal	L13a	unit 43 (hearth) (*Çilingiroğlu* et al. *2012*)
Ulucak VI	**Beta-250265**	7910	50	6990–6650	Charcoal	L13a	red painted lime floor (*Çilingiroğlu* et al. *2012*)

Tab. 1. Selected ^{14}C-dates from Franchthi, Knossos and Ulucak falling into the flat part of the calibration curve (first half of the 7th millennium BC, compare Fig. 6).

she proposed the term *Initial Neolithic* (compare *Perlès 2001.64*)

Recently, the lowest levels in Ulucak near Izmir devoid of pottery have been compared to the Anatolian *PPNB*, especially in respect to the "*elaborately painted plaster floors*" (*Çilingiroğlu, Çakırlar 2013.26*). From a technological point of view these floors are considered to be similar to those found in *Aceramic* Hacılar and at *PPNB*-sites further east (*Çilingiroğlu, Çakırlar 2013.24*). Detailed descriptions of this specific technology will be essential in support of such broad supra-regional comparisons.

In an attempt to overcome this terminological medley, it has been suggested that we use the name *Initial Neolithic* to describe the relevant sites not only in W-Anatolia (Ulucak), but also in the Lake District (Hacılar and Bademağacı), as well as for the pottery-bearing site of Barcın in NW-Anatolia (*Özdoğan 2015. Fig. 6*). Indeed, the term *Initial Neolithic* does seem to simplify these complicated terminological issues, all the more since in most cases it is not clear whether pottery actually occurred *in situ* or was intrusive from levels above. However, and notwithstanding the merits of this specific term, the problem itself cannot be solved by the application of any such new term, but only by large-scale excavations, precise observations and by detailed descriptions of the levels under study, as is the case at the ongoing excavations at Barcın (*Gerritsen* et al. *2013*), Çukuriçi (*Horejs 2012*) and Ulucak (*Çilingiroğlu* et al. *2012*). The pertinent question, whether a newly founded Neolithic settlement was either coeval with pottery-bearing Neolithic sites, or instead pre-dated such sites, can be resolved also by its radiocarbon-based absolute age.

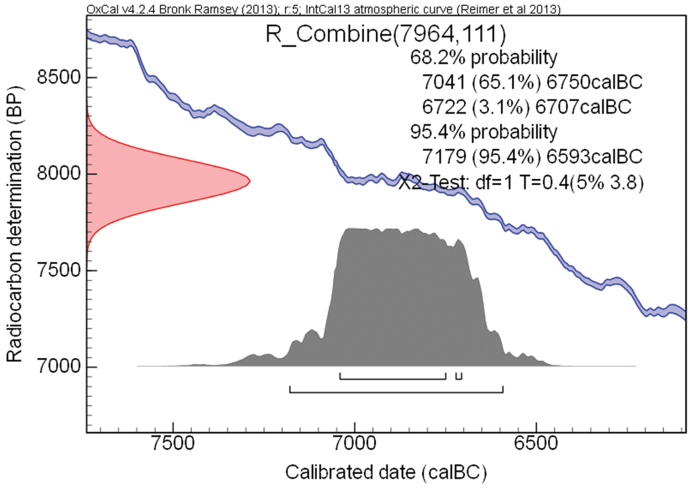

Fig. 2. Radiocarbon dates from Knossos (**Reingruber, Thissen 2005.305*****).***

Old and new radiocarbon dates

At the Central Anatolian site of Çatal Höyük it is now well-established that pottery came into use shortly after 7000 calBC (*Thissen 2007.219*). Therefore, if the definition of a *Preceramic* period, comparable with the Near Eastern *PPN* and of Anatolian formation, should remain an issue in Aegean prehistory, already from terminological considerations (see above) we may expect this phase to have dates prior to at least 6900 calBC. And indeed, the results of the radiocarbon dating method from the early 1960's seemingly corroborate such a high age: charcoal samples from Knossos had been dated to before and/or around 7000 calBC (*Barker, Mackey 1963.104; Barker* et al. *1969.279–280*). The R combine-value of two dates measured on the same sample (Tab. 1) does in fact fall into the first quarter of the 7th millennium calBC (Fig. 2). But a much more reliable date was obtained on carbonised grain, although with a huge standard deviation. It gives a much younger result, dating into the second quarter of that millennium (*c.* 6750–6500 calBC), similar to a date said to derive from Knossos IX (BM-272: 7570±150 – compare *Reingruber, Thissen 2005.305*). These early dates are followed by a gap of around 1000 years. Interestingly, this interpretation – which is not at all self-evident due to the early ^{14}C-measurement – were confirmed by the investigations in 1997 (*Efstratiou* et al. *2004*). A new set of ^{14}C-samples from Knossos is now being prepared for dating (*personal communication Peter Tomkins, 30 May 2015*), and we are looking forward to the results, which are crucial for the inter-

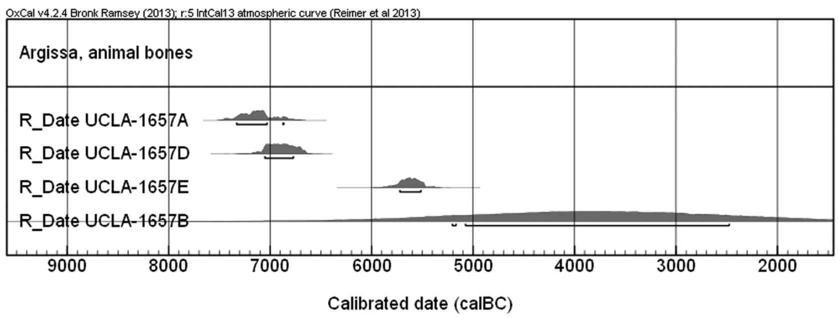

Fig. 3. Radiocarbon dates from Argissa-Magoula on animal bones (**Reingruber 2008.157, Tab. 3.4*****).***

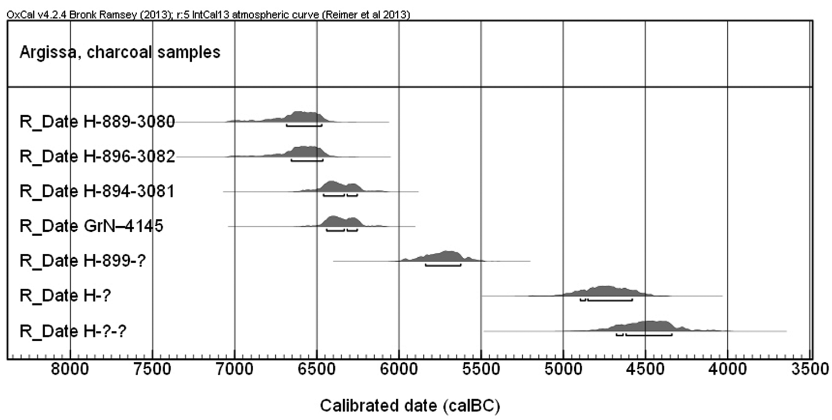

Fig. 4. Radiocarbon dates from Argissa-Magoula on charcoal (**Reingruber 2008.157, Tab. 3.4*****).***

pretation of the site. Meanwhile, let us have a closer look at the presently available ^{14}C-data from other sites.

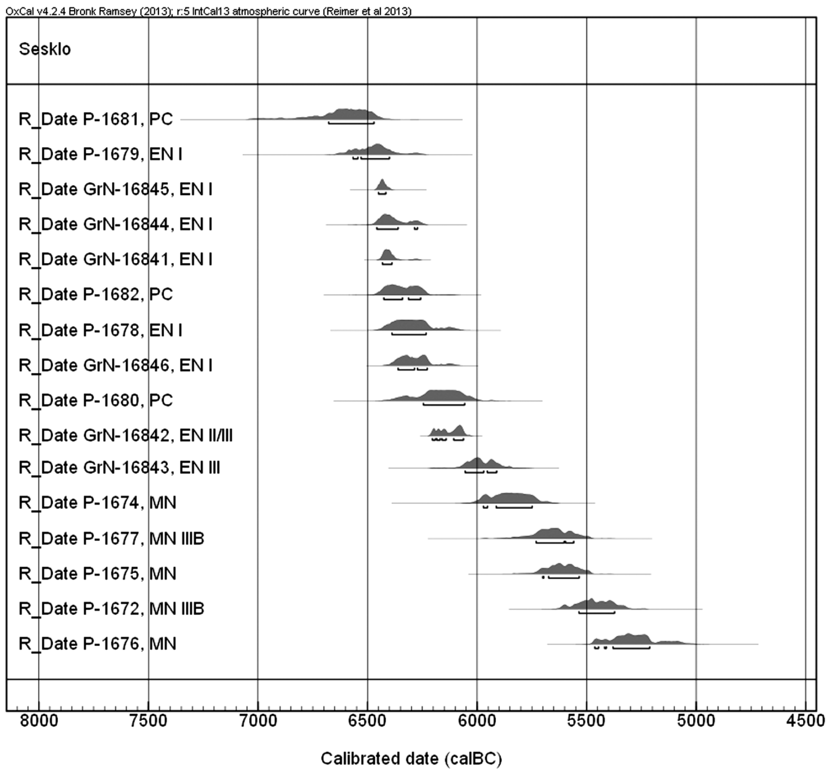

Fig. 5. Radiocarbon dates from Sesklo on charcoal (dates from **Lawn 1973*****).***

Two radiocarbon dates from Nea Nikomedeia with huge standard deviations date to the end of the 8th millennium (*Reingruber, Thissen 2005.306*). Also run in the 1960's, two younger dates from the site with much smaller standard deviations (P-1202 and P-1203A: *Vogel, Waterbolk 1967.129*) fit well with the sequence presented by Yiouni (*1996*) that can be dated to around 6150 calBC (compare *Reingruber 2008.395–396; Reingruber, Thissen 2009*). Therefore, thanks to the AMS-method, it has been established that the settlement of Nea Nikomedeia was founded some 1000 years later, *i.e.* not to 7200 calBC (as it previously appeared), but to after 6200 calBC.

At least five bone samples from Argissa-Magoula were dated at the University of Los Angeles and subsequently published by Reiner Protsch and Rainer Berger (*1973.236*) (Fig. 3). Two of these samples have dates between 7300 and 6700 calBC (UCLA-1657A, D), one dates to around 5600 calBC (UCLA-1657E), whilst sample UCLA-1657B failed. These dates must be considered as highly doubtful, in particular due to the later 'career' of the prime author of the article, Reiner Protsch: as director of the Frankfurt radiocarbon laboratory he is known to have faked results on human bones, and it is also reported that he was expelled from the University in 2005 (http://www.spiegel.de/wissenschaft/mensch/verurteilter-schaedelforscher-der-professor-an-dem-nichts-stimmt-a-631481.html, accessed 11.3.2015). It is open to question whether similar doubts also apply to the UCLA-dates from Argissa. However, ^{14}C-dating of bone-collagen requires complicated chemical processing, and has become reliable only with the advent of the ^{14}C-AMS-technology. Even today, the ultra-filtration method is still in the developmental stage: "*Bones are arguably one of the most highly contaminated samples.*" (http://www.radiocarbon.com/ams-dating-bones.htm. (http://www.canadianarchaeology.ca/radiocarbon/card/bones.htm; accessed 11.3.2015). On the other hand, the charcoal samples were run at the Heidelberg laboratory and also in Groningen (*Vogel,*

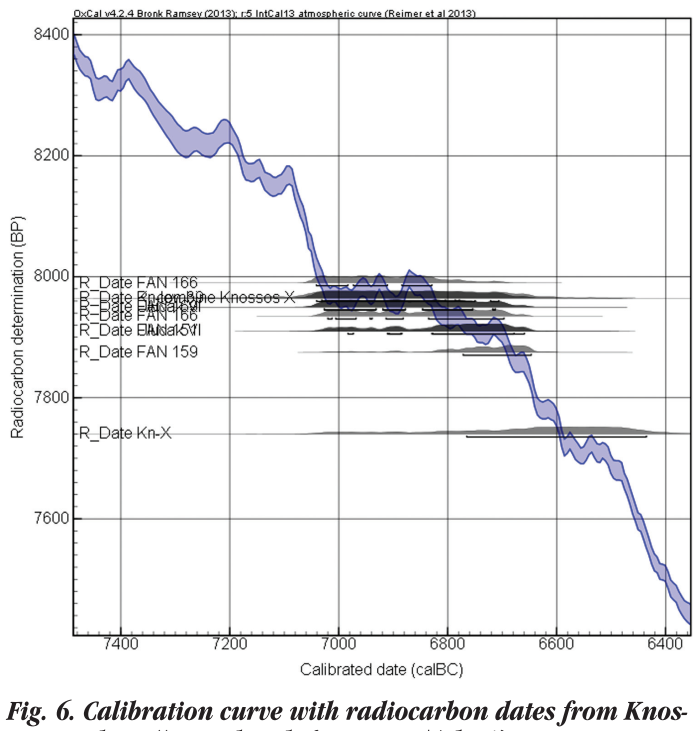

Fig. 6. Calibration curve with radiocarbon dates from Knossos, Bademağacı, Ulucak (compare Tab. 1).

Waterbolk 1967.129; Hauptmann 1971.365), with results that are consistent with a beginning of the site at around 6500 calBC (Fig. 4). The reliability of these dates was confirmed in 1973 (*Lawn 1973.370*) by the charcoal-dates from Sesklo that also indicate a starting date around 6500 calBC (Fig. 5).

Serious doubts as to the supposed early age (~7000 calBC) of the *Preceramic* period are therefore advisable, not only due to the generally much younger calibrated ^{14}C-ages, but also because of the high amount of sherds found in the alleged *Preceramic* levels.

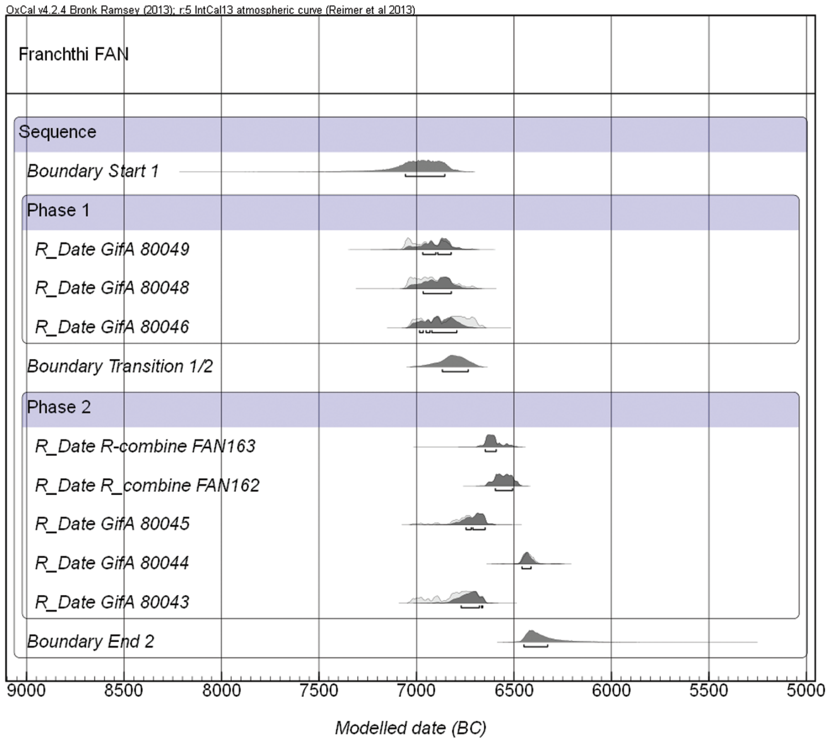

Fig. 7. Radiocarbon dates from Franchthi Cave, trench FAN (dates from **Perlès *et al.* 2013.Tab. 2*).***

A further point that we must address when discussing very early dates around 7000 calBC pertains to the flat shape of the calibration curve between 7000 and 6600 calBC (Tab. 1 and Fig. 6). All dates, even with a narrow spread of BP-values between 7900 and 8000 BP (*i.e.* 100 ^{14}C-yrs), will inevitably have readings within this wide range (*i.e.* 400 calendric years). Since this and any other specific shape of the calibration curve is due to the secular atmospheric ^{14}C-variability, and therefore has a global character, this naturally also applies to the dangers of inadvertently misreading any given ^{14}C-dates. This appears to be the case for the recently published (four) dates on two domesticated seed samples from Franchthi Cave that were described as dating to the "*early 7th millennium*" (*Perlès* et al. *2013.1001–1015*). In actual fact, from Franchthi Cave we do have some dates (excepting short-lived seeds) that are of early 7th millennium age and that indeed fall within the plateau of the calibration curve. However, these dates were measured in charcoal and belong to the Final Mesolithic. Another group of dates is younger and can be placed together with the dates on seeds in the middle of the 7th millennium. They derive from contexts with a very

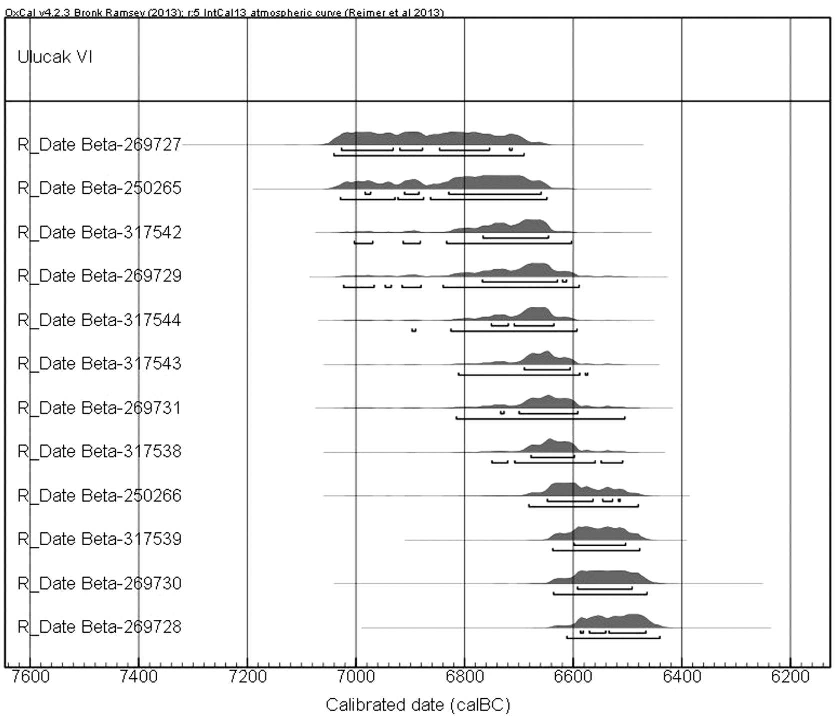

Fig. 8. Radiocarbon dates from Ulucak VI (dates from **Çilingiroğlu *et al.* 2012*).***

small amount of pottery (that might have been intrusive). When modelling the sequence of radiocarbon dates, it is advisable to take into account only samples from a good stratigraphic context, namely those from trench FAN (Fig. 7): the Neolithic dates on short-lived material are demonstrably from the middle of the 7th millennium around 6600–6400 calBC, whereas two dates on long-lived material are, not surprisingly, slightly older.

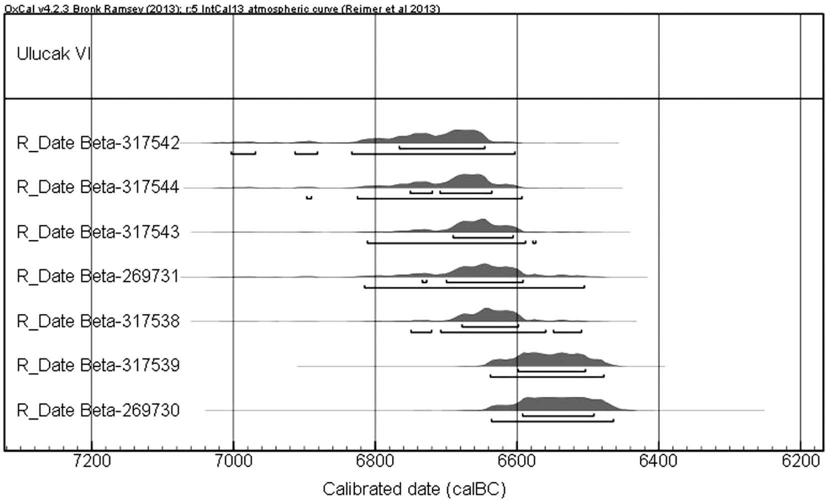

Fig. 9. Results on short-lived samples from Ulucak VI.

Indeed, this result fits perfectly with the interpretation of the dates from Knossos – and the Franchthi dates agree well with the dates from Ulucak near Izmir. There, on the other side of the Aegean, a new body of ^{14}C-dates was placed by the excavators in the second quarter of the 7th millennium (*Çilingiroğlu* et al. *2012.153*). Especially when considering the very short-lived (annual) and therefore reliable dates on mainly Emmer wheat, phase VI in Ulucak can indeed be dated between 6700 and 6500 calBC (Figs. 8–9).

In combination, therefore, what we now recognise is that the new dates from Ulucak and Franchthi Cave are not only part of the problem, but also of the solution. When looking at the Aegean as an interrelated communication area, we can now state that the earliest evidence for food-producing communities appeared in its southern part around 6700–6500 calBC and not at 7000 calBC. However, it was obviously only a very short phase, followed by a gap in dates and finds. The next body of dates start some 250 years later in Ulucak, some 500 years later in Franchthi Cave, and at Knossos, probably even 1000 years later (Figs. 10–11).

Discussion and conclusions

The relative chronology of the Early Neolithic period in Greece was established half a century ago by Milojčić and Theocharis. Only a few years earlier, the first sites of the *Pre-Pottery-Neolithic* (*PPN*) were investigated by Kenyon (Jericho) and Braidwood (Jarmo) in the Near East; an *Aceramic* site was asserted by Mellaart to have existed in Anatolia (Hacılar). Both concepts – that of the *Preceramic* and that of the *Aceramic* – were introduced into Greek research shortly thereafter (*Milojčić 1956; Evans 1964*). More recently, other and in respect to the question of pottery-production, more neutral names have been proposed: the *Initial Neolithic* (*Perlès 2001*). But again, there is still a strong affiliation with the *Pre-Pottery-Neolithic*, as requested for the site of Ulucak, and in our view this needs some more thorough specification.

More than fifty years after the important investigations led by the two promoters of Thessalian Neolithic research, Milojčić and Theocharis, a number of rectifications are thus appropriate. It is important to recognise that subsequent excavations in Soufli and Achilleion, as well as the re-evaluation of the documentation in Argissa, did not substantiate the initial interpretation of Milojčić and Theocharis that these sites were founded by *Preceramic* communities. Not only did the earliest levels in Argissa contain sherds of the Early Ceramic phase, but they were many centuries, if not a millennium, younger than the supposedly coeval sites of the Near-Eastern *PPN*; this is already indicated by careful evaluation of the radiocarbon dates presented in the 1960's. The initial interpretation of the radiocarbon dates seemingly supported the existence of a *Preceramic* phase in the Aegean before or around 7000 calBC, since pottery appeared in Central Anatolia only later, between 7000 and 6700 calBC. Even in recent studies, this high temporal frame is often taken as representative of the beginning of the Neolithic in the Aegean. However, a closer look at the shape of the tree-ring calibration curve shows that a plateau occurs between 7000 and 6600 calBC, that is a flat portion with many wiggles. This specific shape of the ^{14}C-age calibration curve is the result of the highly variable (and in this case, increasing) production of ^{14}C in the atmosphere. An increasing number of publications in contemporary archaeological literature focus on readings on the upper end of the plateau, but with no further archaeological foundation. However, when modelled with statistical methods, it appears that the lower end at 6600 calBC rather than the upper end at 7000 calBC is the adequate temporal position for many of the samples under study. New dating methods (AMS), new radiocarbon sequences and new statistical approaches (Bayesian modelling) show that the Early Neolithic started in Thessaly around 6500 calBC with an early pottery phase. Nevertheless, a short episode of possibly *Aceramic* communities can indeed be traced at three sites in the Southern Aegean (Franchthi Cave, Knossos and Ulucak), dating between 6700–6500 calBC, after the introduction of pottery in neighbouring Central and Southwestern Anatolia.

With this result, we now face a hitherto unexplored situation: a *Preceramic* period co-eval with the *PPN* cannot be verified, nor can the term *Aceramic* be applied (beyond all doubt) to levels containing sherds that were interpreted as intrusive. At this point, the question must be allowed: why are we (so selectively) looking at the transition from the Mesolithic to the Neolithic in the Aegean always from the Neolithic point of view and why especially from a pottery Neolithic point of view? As already pointed out at by Kotsakis (*2003.217–221*), with this approach we restrict the important transition from one age to the other, in this case from the 'Mesolithic' to the 'Neolithic', to the occurrence (or absence) of ceramic containers. There are manifold solutions to this problem, but perhaps the most prominent is the widely neglected research on a systematic approach to understanding the Mesolithic population and their cultural legacy. For many decades archaeological research has been engaged in the solidification of colonisation and migration models, which ultimately have their roots in the ever-dominant *Ex Oriente Lux*-model. This is despite the fact that, nowadays, in contrast to the research situation some 20 years ago, there is strong evidence for widespread Mesolithic communities especially from the Western Aegean (*Reingruber 2008.11–84*). We have knowledge of such communities, more recently, from the Southern Aegean (Crete and Gavdos: *Kopaka, Matzanas 2009; Strasser* et al. *2010*) as well as from the Eastern Aegean (Ikaria and Girmeler: *Sampson* et al. *2012; Takaoğlu* et

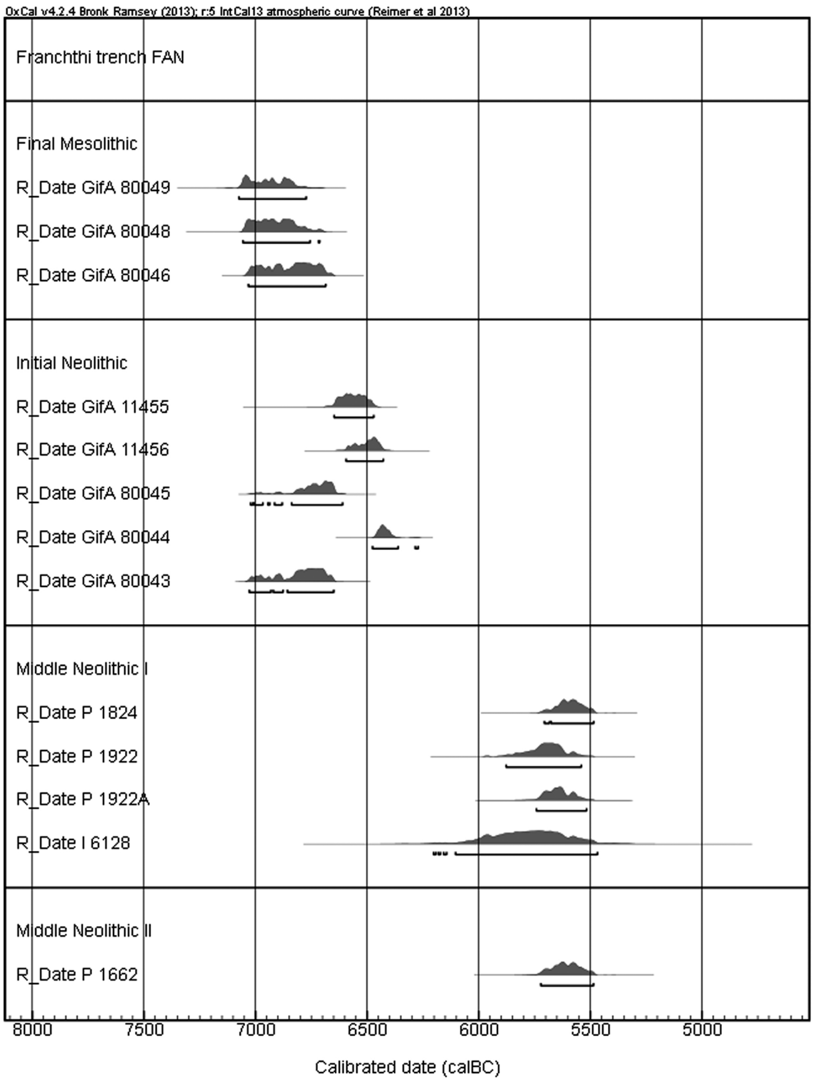

Fig. 10. Radiocarbon dates from Franchthi Cave, trench FAN (dates from* Jacobsen, Farrand 1987.Tab. 71*). No dates from this trench can be attributed to the EN before 6000 calBC, but date P-2093 from neighbouring FAS-129 with 6940±90 BP (5970–5730 calBC) places the FCP1-pottery phase of the (local) EN in the period after 6000 calBC, coeval with the Thessalian early MN. Ultimately, the dates of the MN I in Franchthi Cave (5700–5500 calBC) are coeval with the MN II–III in Thessaly (*Reingruber 2008.Tab. 7.3*).

al. *2014*). It is too early to describe in detail what happened during the transitional decades between 6600 and 6500 calBC, since – for example – new data can be expected from Knossos, Ulucak, Çukuriçi Höyük and Barcın; but even when available, it will be of paramount importance to analyse the new data in context with already available evidence from all regions of the Aegean, and this includes finding a common and meaningful terminology.

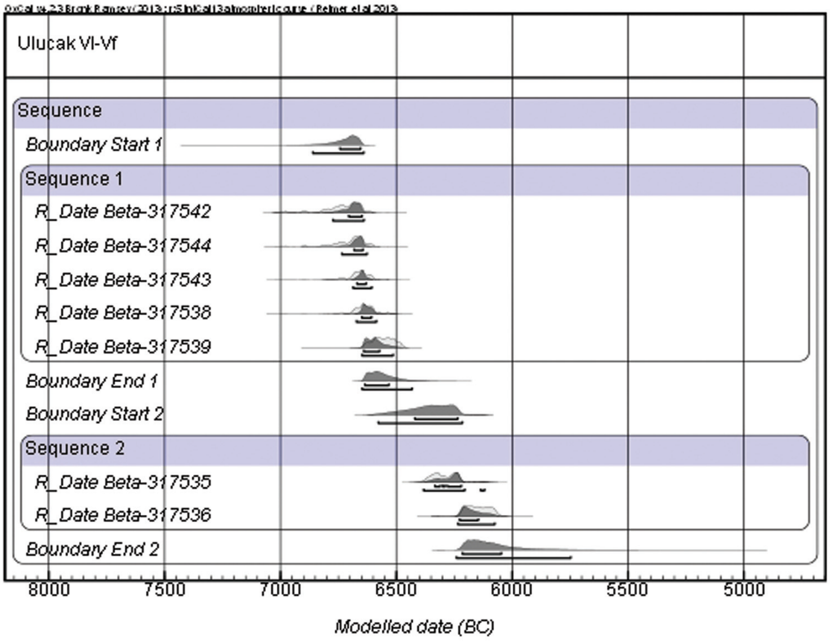

Fig. 11. Modelled radiocarbon dates from Ulucak VI and Vf.

Although it served as a good tool to explain Neolithisation processes in Thessaly during the 1960's, the so-called *Preceramic* period in Greece is now best understood as a concept that belongs to the history of research. A precise definition of the relevant terms, including the underlying concepts, will certainly remain a matter of future debates. In order to understand and ultimately resolve the long-standing terminological problems, it will be necessary, in particular, to overcome existing local and national viewpoints. More recent publications (*e.g.*, *Lichter 2005*) have demonstrated that it is possible to look at the Aegean world in its entirety.

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Hard water and old food. The freshwater reservoir effect in radiocarbon dating of food residues on pottery

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ABSTRACT – *This paper discusses the problem of the freshwater reservoir effect in the radiocarbon dating of different sample materials, in particular food crusts on pottery. Charred food residue can be used to directly date of the use of the pottery. However, this material is highly complex, which can lead to various dating errors.*

IZVLEČEK – *V članku predstavljamo problem sladkovodnega 'rezervoar učinka' pri radiokarbonskem datiranju različnih materialov, še posebno zoglenelih ostankov hrane na lončenini. Ti se lahko uporabijo za neposredno datiranje rabe keramičnih posod. Ker je njihova sestava zelo kompleksna, lahko pride do napak pri datiranju.*

KEY WORDS – *radiocarbon dating; freshwater reservoir effect; hardwater effect; pottery; food crusts; food residues*

Introduction

Charred food residues on prehistoric pottery can be used in the direct radiocarbon dating of the use of the pottery. However, this material is highly complex, which can lead to different dating errors. Especially reservoir effects have to be taken into account. The freshwater reservoir effect is of particular concern due to its potentially large order of magnitude and high degree of variability. Different biomolecular methods can be used to discern the former contents of the pottery, but not all of them are equally well suited to predict reservoir effects in food crust dating.

In this paper I discuss the problem of the freshwater reservoir effect in radiocarbon dating of different sample materials, in particular food crusts on pottery. I will elaborate on this topic based on my own research (*e.g., Philippsen 2012*), but try to draw some more general conclusions and suggest guidelines for radiocarbon dating of food crusts.

The freshwater reservoir effect

The carbon concentration in freshwater systems, lakes and rivers, can potentially be much lower than the carbon concentration of the atmosphere. Radiocarbon dating of materials originating in the aquatic environment can therefore lead to spurious, too high ages – the so-called freshwater reservoir effect (FRE). The principle of radiocarbon reservoir effects is explained in Figure 1. Usually, we assume that all living materials are in ^{14}C equilibrium with the atmosphere (black curve). The ^{14}C concentration of the sample is measured (in this example, it is measured to 50% of the original concentration), and the radiocarbon age of the sample can be read from the graph. However, aquatic samples can have a lower ^{14}C concentration to begin with. In Figure 1, this is exemplified by a fish that only has 80% of the ^{14}C concentration of contemporaneous terrestrial samples. After its death, its ^{14}C concentration decreases according to the exponential decay law (the blue curve). When a radiocarbon concentration of 50%

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modern is measured in this case, the blue curve should be used to read off the age – which is significantly lower than the 5730 years one would read from the graph when being unaware of the reservoir effect. The difference between the radiocarbon age of the aquatic sample and the contemporaneous terrestrial sample is called 'reservoir age', or 'reservoir offset'.

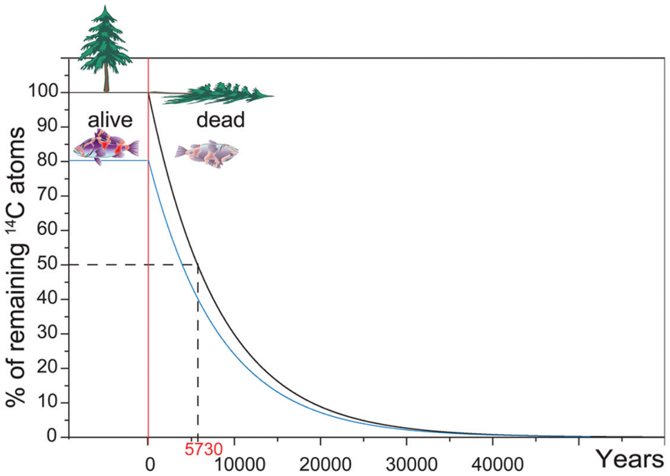

Fig. 1. The principle of radiocarbon reservoir effects. Please see the text for details. Author's own work.

The risk of a freshwater reservoir effect was recognized already in the early years of radiocarbon dating, even before the marine reservoir effect was discussed (*Deevey* et al. *1954; Oana, Deevey 1960; Godwin 1951*). During the last two decades, research about the FRE has intensified with the studies of FREs in human bones and food residues on pottery (*Lanting, van der Plicht 1995/1996; Cook* et al. *2001; Fischer, Heinemeier 2003; Shishlina* et al. *2007; Smits, van der Plicht 2009; Boudin, Strydonck and Crombé 2009; Olsen* et al. *2010; Philippsen 2010; Philippsen* et al. *2010; Shishlina 2012*).

Different mechanisms introduce 'old' carbon into lakes and rivers. The most important mechanism is the dissolution of carbonate minerals, leading to hard water and thus the 'hardwater effect'. Other mechanisms include the mineralisation of old organic matter, long residence time in aquifers, or CO_2 from volcanic activity.

The hardwater effect

Dissolved inorganic carbon, DIC, is the basis of the aquatic food chain, as it is photosynthesized by the aquatic vegetation. DIC comprises dissolved carbonate, bicarbonate and CO_2. It can be formed through the following process: rainwater seeps through the root zone, taking up CO_2 from decaying vegetation (which has fairly recent radiocarbon ages and $\delta^{13}C$ values around –25‰). The resulting carbonic acid can dissolve carbonate minerals, if present (which are infinitely old, '^{14}C dead', and have $\delta^{13}C$ values around 0‰). In summary, the reaction is:

$$CaCO_3 + H_2O + CO_2 = Ca_2^+ + 2HCO_3^-$$

Thus, for each carbon atom from root zone CO_2, one carbon atom from dissolved carbonate is added to the water. The resulting reservoir age can therefore be one half-life of radiocarbon (5730 years) at maximum. Typically, though, reservoir ages will be lower even in very carbonate-rich water, due to CO_2 exchange with the atmosphere. The $\delta^{13}C$ values of water DIC depend also on the $\delta^{13}C$ values of the carbon sources and their relative contributions. Figure 2 illustrates the mechanisms and the resulting $\delta^{13}C$ values.

The FRE is therefore correlated with the carbonate concentration (alkalinity, or water hardness (*Keaveney, Reime 2012*)). However, the hardwater effect is not the only FRE. Other mechanisms can cause high freshwater reservoir offsets (FRO) as well. Therefore, low alkalinity does not necessarily indicate the absence of an FRE.

Other causes for FREs

There are several sources of old carbon in lakes and rivers, beyond the hardwater effect. Therefore, even carbonate-free groundwater and surface water can have high FROs. In lakes, these can be caused by slow CO_2-exchange with the atmosphere due to a large depth-to-surface ratio, good wind protection or extended periods of ice cover (*Håkansson 1976; Björk, Wohlfarth 2001*). Old groundwater (due to long residence times in the aquifer) can increase the FRO as well as the inflow of glacier meltwater containing old CO_2 or geothermal water and water containing CO_2 from volcanic activity (*Sveinbjörnsdottir 1992; Boaretto* et al. *1998*). Mineralisation of old organic matter is another mechanism that introduces ^{14}C-depleted carbon into the water (*Boaretto* et al. *1998*).

Reservoir ages measured in two Northern German rivers illustrate those mechanisms. The river with the higher alkalinity, the Trave River, has, contrary to expectation, a lower reservoir age than the less-alkaline Alster River. The Alster originates in a spring

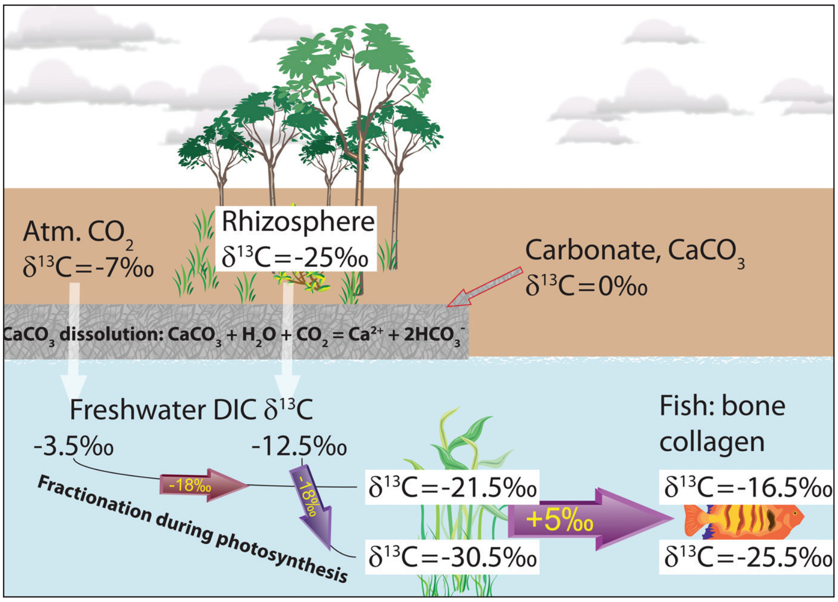

Fig. 2. Carbonate dissolution, fractionation processes in a freshwater system, and resulting δ13C values. Author's own work.

fen, which possibly introduces old organic carbon. Furthermore, the Trave flows through a shallow lake, which lies before the sampling locations. Therefore, CO_2 exchange between water and atmosphere is possible, which lowers the reservoir age (*Philippsen, Heinemeier 2013*). Figure 3 shows the effect of different carbon sources on the reservoir age and $\delta^{13}C$ values of the water DIC. Fossil carbonate and old organic matter CO_2 increase the reservoir age, while atmospheric CO_2 and root zone CO_2 have young or negligible radiocarbon ages. The decay of organic matter, both old organic matter and recent organic matter in the root zone, lowers the DIC $\delta^{13}C$ values. Fossil carbonate, in contrast, has high $\delta^{13}C$ values around 0‰. The $\delta^{13}C$ values of atmospheric CO_2 are high as well, and usually vary around -7‰.

Freshwater reservoir effect variability

Freshwater reservoir effects can vary with time, space, and between different species or individuals from the same freshwater system. Temporal variation can be caused by long-term changes in the relief of the landscape and the development of the lake or river. But also short-term changes in the reservoir age of the water can be observed, causing the reservoir age to vary from one year to the other.

Water DIC

This short-term variability is illustrated in Figure 3, where measurements on two rivers, the Alster and the Trave River in Northern Germany, are summarized. The sampling localities were not many kilometres apart; however, the rivers are separated by a watershed and have different reservoir ages and $\delta^{13}C$ values. Within one river, the reservoir age varies by over 1000 ^{14}C years during the three-year study period. Much of this variation can be explained by short-term weather fluctuations. For example, the strong influence of atmospheric CO_2 on the Trave values from February 2009 might be due to the fact that the ground was still frozen. Thus, any rain- or meltwater flowed directly into the river, without percolating through the root zone. For the other sampling dates, a correlation with the amount of precipitation in the week prior to sampling could be found (*Philippsen, Heinemeier 2013*). Large amounts of precipitation cause the reservoir age and the $\delta^{13}C$ values of the water DIC to decrease. This is probably due to the fact that large proportions of this rainwater enter the rivers as surface-runoff, flowing through the root-zone. During this process, the water absorbs CO_2 from the decay of vegetation. Root zone CO_2 usually has the same $\delta^{13}C$ values as the vegetation:

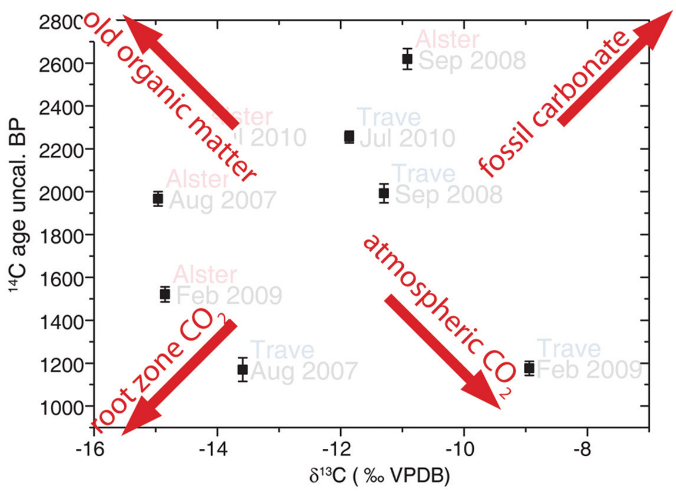

Fig. 3. Squares with error bars: 14C age and δ13C values of water DIC from two rivers (Alster and Trave) in Northern Germany. Month and year of sampling are stated in semi-transparent writing. Arrows indicate how the values would change with increasing influence of different carbon sources. Author's own work.

the reactions during the decay of organic matter usually proceed to the end. Therefore, no fractionation is associated with this process (*Galimov 1966*) and root zone CO_2 has $\delta^{13}C$ values around –25 ‰.

The correlations with short-term precipitation fluctuations, as well as the highly variable reservoir ages during the study period of only three years, indicate that rivers are highly complex systems in the context of the FRE. A high degree of variability is to be expected for river systems in general, especially because weather fluctuations and changes in the course of the rivers can be much larger during millennia, than during the short study period. However, it could be argued that short-term fluctuations are balanced during the growing season. Therefore, fluctuations might be smaller in plants and animals from those rivers. To test this hypothesis, several projects (including my own) have radiocarbon dated modern samples of aquatic flora and fauna.

Freshwater plants

In terms of radiocarbon dating and stable carbon isotopes, aquatic plants are very complicated organisms. The reason is the multitude of possible carbon sources for aquatic photosynthesis:

❶ DIC in the water is one possible carbon source. It occurs as different species, mainly CO_2 and bicarbonate (HCO_3^-), with different ^{13}C values (*Osmond 1981; Emrich, Ehhalt and Vogel 1970; Andrews, Riding and Dennis 1993; Romanek, Grossman and Morse 1992*). Some plants can use both species, others specialise in one of them. Depending on which species the plants specialise in, and how abundant it is at the pH value of the water, the plants might experience a restricted carbon pool, which limits fractionation. As mentioned above, the DIC itself can have different origins with potentially very different radiocarbon ages and $\delta^{13}C$ values.

❷ Floating and emerging plants or leaves can assimilate atmospheric CO_2, in addition to other carbon sources.

❸ CO_2 from the rhizomes or sediment can be transported through the plant's stems and photosynthesized in the leaves or stem and leaf sheaths (*Dacey 1980*).

Ten samples of aquatic plants from two northern German rivers illustrate the complexity of aquatic photosynthesis. They are shown in Figure 4, which presents radiocarbon ages and $\delta^{13}C$ values of water DIC, aquatic plants and animals such as fish, molluscs and crayfish. The data have been published before; tables with all isotope data and radiocarbon dates can be found in Philippsen (*2012*) and Philippsen, Heinemeier (*2013*).

The radiocarbon ages of the aquatic plants range from –74 to 2273 ^{14}C yr BP (Fig. 4). Compared to the atmospheric ^{14}C level of the respective growing season, this results in reservoir ages between 347 and 2700 ^{14}C years (*Philippsen, Heinemeier 2013*). Currently, no factors are known which could explain the reservoir ages of the individual samples. The reservoir age is not connected to species or whether the plant grows submerged or floating; not to which river it grew in; and not to sampling season. For example, a floating plant with a reservoir age of 1300 ^{14}C years was collected on the same day and location as a submerged plant with a reservoir age of only 350 ^{14}C years.

Freshwater fish and mollusks

The great variability in radiocarbon ages can also be found on higher levels of the aquatic food chain. For this study, different samples of the aquatic fauna have been dated (orange symbols in Fig. 4). Most samples were fish bones, but also a crayfish, a snail shell and a bivalve shell, and a mallard feather were

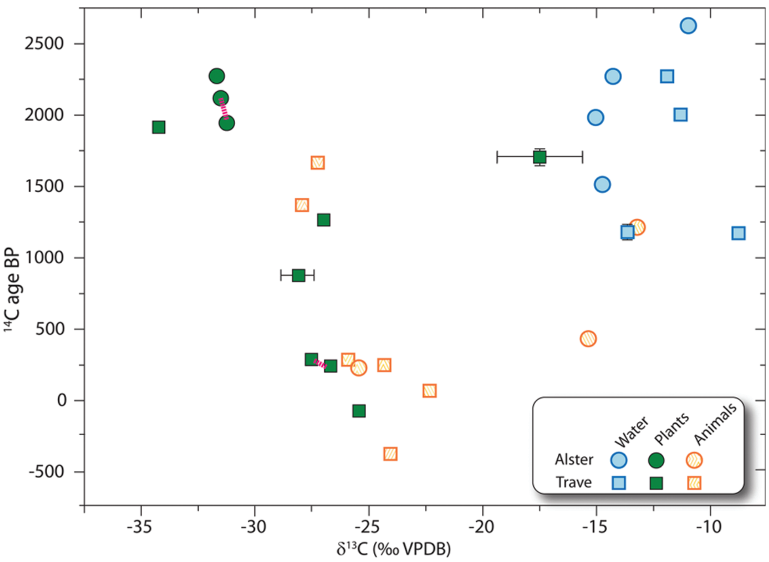

Fig. 4. Radiocarbon dates and δ13C values of water DIC, plant and animal samples from two North German rivers, Alster and Trave. The hatched pink lines connect samples from the same individual of Nuphar lutea (leaf and petiole, respectively) (after* Philippsen 2012*;* Philippsen, Heinemeier 2013*;* Philippsen *et al.* 2013*).

analysed. The latter had the same age as the contemporaneous atmosphere (a negative ^{14}C age in Fig. 4), so this mallard must have had a terrestrial diet. Generally, the fauna samples span about the same range as the aquatic vegetation, although none of them has as high reservoir ages as the 'oldest' plants. Correspondingly, the fauna $\delta^{13}C$ values follow the same trend as the plants' values. They are shifted slightly towards more positive $\delta^{13}C$ values, which is to be expected when, for example, comparing a fishbone with the fish's diet. Two fauna samples have very positive $\delta^{13}C$ values; these were carbonate samples of a snail shell and a bivalve shell. Generally, most plant and animal samples from these rivers follow a roughly linear relationship, where higher ^{14}C-ages are correlated with more negative $\delta^{13}C$-values. However, to draw any secure conclusions or to formulate a correction for the reservoir effect, more samples would be needed.

Reservoir effects in food crusts on pottery

It was hypothesized that surprisingly old radiocarbon dates on charred food residues on pottery were the result of the freshwater reservoir effect. This hypothesis was tested using a two-fold approach: on the one hand, food crusts were prepared experimentally from ingredients with known reservoir ages; on the other hand, multiple archaeological samples from two sites with hunter-gatherer pottery were analysed.

Experiments

Three series of food crusts experiments have been performed so far; the material from the third is still under analysis. Ingredients with different radiocarbon ages, as well as different carbon and nitrogen isotope values, have been prepared in the pottery. These include cereals, nuts, roots and leaf vegetables, freshwater and marine fish, bovine milk, and terrestrial herbivore meat. Different mixtures of these resources were prepared to test whether certain ingredients would dominate the food crusts.

The result of these experiments was a reference collection of food crust samples made of known ingredients. As an interesting side effect, we were able to study the suitability of the pottery for food preparation (*Glykou 2012; Philippsen, Glykou and Paulsen 2012*). One conclusion was that the formation of food crusts requires a lot of time and energy, especially in the case of lean fish and/or vegetables. New experiments in August 2015 will show if food crusts also can form during long-term 'normal use', *i.e.* food preparation without charring.

The first question was whether an ingredient with a reservoir age would form a food crust with the same reservoir age. Therefore, a food crust was made from freshwater fish, roach (*Rutilus rutilus*), with a reservoir age of 722±47 years. The crust had a reservoir age of 756±41 years, which is statistically undis-

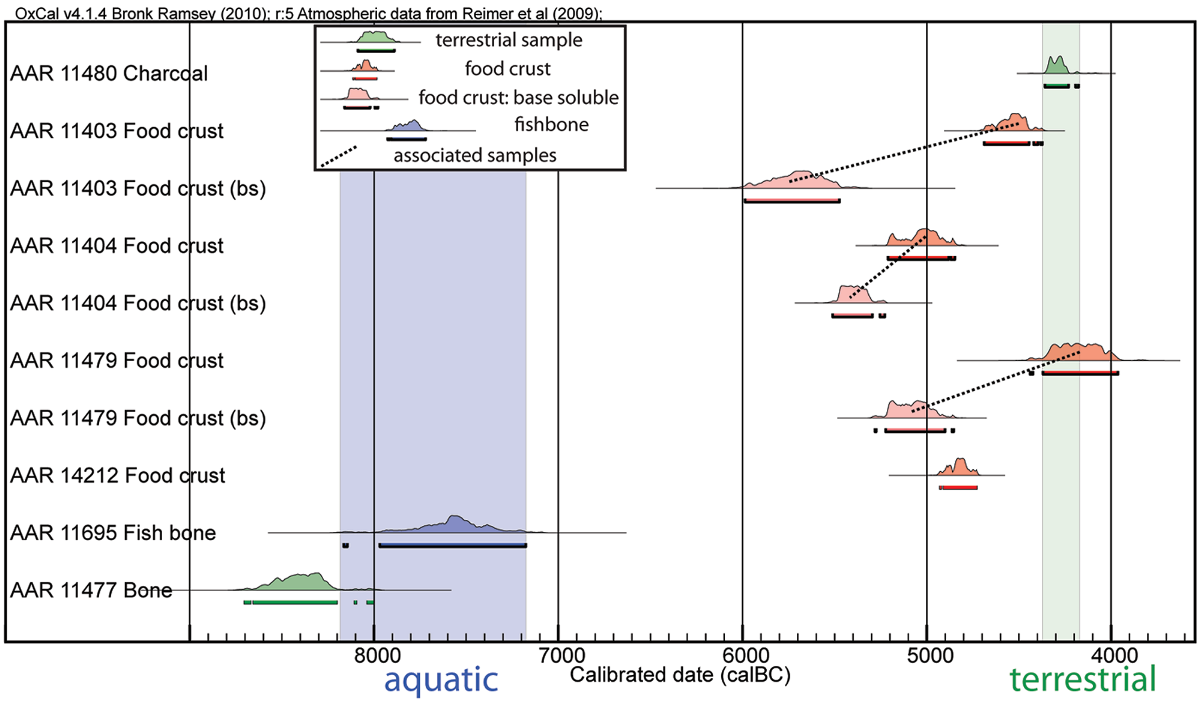

Fig. 5. Calibrated radiocarbon ages from the Ertebølle site Kayhude, Northern Germany (from* Philippsen 2012*). Calibrated with OxCal4 and IntCal09 (*Bronk Ramsey 2009; Reimer *et al.* 2009*).

tinguishable from the fish's reservoir age (*Philippsen 2010*). The second question was whether the reservoir age of the cooking water would have an influence on the reservoir age of the food crust. Therefore, a sample of wild boar meat was cooked in river water; the water had a radiocarbon age of more than 1000 ^{14}C years. The wild boar food crust had a reservoir age of −540 ^{14}C years. Calibrated with the bomb pulse calibration curve (*Kueppers 2004*), extended to present using an exponentially decreasing curve, this resulted in a calibrated age of 3±2 years (*Philippsen 2010*). Therefore, we can conclude that the reservoir age of the ingredients determines the reservoir age of a food crust, irrespective of the radiocarbon age of the cooking water.

Case study: Hunter-gatherer pottery from Northern Germany

Several samples from the inland Ertebølle sites Kayhude on the River Alster and Schlamersdorf on the River Trave were radiocarbon dated to determine the local reservoir effect, the risk of reservoir effects in food crusts on pottery, and the true age of the earliest pottery in this part of Germany. The results are presented in Figures 5 and 6.

In Kayhude, the samples were collected from a relatively undisturbed stone paving (*pers. comm. I. Clausen 2007*). The age difference of over 3000 years between the fish and the charcoal from Kayhude is much larger than the reservoir ages that we

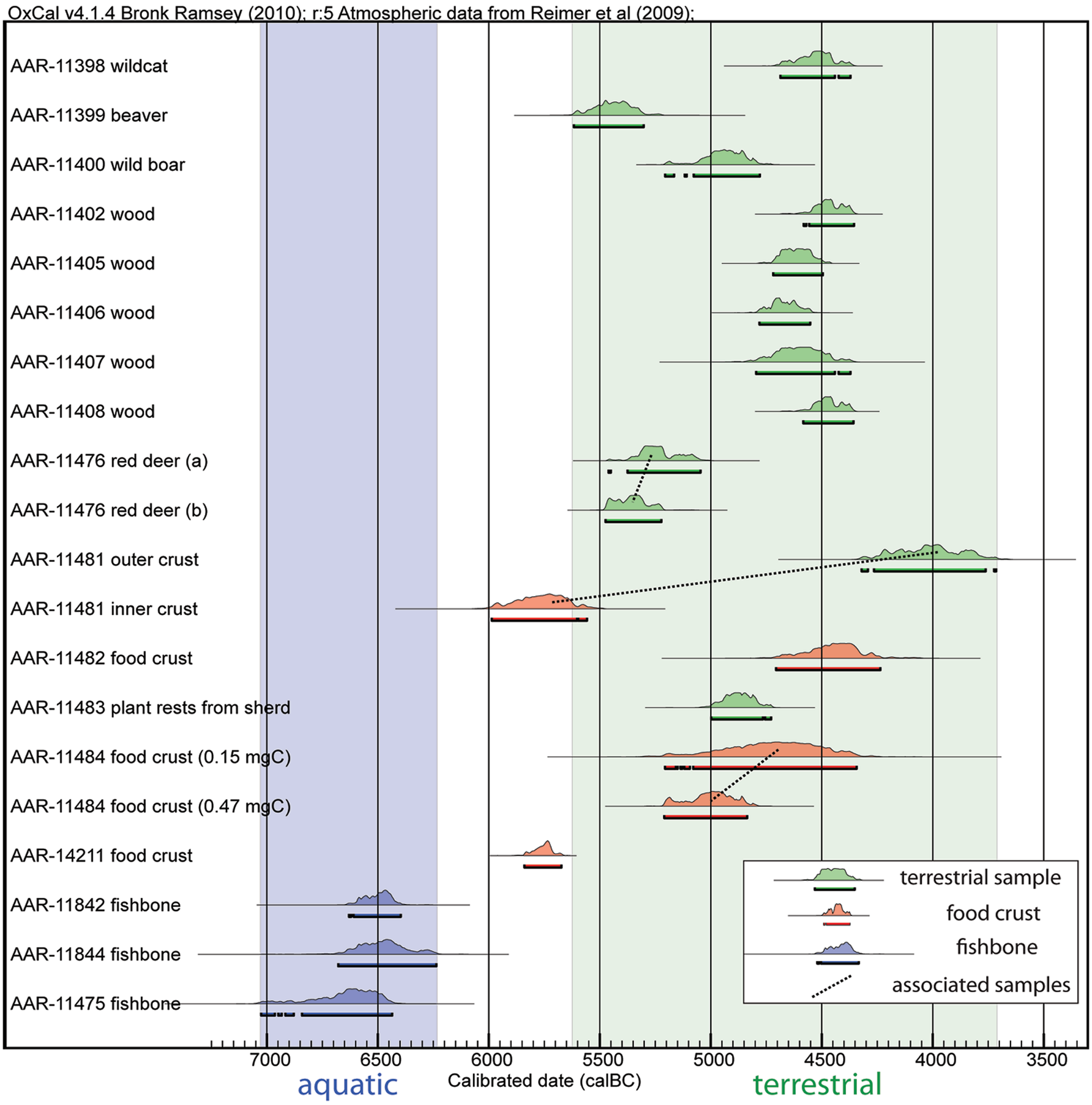

Fig. 6. Calibrated radiocarbon ages from the Ertebølle site Schlamersdorf, Northern Germany (from Philippsen 2012*). Calibrated with OxCal4 and IntCal09 (*Bronk Ramsey 2009; Reimer *et al.* 2009*).*

find for modern fish, but of the same order of magnitude as the reservoir age for modern water and plants (see above). One terrestrial sample has a radiocarbon age of more than 9000 BP. This bone must be an admixture from earlier layers, as it is not only older than the other terrestrial sample from Kayhude, but also older than the oldest finds of the entire Ertebølle culture. This exemplifies that the stone paving where we found our samples cannot be regarded as totally undisturbed. Direct radiocarbon dating of the pottery is thus necessary as we cannot be sure which terrestrial samples are clearly associated with the pottery. None of the food crusts are as old as the fish bones, though. The base-soluble fraction of three food crusts has also been dated. It is likely to consist of humic acids and other degradation products from the soil, and is thus removed from the samples. Here it is older than the food crusts (Fig. 5), indicating contamination with an older soil substance. However, all purification procedures are also likely to remove some of the original food crust. The base-soluble fraction, for example, could contain fat or other base-soluble food remains. Therefore, it can be difficult to find the right balance between removing as much contamination as possible, while removing as little original food crust as possible.

that period is thus more than one thousand years. Two sub-samples of the food crust AAR-11484 have been dated. The smaller sample is slightly younger. This might be the effect of a constant amount of modern contamination that enters the samples during preparation or measurement. The wildcat bone AAR-11398 and the food crusts AAR-11482 and AAR-11484 had been found quite close to each other. It is therefore probable that they are contemporaneous. Their radiocarbon ages indicate a small reservoir effect in the case of AAR-11484 (the larger sample is the one dated more precisely), and no reservoir effect on AAR-11482.

Methods to detect aquatic ingredients

The formation of food crusts is a highly complex chemical process. It depends on the nutrients present in the pot and on the cooking parameters such as temperature and duration. If the cooking temperature is high enough, and the food left to cook long enough, the water will evaporate completely. Therefore, the temperature inside the pot can increase to over 100°C. In the water-free food, proteins and some sugars combine in the Maillard reaction, while the carbohydrates caramelize. Finally, the food carbonises to form the characteristic food crusts.

The terrestrial age range of Schlamersdorf (Fig. 6) complies with earlier charcoal dates from this site (*Hartz 1993*). The age range of terrestrial samples is very broad. This does not mean that this site has been inhabited constantly for 1000 ^{14}C years. It was probably occupied repeatedly for shorter periods, as archaeological analysis indicated that the site was a hunting or fishing station. The broad terrestrial age range reveals the necessity of direct pottery dating. Two fish bone samples, AAR-11842 and AAR-11844, were associated with the red deer sample AAR-11476. The radiocarbon ages of the fish bones agree with each other, whereas they are significantly older than the red deer sample. The full freshwater reservoir effect during

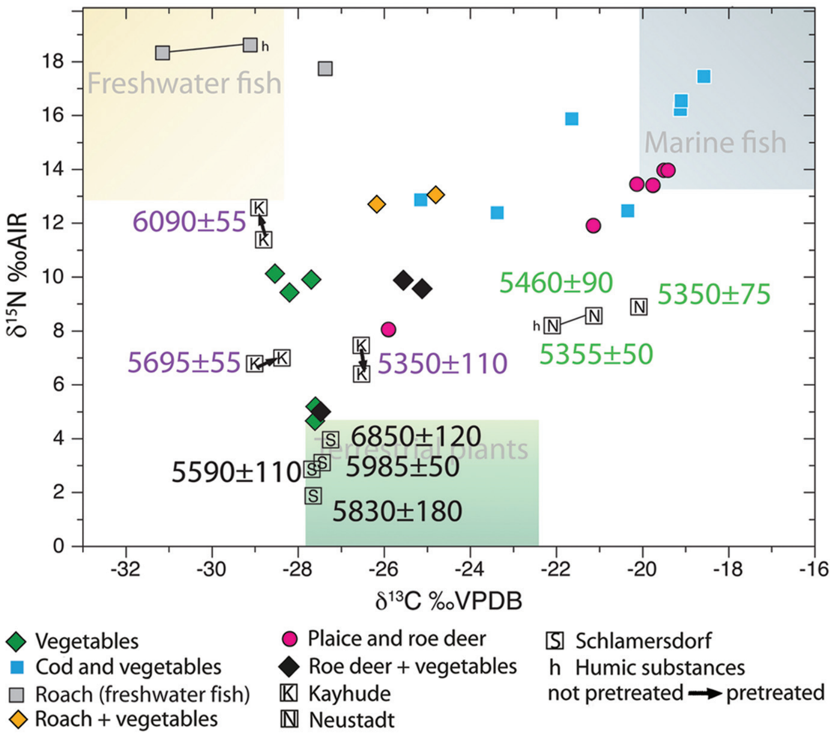

Fig. 7. $\delta^{15}N$ and $\delta^{13}C$ values of experimental and archaeological food crusts. The experimental food crust values are denoted by symbols of different shape and colour, while letters mark the values of food crusts from three archaeological sites (Schlamersdorf and Kayhude, inland sites; Neustadt, coastal site; all are Ertebølle sites from northernmost Germany).

Stable isotopes

Often, the bulk food crust material is used for radiocarbon dating (after removal of possible contaminations). Therefore, a method is needed which detects the presence and preferably abundance of aquatic ingredients in the bulk food crust. Stable isotope analysis is such a method. The δ13C values are in fact measured on exactly the same material as the radiocarbon age. However, δ13C values alone are not very accurate for the reconstruction of ingredients. Therefore, other isotopes are usually measured together with the δ13C values, typically δ15N. Measurements on modern samples provide reference values. Preferably, charred food crusts are analysed instead of the raw ingredients, as isotope values might change during cooking (*Fernandes* et al. *2014*). However, in this study, only minimal changes in isotope ratios during cooking and charring were observed (*Philippsen 2012*). Isotope values of several experimental and archaeological food crusts are presented in Figure 7.

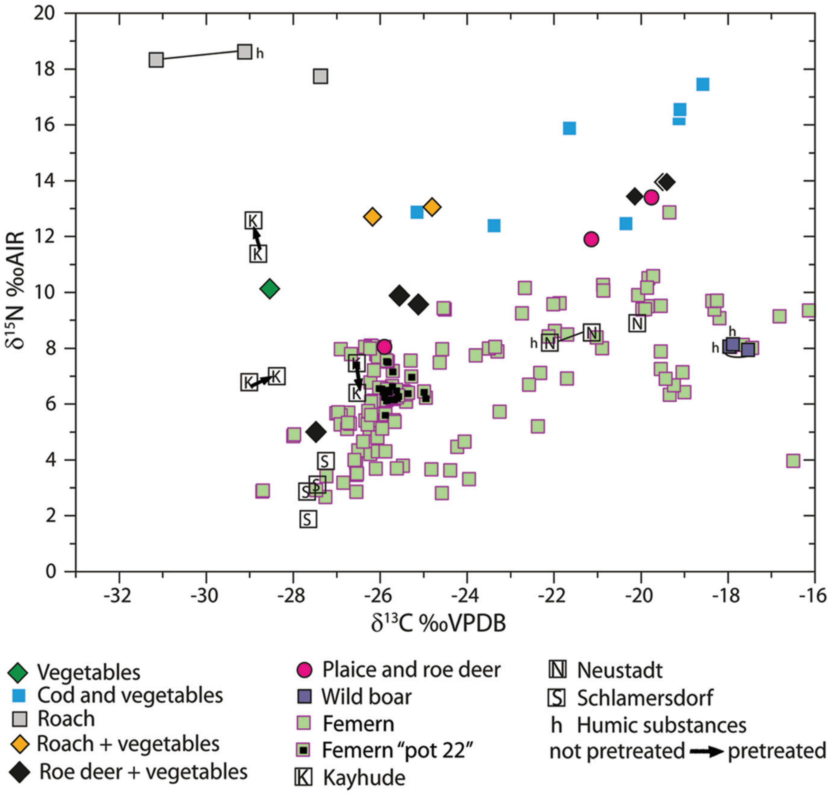

Fig. 8. Stable isotope measurements on experimental and archaeological food crusts (*cf. *Fig.* 7*). Measurements on samples from the Femern project on the island of Lolland, Denmark, are marked by light-green squares. Measurements on sherds belonging to the same vessel ('pot 22') are additionally marked by a little black square.

Interestingly, samples from the same experimental pot can have very different δ13C and δ15N values. The δ13C values of mixtures of marine and terrestrial ingredients can cover a large range of up to 6‰. The δ15N ranges of some of the mixtures are of the same order of magnitude (Fig. 7). This implies that measurements on a single sherd might not be sufficient to reconstruct the former contents of the vessel. Many measurements would be necessary to get the whole picture. Furthermore, when using stable isotope measurements to correct radiocarbon dates, one should make sure to perform the measurements on the same, homogenized, sub-sample.

The expected isotope values of the experimental food crusts were calculated with the relative proportions of the different ingredients, their isotope values and their carbon and nitrogen concentrations. In some cases, the measured isotope ratios deviated clearly from the calculated expected values. This is most likely caused by the inhomogeneity of the charred food residue, as none of the measured values was outside the range of the isotopic values of the different ingredients (*Philippsen 2012*).

The effect of pretreatment was tested for three archaeological food crust samples from Kayhude. The chemical pretreatment procedures remove contamination from the burial environment such as carbonates and humic substances. However, the pretreatment does not result in a systematic shift of isotope ratios (Fig. 7). Furthermore, the changes are small compared to the wide range of possible isotope values and compared to the variability of values even within one vessel. Therefore, it is concluded that the chemical pretreatment is not necessary prior to food crust isotope analysis.

The archaeological food crusts from Kayhude indicate different proportions of terrestrial and freshwater ingredients. Lower δ13C values and higher δ15N values are associated with older radiocarbon ages. This agrees with our expectations, as freshwater resources are characterized by low δ13C and high δ15N values.

The $\delta^{15}N$ values from Schlamersdorf would suggest a mixture of terrestrial plants and terrestrial herbivore meat. The $\delta^{13}C$ values are also in the range of terrestrial plants, but in the very negative part of the range, with values around –28 ‰. However, the very old radiocarbon ages of the food crusts from Schlamersdorf indicate a significant freshwater reservoir effect. It is therefore possible that low-trophic level aquatic food was used. Changes of isotopic ratios in the burial environment cannot be excluded as well and will be tested through the analysis of buried experimental food crusts.

In Figure 8, food crust measurements from the Femern project on the island of Lolland, Denmark, are compared to the food crust data discussed above. These data are part of an ongoing project with Carl Heron and John Meadows (Universities of Bradford and Kiel). The sherds have not been dated directly yet, but context dates and the archaeological interpretation indicate that they belong to the late Ertebølle culture and Funnel Beaker culture, *i.e.* the transitional phase between the Mesolithic and the Neolithic of this region. The $\delta^{13}C$ and $\delta^{15}N$ measurements indicate that both terrestrial and marine resources were exploited, while freshwater resources could not be detected. The $\delta^{15}N$ values are generally lower than those of the experimental food crusts. This could be due to changes in land-use practice, *e.g.*, manuring of modern-day vegetables, or to processes in the burial environment. Several sherds from our food crust experiments have been buried and were excavated again – they will indicate isotopic changes during burial.

Many of the analysed sherds from the Femern project belonged to one vessel, 'pot 22'. They are marked by additional small black squares in Figure 6. Interestingly, the food crust from this pot seems to be quite homogeneous. The $\delta^{13}C$ values cover a range of less than 1‰, while the $\delta^{15}N$ values vary by about 2‰. The food prepared in this vessel most likely derived from terrestrial herbivores, probably mixed with plants. Ingredients with very similar isotope values were used, or the food was thoroughly mixed and homogenized during preparation.

Other methods

Several biomolecular methods are available to reconstruct vessel use and, important in the context of radiocarbon dating, detect aquatic ingredients. Probably the most widespread method is lipid analysis. Lipids can be preserved in the food crust or absorbed in the clay matrix. They indicate the presence or absence of a variety of fats and can, for example, distinguish between ruminant and non-ruminant fat, marine and terrestrial fish, milk and body fat (*Copley 2004; 2005; Evershed 2007; Evershed* et al. *2001; Heron, Craig 2011; Craig* et al. *2007; 2011*). However, lipid residues and charred food crusts can potentially form from different ingredients (the food crusts from proteins and carbohydrates). Therefore, the results of a lipid analysis can only be used with caution for correcting pottery dates or identifying reservoir effects in food crusts.

Reservoir effects as a source of information

So far, we have treated radiocarbon reservoir effects as a source of error. However, when the objective of food crust analysis is more than a chronology of pottery-use, reservoir effects can be used as a source of information. When a chronological control is available, *e.g.*, radiocarbon dates of terrestrial material from a secure context with the pottery, the reservoir effect can detect the preparation of aquatic resources in two difficult cases:

❶ When the concentration of aquatic food is very low, it will be difficult to detect with isotopic methods. This is especially the case with freshwater resources. When the freshwater reservoir effect in the study region is high, even small amounts of freshwater food will result in a measurable reservoir age.

❷ In some cases, aquatic food can have the same isotopic signature as terrestrial food. Low-trophic level aquatic food has approximately the same $\delta^{15}N$-values as terrestrial food. Furthermore, a mixture of freshwater and marine resources can result in 'terrestrial' $\delta^{13}C$-values. Here, again, a reservoir effect in a 'terrestrial' food crust will indicate the preparation of aquatic ingredients.

The same principles can also be transferred to radiocarbon dating of human remains.

Conclusion

The freshwater reservoir effect is a highly complex issue. In general, the characterisation of the reservoir effect in a freshwater system requires more than a few water, plant and animal samples. Freshwater reservoir effects in a river can vary significantly on short and long timescales, spatially, and even between individuals of the same plant species, growing in the same year in the same part of the river.

This complexity is transferred throughout the food chain, further complicated by the fact that fish can migrate within the river system or include smaller or larger proportions of terrestrial food into their diet. Food residues on pottery can be a mixture of terrestrial, marine and/or freshwater resources. Even 'terrestrial' animals can have reservoir effects, *e.g.*, elk/moose which consume aquatic plants (*Philippsen 2015*) or sheep fed with seaweed (*Balasse 2005*). As the radiocarbon ages of the ingredients are transferred to the food crusts, they can also have very high and variable reservoir ages. In an estuarine environment, varying influence of sea water *vs.* terrestrial run-off and freshwater will furthermore complicate the analysis of radiocarbon dates (*e.g.*, *Philippsen* et al. *2013*).

Therefore, samples for radiocarbon dating should be chosen wisely when the aim is to construct a chronology. Stable isotope analysis ($\delta^{13}C$, $\delta^{15}N$) of food crusts on pottery can indicate which of the samples contain the smallest proportions of freshwater and marine ingredients. Therefore, food crusts with the lowest risk for reservoir effects can be selected for dating. In many cases, however, reservoir effects can also be a source of information regarding the cuisine and diet of the past, or changes in the aquatic environment.

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Archaeology and rapid climate changes: from the collapse concept to a panarchy interpretative model

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ABSTRACT – *The 'rapid climate change', 'cycles of abrupt climate shift', and 'cold events' in the Holocene are discussed in relation to the 'collapse of civilisation' concept, and adaptive cycles and the panarchy interpretative model.*

IZVLEČEK – *V članku predstavljamo 'hitre klimatske spremembe', 'cikle nenadnih klimatskih premen' in 'hladne dogodke' v povezavi s konceptom 'kolapsa civilizacij', adaptivnimi cikli in interpretativnim modelom 'panarhije'.*

KEY WORDS – *archaeology; rapid climate changes; collapse; resilience; sustainability; adaptive cycles; panarchy*

Introduction

The first interpretations linking climate change to the trajectories of civilisation and culture appeared at the beginning of the 20th century, and were embedded in geographical, climatological and archaeological studies. Sudden droughts and aridification were recognised as climatic and environmental determinants related to catastrophic scenarios and the collapse of civilisations in Egypt, Mesopotamia, and India, as well as nomadic tribes from Central Asia invading Europe (*Huntigton 1926; Brooks 1926*). In a parallel adaptive scenario within the context of cultural evolution, the 'oasis theory' determined the development of subsistence strategies, including the cultivation of plants and domestication of animals, and the introduction of farming (*Childe 1928*).

By the end of the 20th century, climatologists had introduced a model of long-term global and regional dynamics of climate changes at 3000-year intervals within the period 18 000 BP and the present, which was embedded in the Cooperative Holocene Mapping Project (COHMAP). The model simulation was based on well-dated radiocarbon biological and geological proxy data, such as pollen in lake sediments, lake levels, marine plankton, ice sheet dimensions and sea-ice extent. They suggested that the driving forces behind many long-term climatic changes were the varying insolation in the upper atmosphere and dynamics in global atmospheric circulation (*COHMAP Members 1988*). They correlated the first climate change in the Holocene within the interval between 13 000 in 10 000 BP with the Neolithic revolution in the Near East. Transition to farming was marked in this context as an "*early human response to a unique sequence of climatic events*" (*Wright 1993.466*).

Rapid climate changes

The model of long-term climate changes was soon replaced by Bond's 'cycle of abrupt climate shifts', 'rapid climate changes' (RCC) and 'cooling events'. The first was introduced by Gerard Bond *et al.* (*1997; 1999*) and linked to eight 'Ice Rafting Detritus' (IRD) phases in the North Atlantic in a cycle of ~1470 ± 500 years. In deep core drillings, these phases are marked by the accumulation of eight layers of ice-rafted lithic debris, primarily caused by iceberg discharges from the northern ice-shield. Ice-rafting episodes were associated with ocean surface cooling, each case of which appears to have been caused by a rather substantial change in the North Atlantic thermohaline circulation. The eight IRD events were dated by planktonic foraminifera AMS ^{14}C dating in two deep-sea drilling cores, and embedded in the following sequence: 11.3, 10.3, 9.5, 8.2, 5.9, 4.3, 2.8 and 1.4 years calBP (*Bond* et al. *1997.Fig. 2*). It was suggested that increased inflows of glacial water in the correlate with the periods of reduced solar activity (*Bond* et al. *2001; Barber* et al. *2004*). However, Bond's annual cycle has not been confirmed in either the Eastern or Western Mediterranean; intervals of ~2300 to 2500 years were suggested for the former (*Rohling* et al. *2002b*), and 1300, 1515, 2000, and 5000 years for the latter (*Rodrigo-Gámiz 2014*). The cooling events in the Eastern Mediterranean have been associated with reductions in solar output and in stratospheric ozone production, which led to cooling of the lower stratosphere and later to the changed meridional extent of atmospheric cells. These were ascribed to an intensification and increased frequency of wintertime northerly outbreaks of cold polar and continental air over the basin in the periods 8.6–8.0, 6.0–5.2, 4.2–4.0 and 3.1–2.9 calBP. Contemporaneous cooling events have been identified in the Adriatic Sea (*Rohling* et al. *2002a; Siani* et al. *2013*).

The rapid climate changes (RCC) model was introduced by Paul A. Mayewski *et al.* (*2004*). They identified as many as six RCC periods for the Holocene in a cycles of ~2800–2000 and 1500 years. RCC are given as 9000–8000, 6000–5000, 4200–3800, 3500–2500, 1200–1000, and 600–150 calBP years (Fig. 1). These periods were documented by a comparison of ~50 globally distributed palaeoclimate records, carefully selected according to length (full Holocene coverage), sampling resolution (dating resolution better than 500 years), interpretation quality, and geographic distribution. The first rapid climate change, well known as the '8.2ka calBP event', relates to the process of Neolithisation in Europe. It was caused by a strong, cold fresh-water pulse from the Laurentide Lakes in North America into the North Atlantic. The others relate to variations in solar radiation output. The cooling of the Northern Hemisphere, droughts in the tropics and changes in atmospheric circulation are characteristics of all rapid climate changes. A contrasting pattern is documented at the mid-latitudes 43° and 50°N in the French Pre-Alps, on the Swiss Plateau, and in Central Europe. Pollen records, palaeohydrological and other proxy data in lake sediments during the first RCC point to an evidently wet period. Lake level fluctuations show a sequence of lake level maxima, preceded and followed by lake level minima (*Magny* et al. *2003*). A similar tripartite sequence has been recorded in the Central and Western Mediterranean within the 4.2ka calBP event. Wet periods and high lake levels at *c.* 4300–4100 and 3950–3850 years calBP were interrupted by a dry period with low lake levels between *c.* 4100–3950 years calBP (*Magny* et al. *2009; 2012*).

The concept of centennial-scale 'cold events' relates to Bond's cycles model. It was grounded on analyses of temperature, precipitation and glacier dynamics proxy data that are preserved in various terrestrial, lake and deep-water sediment and ice-core palaeoclimatic archives. Heinz Wanner *et al.* (*2008; 2011*) thus identified six cold events in the Holocene. The first, the 8.2ka BP cold event, was embedded in the period 8300–8100 calBP. It should be stressed, however, that cooling anomalies in different regions are given in a longer period of 4 to 6 centuries (*Rohling, Pälike 2005*). The first was followed by the 6.5–5.9, 4.8–4.5 and 3.3–2.5 events at *c.* 6400–6200, 4800–4600 in 2800–2600 calBP. The latest two, the fifth (1.75–1.35) and the sixth (0.7–0.15) cold events date to the periods between 500–300 and 650–450 calBP (300–600 and 1200–1800 AD). These are associated with the Dark Ages, the Migration Period, and the Little Ice Age (*Wanner* et al. *2011*).

The fifteen episodes of high lake levels parallel the rapid climate changes and cold events. These were documented in 26 lakes in the foothills of the Western Alps, the Jura Mountains and in the central plateau in Switzerland. The episodes are radiocarbon dated and embedded in the following calendar sequences: 11 250–11 050, 10 300–10 000, 9550–9150, 8300–8050, 7550–7250, 6350–5900, 5650–5200, 4850–4800, 4150–3950, 3500–3100, 2750–2350, 1800–1700, 1300–1100, and 750–650 calBP (*Magny 2004*).

South of this area, in the Central Mediterranean, wet periods occurred in the time intervals *c.* 10 200, 9300, 8200, 7300, 6200, 5700–5300, 4800, 4400–3800, 3300, 2700–2300, 1700, 1200 and 300 calBP. In the Middle Holocene, a trend of a contrasting pattern of the precipitation regime can be observed. Wet winters and dry summers are documented above 40° N, and wet winters and wet summers in the southern regions. This pattern reversed in the Late Holocene (*Magny* et al. *2012; 2013; Peyron* et al. *2013*).

In archaeology, associations between prehistoric cultures and climate changes were determined by various theoretical concepts and interpretative contexts (*Trigger 1971; 1996*). They were embedded in the deterministic model of unilineal cultural evolution and diffusion. This model postulates that every change in human behaviour patterns, in the progress of economy and technology, as well as cultural trajectories was directly connected to climate and environmental changes (*Clark 1936; Childe 1958*). A similar concept was introduced by new or processual archaeology, whereby the evolution of prehistoric societies was determined by a successful cultural adaption to climate and environmental change (*Binford 1968; Tainter 1988*). In post-processual archaeology, the opposite was proposed: all changes in past societies, even in the natural environment, were triggered by human agency (*Hodder 1986; Tilley 1994*).

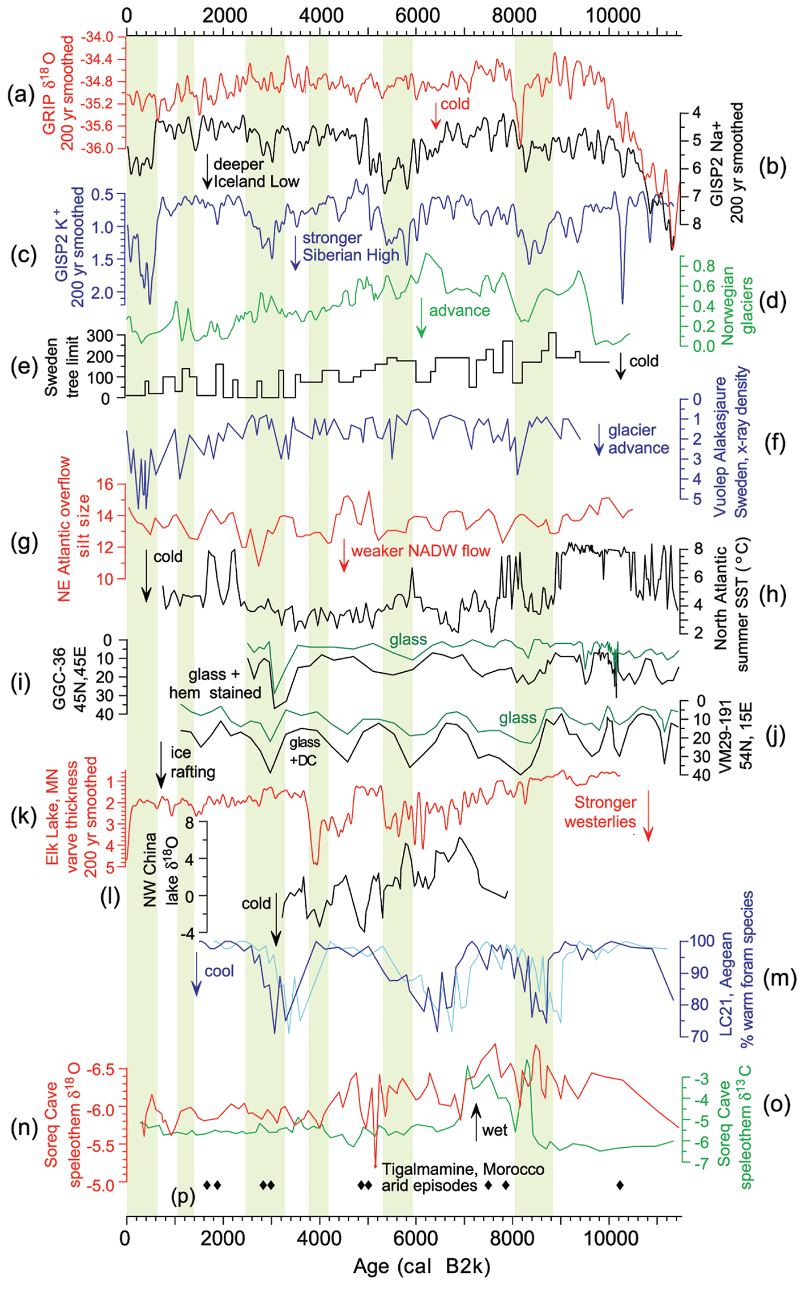

Fig. 1. Rapid climate changes (RCC) in the Holocene (after* Mayewski *et al.* 2004.Fig. 3*).

In parallel interdisciplinary studies, the landscape dynamics and cultural transformations in the Holocene have always been directly related to climate and environmental fluctuations at the regional and global level (for an overview, see *Berglund 2003; Brown, Bailey, Passmore 2015*). The correlation was based on the radiocarbon dates both of archaeological contexts and glaciological (ice cores), geological and geochemical (terrestrial and marine) and biotic palaeoclimate archives. The most important proxy data on past climates and climate events are: oxygen and carbon isotopic composition, trace element and micro-particle concentrations, gas content in air bubbles; glacial deposits and features of glacial erosion, periglacial features, lacustrine sediments, and erosional features, relict soils and volcano eruptions; biochemical markers in fossil plant and animal planktic, oxygen and carbon isotopic composition in ocean deposits and sapropel deposits; pollen and plant macrofossils in lake and terrestrial sediments, diatoms, ostracods, and insects in lake sediments; stable oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopes in speleothems; tree ring width, density and carbon stable isotope composition, stable carbon isotope in barley grains (*Bradley 1999; Briffa 2000; Sach* et al. *2000; Barber* et al. *2004; Rudiman 2008; Marino* et al. *2009; Steinhilber* et al. *2012; Wanner* et al. *2012; Riehl* et al. *2014; Magny* et al. *2004*).

The first comprehensive connection between rapid climate changes, past cultural dynamics, and archaeological cultures on a global scale was embedded in the paleoclimatic interpretative context. It was based on a statistical analysis of the distribution of 815 radiocarbon dates connected to fluctuations in the pollen sequence, the rise in sea levels, and the presence of peat in palaeobotanical data, as well as on 3700 dates connected to 155 archaeological cultural sequences (*Wendland, Bryson 1974*).

The continuing catastrophic explanations present rapid climate changes as the cause, and the collapse of population and civilisation as well as the 'Dark Ages' as its effects. The collapse of cultures such as the Mycenae in Greece, the Hittite and Akkadian empires, and the 3rd dynasty in Ur in Mesopotamia, and dynastic periods V and VI in Egypt were all linked to rapid climate changes (*Carpenter 1966; Bell 1971; Bryson* et al. *1974; deMenocal 2001*). All these events have been connected with sudden cooling events and dry periods, and the desertification of these regions. These interpretations were legitimised by Barbara Bell's postulate that climate fluctuations present a historical reality as much as the 'Dark Ages' (*Bell 1971.2*). Great emphasis was placed on the so-called 'Tell Leilan event', a disruption in the settlement of many tell sites in northern Mesopotamia (*i.e.* Tell Leilan, Tell Brak, Tepe Gawra) around 2200 calBC that marks the rapid climate change and desertification of the region, the collapse of the irrigation system and of the Akkadian Empire (*Weiss* et al. *1993; Courty, Weiss 1997; Weiss, Bradley 2001; Cullen* et al. *2000; deMenocal 2001*). A similar scenario was proposed for the fall of Mayan civilisation (*Hodell* et al. *1995; deMenocal 2001; Haug* et al. *2003*). Karl W. Butzer indicated the conceptual weakness and interpretative limitations of deterministic models (*Butzer 1972; 1975; 2012; Butzer, Endfield 2012*). He offered an alternative, cultural ecology approach to the concepts of climate fluctuation and the hypothesis of climate as the only cause of social collapse. Butzer emphasises that the activities of past pre-industrial societies destroyed the balance in regional ecosystems and caused shifts in subsistence, population, and culture that did not result in the collapse of systems, but in cultural and economic adaptations to new environments and a changed climate. A similar concept was introduced by the French Annales School, where historians emphasised that the influence of climate change on past societies was only indirect and barely visible. As an example, they referred to the Little Ice Age and the plague outbreak at the end of the 16th in addition to the general crisis in the 17th century in Europe. However, Le Roy Ladurie (*1971.17*) suggested that famine, pandemics, migrations, low food production and its high cost, as well as lack of money "*are not and cannot be facts which are strictly climatic*". Crawford S. Holling (*1973*) introduced the concept of 'resilience' into ecological studies, in which he stressed that natural systems have a capacity to absorb environmental and climate changes without dramatically altering. But resilience has its limitations, and as the changes reach a critical limit, the system then changes and adapts to another condition.

Change in paradigms

The climatologist Wallace S. Broecker already warned in the 1970s of an "*inevitable global warming*" (*Broecker 1975*), and the oceanographer John Imbrie of the possibility that the use of fossil fuels would push our planet into a "*super-interglacial age, unlike anything experienced in the last million years*" (*Imbrie, Imbrie 1979.185*).

The global warming scenario became increasingly popular after the first assessment report on the climate system and its estimated changes in the future which was published in 1990 by the Intergovernmental Panel on Climate Change (IPCC) at the UN. The substitution of the rapid global cooling paradigm with the paradigm on global warming was based on new proxy data on the correlation between past gas concentrations in the atmosphere and climate changes in ice-core and deep-water paleoclimate archives, the use of climate models such as the atmospheric and oceanic general circulation model (GCM), and the rise of global temperatures in the last century (*Chambers, Brain 2002; Alley* et al. *2003*). In the fourth assessment report, which comprised progress reports by three different working groups (the second group focused on the environmental impact and human adaptability to climate change) it was stated that the increasing greenhouse gas emissions since 1750 were the result of human activities. Carbon dioxide (CO_2) and methane (CH_4) concentrations are higher now than at any time in the past 650 000 years. The same applies to nitrous oxide (N_2O) concentrations in the past 16 000 years (*Bernstein* et al. *2008; Parry* et al. *2007*). The documented increase in carbon dioxide and methane concentration levels in the time span between 6000 and 3000 BC could be connected with the beginning of agriculture and deforestation in Europe and to rice cultivation, rice fields and irrigation systems in India and China (*Ruddiman 2003*).

Concerns due to the human influence on current global warming and the rapid reinforcement of assessments on the frequency, rapidity and volume of climate changes in the past have encouraged a series of reflections on past environmental disasters and the human response to them. In this context, the catastrophic approach and the collapse concepts as single-cause interpretative hypotheses became increasingly popular. These hypotheses linked sudden cooling and droughts in the past with the collapse of ancient civilisations: the Akkadian Empire in Mesopotamia, the Old Kingdom in Egypt, the pre-Columbian American civilisations, the Mayan and Moche civilisations in Mesoamerica and South America, as well as the Norse culture in Greenland (*Arneborg* et al. *1999; Cullen* et al. *2000; Gill 2000; deMenocal, 2001; Van Buren 2001; Hassan 2001; Hodell* et al. *2001; 2005; Williams 2002; Haug* et al. *2003; Stanley* et al. *2003; Dillehay* et al. *2004; Fagan 2004; Diamond 2005; Rodning 2010*). Jared Diamond (*2005.3, 6, 20*) was the only one of these authors who cautioned on the complexity of the processes and the often ignored fact that these past shifts in civilisation (*e.g.*, population decline and/or reduction of political, economic and social complexity on a larger scale over a long period) were not necessarily real ecological collapses, but collapses induced by unsustainable subsistence strategies, poor natural resource management, and the degradation of ecosystems.

The concept of adaptive strategies

Collapse is seen as the most radical adaptation strategy of past societies to climate change (*Tainter 2000a.332*). Colin Renfrew (*1979a; 1979b*) has defined collapse with the help of system theory and catastrophe theory as an allactic type of cultural change defined by two development trajectories, the anastrophic and the catastrophic. Anastrophe denotes the rise in organisational complexity and centralisation, as well as the emergence of new bureaucratic and other authoritative structures, resulting in an increase in the use of economic resources. Catastrophe denotes the fall of centralised and socially structured complex societies and their regressive transformation into fragmentary and dissociated chiefdoms and tribal communities. In both trajectories, the bifurcation point presents key elements; these are division points in which a system takes its own trajectory, which is always limited by old systemic political, economic, technological postulates and values. Bifurcation points are also destabilisation points, where even the smallest internal and/or external causes (climate change, political and economic shifts, war, and migration) can effect huge, although gradual, changes. Collapse is therefore a transformation trajectory that can take centuries and leads back to less structured and poorly connected tribal communities. Renfrew predicted that in marginal areas, some old social structures survived and triggered the process of renewed transformation into complex and centralised communities.

Additionally, Joseph A. Tainter (*1988*) defined the collapse of complex prehistoric and historical societies as a political process in which a society displays a rapid, *i.e.* in a few decades, loss of an established level of socio-political complexity, whereby a society either collapses or enters into a new development cycle. Similarly to Renfrew, he anticipated that this process is connected to the economic effect of marginal returns and the operation of social elites, which in the short term may facilitate a successful adaptation to the changed natural environment by means of transformed economic strategies and the intensive use of natural resources. Next, due to erroneous economic policies and the overdevelopment of social structures, the process causes social collapse (*Tainter 2006a*). Tainter based his ideas on James G. Miller's (*1978*) general theory of living systems that are organised into interactive sub-systems, on their interaction, influence and attitude to the environment. The premise underlying this theory is that nature presents a continuum of complex life action organised into various patterns that are repeated at all system levels. Nevertheless, Tainter (*2006b*) noted a key difference between the two theories. The relationship of environmental conditions to human sustainability is indirect and subtle. The relationship is mediated by human capacities in problem solving. Sustainability is not the achievement of stasis; it is not a passive consequence of having fewer humans consuming more limited resources: one must work at sustainability. The challenges to sustainability that any society (or other institution) might confront are, for practical purposes, endless in number and infinite in variety. This being so, sustainability is a matter of problem solving, an activity so commonplace that we perform it with little reflection. Rarely does science address the issue of problem solving, or its long-term consequences.

Complexity, according to Tainter (*200b*), is therefore an economic category and a basic problem-solving tool. Complexity is generally understood to refer to such things as the size of a society, the number and distinctiveness of its parts, the variety of specialised social roles that it incorporates, the number of distinct social personalities present, and the variety of mechanisms for organising these into a coherent, functioning whole (*Tainter 2006b.92;*

1988. 23). We define sustainability as maintaining, or fostering the development of systemic contexts that produce goods, services and amenities that people need or value at an acceptable cost for as long as they are needed or valued (*Allen, Tainter, Hockstra 2003.26*).

According to the diminishing return and marginal productivity theories introduced by the neo-classical school of economics, problems can only be addressed successfully within a given time. Namely, the cost of problem management can eventually reach a point where continual investments in complexity will not be correspondingly profitable. Higher input costs usually result in lower profits. When they reach marginal productivity, any further investment in complexity contributes less to general productivity than the previous investment. After an extended period of diminishing returns, problem solving becomes ineffective and sustainability unstable, and societies become vulnerable. Problem-solving trajectories can continue for decades, generations or centuries; the results are: collapse, adaptation and recovery with a lower level of complexity, the maintenance of sustainability with increased levels of complexity and the exploitation of alternative resources. Sustainable development is therefore the ability of a society to maintain a continuing action of political and social structures, their hierarchy and permanent accessibility to economic resources (*Tainter 2006b. 92; 2014.202*). Tainter cited the collapse of the Akkadian Empire, the fall of the Roman Empire and Mayan civilisation on the one hand, and the recovery of the Byzantine Empire and colonial Europe on the other.

The interpretative estimate of sustainability is resilience in certain conditions. Although, Timothy F. H. Allen *et al.* (*2003.26*) cautioned that it is important to distinguish sustainability from resilience. Sustainability is the capacity to continue a desired condition or process, social or ecological. Resilience is the ability of a system to adjust its configuration and functioning despite disturbance. In social systems, resilience can mean abandoning sustainability goals and the values that underlie them. Sustainability and resilience can conflict.

On the other hand, Fikret Berkes *et al.* (*2003.2, 6*) obscured the distinction between sustainability and resilience. They described sustainability as a dynamic process and the adaptive capacity of societies to adjust to any given climate and environmental condition. At the same time, sustainability is the protective capacity of ecosystems to support social and economic systems. They linked resilience to the capacity to adapt to changes in terms of growth and renewal cycles.

As already stated, the concept of resilience was introduced to ecology by Holling in the early 1980s. He later connected resilience with the adaptive cycle (*Holling 1986*) and with the hierarchy of social-ecological systems, and termed this 'panarchy' (*Holling, Gunderson 2000; Holling 2001; Holling, Gunderson, Ludwig 2002.5*)[1]. He conceptualised it as the continuum of hierarchical cross-scale dynamics and the intertwined set of adaptive and renewal cycles that define the sustainability of social-ecological systems (*Holling 2001.396; Gunderson* et al. *2002*). In other words, panarchy is a hierarchical structure in which systems of nature and humans, as well as combined human-nature systems and social-ecological systems are interlinked in unending adaptive cycles of growth, accumulation, restructuring, and renewal (*Gunderson* et al. *1995; Folke* et al. *1998*). The size of this structure in social contexts ranges from a household to an empire.

Panarchy is the recurrent adaptive cycle of four phases of processes and events. The first phase, the 'r' phase, is associated with exploitation, fast migration to uninhabited or sparsely inhabited areas, rapid population growth, new technologies, and subsistence strategies. The second, the 'K' phase, is associated with a static period, mismanagement, and increasing rigidity. The third, the 'Ω' phase, is the period of creative destruction and chaotic problem solving, the abandonment of economic resources, collapse and migrations. The fourth and final phase, the 'α' phase, is a period of reorganisation and renewal (*Gunderson* et al. *2002; Berkes* et al. *2003; Walker, Salt 2006.163; Folke 2006; Scheffer 2009; Aimers, Iannone 2014*). Due to sudden, unpredicted and long-term events and processes formed outside these cycles, especially in the adaptive phase, the total collapse of panarchy and permanent disruption of the continuum of system functions are possible. Holling (*2001.399*) linked the collapse to long-term and catastrophic events.

1 Panarchy is coined from two words, pan-hierarchy, and denotes the correlation between change and sustainability, between the predictable and unpredictable. Crawford S. Holling, Lance H. Gunderson and and Donald Ludwig (*2002.5*) combined the name of the Greek god Pan (change and unpredictability) and the term hierarchy to denominate structures that maintain the system and allow for progress. In should be stated that philosophers have used the term since 1591. Panarchy is also included in system theory as the opposite of hierarchy.

Panarchy is therefore a model of the reorganisation of hierarchical structures into dynamic adaptive entities, sensitive to even small disruptions in the transition from the growth phase to the 'omega' collapse and reorganisation phase, as well as in the transition from the 'alpha' phase of fast growth. Special emphasis is placed on the importance of inter-level dynamics and interactions that lead from revolt to creative destruction and to the activation of memory. This directs both reorganisation and renewal. Memory is the accumulated experience and history of the system, providing context and sources for renewal, recombination, innovation, novelty and self-organisation following disruption (*Holling 2001; Gunderson* et al. *2002.16*). In other words, social memory refers to the long-term communal understanding of the dynamics of environmental change and the transmission of the pertinent experience, as used, for example, in the context of climate change (*McIntosh 2000.24*). Panarchy is therefore both creative and conservative, maintaining the dynamic balance between rapid changes and traditions on the one hand, and interactive inter-level dynamics on the other. The system is maintained and advanced simultaneously (*Holling 2001*). Resilience is therefore the ability to constantly reorganise existing social structures, hierarchies and economic practices and to start the growth cycle again and again. In other words, resilience is the ability to maintain sustainable development (*Smit, Wandel 2006*).

Historical geographers and paleoecologists have placed collapse in scenarios of trajectories of vulnerability and environment-culture interactions. They maintain that the collapse of past civilisations is the direct consequence of climate change, and refer to various economic-development and population models based on the evolution paradigm of a gradual, continuous and unilineal growth of past societies. At first, highly vulnerable Mesolithic hunter-gatherers and Neolithic farmers were placed in the trajectory of vulnerability. These are followed by less vulnerable complex and centralised as well as highly productive and stable agrarian-urban societies, although these societies may again become vulnerable in overpopulated areas and in areas where the exploitation of natural resources is uncontrolled. In the first group, the collapse of the whole cultural-demographic system is the only response to climate events. Only the second group has integrated adaptation practices, and it is connected to the beginning of the agricultural revolution at the end of the 18th century (*Messerli* et al. *2000*). In the context of complex environment-culture interactions, four different responses of past societies to climate and environmental changes are presented (*Coombes, Barber 2005*). The first response is the total collapse of population in remote areas due to the loss of the means of subsistence, the rapid decline of the economy, and shifts below the subsistence level. The second response is partial decline in population in remote areas due to the food supply being above the subsistence level. In the third, climate and environmental changes set off technological progress and changes in food production which support new social-economic developments and the formation of new levels of social complexity. This scenario is based on a model of economic development by Ester Boserup (*1965; 1988*) according to which past societies were forced to reform and update their subsistence practices due to population growth and limited natural resources (intensive use and/or loss of subsistence resources due to climate anomalies). The fourth response proposed a general collapse of social structures in the main regions as well as in remote areas. This is based on the scenario of cascade collapse in self-organising systems of complex past societies, which includes key concepts such as fractals and self-organised criticality used in theoretical physics. In our case, this is simply the repeated pattern of critical events in a natural setting, in politics, the economy, and social relations (*Brunk 2002*). Any of these can cause the gradual collapse of a social system. Therefore, Paul Combes and Keith Barber (*2005. 309*) estimated that a general collapse of a self-organising system can be the direct consequence of any type of critical event. They agree that the collapse of Mesopotamian and Mesoamerican civilisations were caused by rapid climate change and the subsequent global cooling periods and droughts.

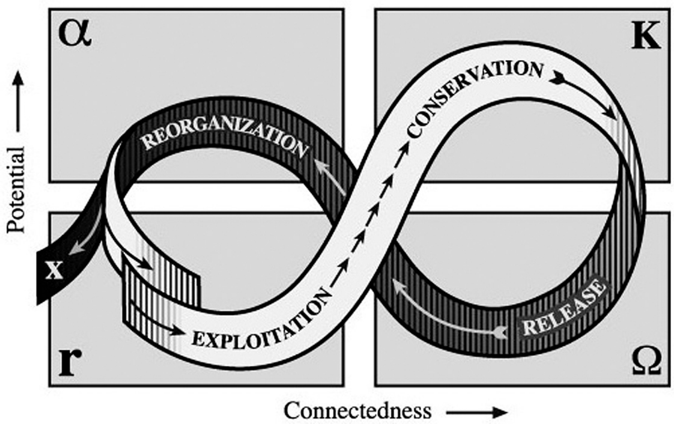

Fig. 2. Holling's continuum of adaptive cycles (after* Holling, Gunderson 2002.Fig. 2–1*).

RCC and collapses or adaptions of prehistoric cultures

The main focus in paleoclimatology and prehistoric archaeology was on the first cooling period and the 8.2 climate event, as well as on paleoclimatic records in the Eastern Mediterranean and western part of the Near East, southern Balkans, and on the Apennine Peninsula (*Rohling, Pälike 2005; Rohling* et al. *2009; Pross* et al. *2009; Dormoy* et al. *2009; Peyron* et al. *2011; Tubi, Dayan 2013; Magny* et al. *2013; Magny, Combourieu Nebout 2013; Francke* et al. *2013; Siani* et al. *2013*). The event was dated from Greenland ice cores to 8300 +10/–40 and 8140 +50/–10 calBP (*Rasmussen* et al. *2014*).

Two scenarios were proposed for the early Neolithic evolution in the Near East and Europe in correlation with the 8.2 BP climate event. The first states that rapid cooling events and droughts caused a cultural, economic, and population collapse, the abandonment of settlements in the Levant, south-western Anatolia (Catalhüyük) and on Cyprus, as well as the migration of farmers and herders into Southeast Europe (*Clare* et al. *2008; Weninger* et al. *2009; 2014; Özdoğan 2014*). The second scenario suggested that the abandonment of settlements and a gap in population density were minor and documented at only a few (4 to 83) Neolithic sites. Farmers and herders developed new social and subsistence adaptation strategies and did not migrate to distant locations in Southeast Europe (*Flohr* et al. *2015*; see also *Budja 2007*). Both scenarios are based on a significant number of archaeological sites and radiocarbon dates. The first includes 42 sites and 735 radiocarbon dates (*Weninger* et al. *2014*), and the second includes 83 sites and 3397 radiocarbon dates (*Flohr* et al. *2015*).

Similarly, Bond's fifth, 5.9 IRD event is connected to the cultural, economic, and population collapse of the first farming communities (early Neolithic Linear Pottery Culture) in Central and Western Europe (*Shennan, Edinborough 2007*) on the one hand. On the other, the resilience and adaptive cycles theory revealed that RCC did not have an immediate and catastrophic impact. Climate change was only one of the destabilising elements. Periods of drought and changed precipitation cycles therefore coincide with population decline and changed settlement patterns (reduction in settlement size and smaller number of houses). Periods with high rainfall coincide with population growth. Periods of peak climate oscillations (5140/30 and 5090/80 denBC) in which dry periods alternate with abnormally wet periods and periods of unusually high temperatures (5106/05 denBC) are connected to the construction of defensive walls around settlements, social conflict and violence in eastern regions, while in western regions the greatest population density can be observed in periods of high rainfall after 5098 denBC. Cultural shifts and population collapse happened only after the documented climate anomalies (*Gronenborn* et al. *2014*).

Mayewski's RCC periods of 6000–5200 and 3000–2930 calBP were suggested to correlate with the collapse of Copper and Bronze Age cultures (the abandonment of Troy VIIb9) in Southeast Europe and parts of Anatolia (*Weninger 2009.48–49*). In contrast, the end of the Bronze Age culture in Ireland is radiocarbon dated after the RCC period and correlates to economic and social collapse caused by a shift to new technologies, namely, iron metallurgy and the formation of new economies and social networks (*Armit* et al. *2014*).

In Mesopotamia, these RCC periods are connected with the loss of monsoon rains, to droughts and cooling events. The first RCC period affected the collapse of Uruk culture in Mesopotamia, and two centuries later, the end of the Jemdet Nasr period (*Brooks 2006; 2011; 2013*). In the central Sahara, an evident decline in the herding economy and transhumance lifestyle occurred. The population structure disintegrated, since the number of sites above latitude 23°N was significantly reduced; population densities remained high only at oases (*di Lernia 2002; Vernet, Faure 2000*).

In Central China, along the Yellow River and in Inner Mongolia, these RCC periods are associated with a set of rapid and strong cooling periods and changes in the East-Asian monsoon cycle, as well as the collapse of farmer-herder cultures such as Liangzhu, Shijiahe, Shangdong Longshan, and Laohushan (*Zhang* et al. *2000; Wu, Liu 2004; Xiao* et al. *2004*).

Recently, attempts to conceptualise the archaeology of climate change can be observed on the theoretical level. These are based on the well-known premise that climate and environmental changes were not the only changes faced by past societies and can therefore not be used as a default to explain their collapse. Great emphasis is placed on regional ecological variability and the economic, social, and emotional responses of past societies. These are recognised in changed subsistence strategies and the formation of ritual landscapes or loci (*van de Noort*

2011a; 2011b). In contrast, Toby Pillatt (*2012*) suggests a research and interpretative retreat from climate and society. In his opinion, the key elements are weather, landscape, and social memory. He recognises weather as a material condition of the landscape, and landscape as a material manifestation of human-environment relations. Social memory is seen as a way of bridging the long-term processes of climate change and the immediate decisions made by people in the past in response to the weather. This functioned as the conceptual and symbolic basis that enabled the transfer of environmental behaviour from generation to generation. Actions at a particular point in history are dependent on perceptions of the environment as they are filtered through the collective knowledge of past experiences stored as social memory. The link with the resilience model described above is evident.

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First salt making in Europe: an overview from Neolithic times

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ABSTRACT – *This paper deals with the origin of salt production and discusses different approaches ranging from technology, ethnoarchaeology and paleoenvironmental studies to chemical analyses. Starting from the current research on the Neolithic exploitation of salt in Europe, we examine the types and nature of the salt resources (sea water, salt springs, soil or rock), the diversity of archaeological evidence of forms of salt working. We also scrutinize the types of production for these early forms of salt exploitation, with or without the use of crudely fired clay vessels (briquetage). Finally, we contextualise the socio-economic dimensions and highlight both the diversity of salt products and their characteristics, which go well beyond dietary roles.*

IZVLEČEK – *V članku predstavljamo izvor pridobivanja soli in razpravljamo o različnih pristopih, ki sežejo od tehnologije, etnoarheologije, paleookoljskih študij in vse do kemijskih analiz. Razpravo začnemo s sodobnimi raziskavami o izkoriščanju soli v neolitiku v Evropi, preiščemo različne tipe in naravo izvorov soli (morska voda, slani izviri, tla ali kamnine) ter raznolikost arheoloških podatkov o pridobivanju in predelavi soli. Temeljito smo preiskali tipe produkcije za prvotne oblike pridobivanja soli, kjer je za nekatere značilna tudi uporaba grobih keramičnih posod ('briquetage'). Na koncu poskušamo kontekstualizirati družbeno-ekonomske vplive predelave soli in osvetliti izdelke iz soli, tako glede na njihovo raznolikost kot tudi glede na njihove značilnosti, saj imajo več kot le prehrambno vlogo.*

KEY WORDS – *salt production; Neolithic; Europe; archaeological evidence*

Introduction

If, today, salt is an ordinary good, a practically inexhaustible substance, both alimentary and industrial, this was not the case in countless pre-industrial societies. It is at least since the Neolithic that European agropastoral societies have sought to extract it from its natural sources, or more precisely since the 6th millennium BC. Nowadays, we probably associate the exploitation of salt with coastal salt marshes; yet a great share of production still comes from artificially heating brine or simply from the extraction of rock salt. While regular table salt, or sodium chloride, seems an inexhaustible natural commodity, neither its geographic distribution, nor its physical forms are uniform. Salt is found in either solid (rocks, outcrops, earths, sands, plants) or liquid form (sea or spring waters, bodily fluids). Furthermore, it is present in highly variable concentrations, ranging from a few grams in blood or urine, to almost 200g/l in certain salt springs or enclosed seas, attaining an average of 30g/l in oceanic waters. It crystallises at concentrations of around 330g/l of water.

Faced with this disparity in concentration and distribution, humanity has resorted to a wide assortment of extraction techniques. Nonetheless, apart from the exploitation of rock salt, extraction most often consists, in some cases after the lixiviation of a salty solid, of processing a liquid by subjecting it to a natural (solar salt) or artificial (ignigenous salt) evaporation process, until crystallisation is achieved (Fig. 1). The grained salt obtained can be then used as such or packaged as hard blocks in standardised shapes

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and weights (*Gouletquer, Weller 2015*), which can be preserved in this form or readily transported and traded over long distances.

The diversity of methods observed around the world seem intimately linked to environmental contexts and types of saliferous resources exploited; it also mirrors the quality of the product being sought (type of salts, salted ashes, grained salt, or salt blocks), and to the specificities of demand and of social context (*Gouletquer* et al. *1994*).

The issue of origins

Although archaeologists and scholars have examined ancient mines or the abundant debris of fired clay (briquetage) produced since the Iron Age up to the 18th century, research on the origins of salt exploitation harking back to the Early Neolithic has not yet even commenced. At first glance, one can easily understand why, in the absence of the very object of research, the issue of salt exploitation in the prehistoric period has remained poorly addressed. However, while nothing has remained of the product, the archaeological realities around salt exploitation have been ascertained in the field with the help of various types of evidence, which inform us non-vicariously of the techniques employed (catchments, pottery or charcoal accumulations), or more indirectly of their impact on the environment, territorial organisation, or circulation of goods.

Besides the discussion on the archaeological remains themselves, it is the general question of the function of salt which emerges. Indeed, how can we explain the appearance of this new exploitation of the natural environment? What were the reasons for which simple occasional collecting from a furrowed rock or from the edge of a salt spring were no longer sufficient for these early Neolithic salt-producing communities, which now set about separating salt from its natural support (water, rocks, soils or plants) and, as such, to produce a hard, transportable and shaped product? While many researchers have turned to biology and psychology to answer this question, others have looked for answers in ethnographic investigations. Indeed, does the biological hypotheses, according to which salt was an essential nutritional element within the new Neolithic alimentary diet, suffices to explain its exploitation?

In order to confront nutritionists' hypotheses with the archaeological realities, and to characterise the production of salt and its socio-economic implications, it is necessary to develop a multidisciplinary approach and to multiply the ethnographic, historical, environmental, archaeometric, and experimental observations. Therefore, it was necessary to make use of several methods that, in conjunction, can shed light on the archaeological realities. By illustrating our goal with various case studies from across Europe, we seek to tackle the issue of salt exploitation from the methodological standpoints of the different approaches that may be invoked, and of the elements that so far seem diagnostic. Also, we will see how the study of known or newly brought to light vestiges and of relative archaeological contexts can allow a reconsideration of the diversity of functions performed by salt, in which alimentation is not necessary the cornerstone.

Archaeological evidence

Whether or not one adheres to the biological argument, pre-historians have only recently considered other possible functions of salt in these early agricultural societies. Yet we know that the scarcity of exploitable natural resources meant that at specific times in history, salt played an important economic and social role, prior to being used for multiple day-to-day applications of which we are now fully aware (preservative, adjuvant for the dairy industry, tanning agent, metallurgy of precious metals, dye-fix-

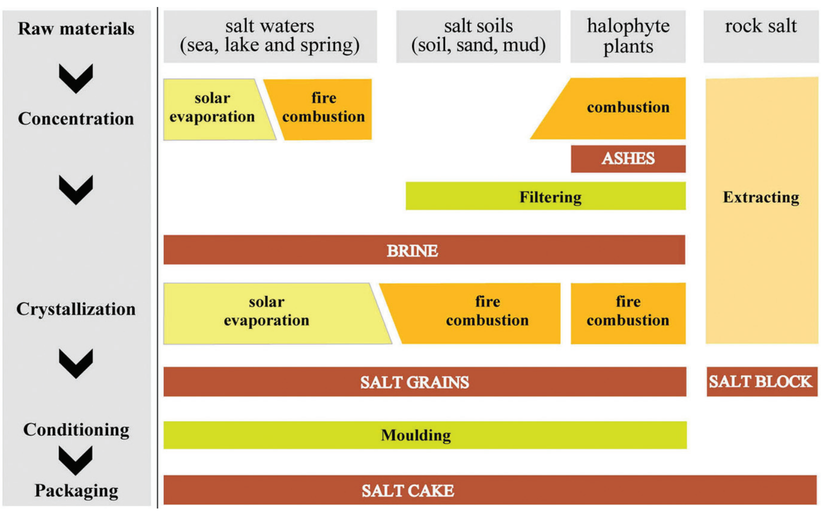

Fig. 1. General principles of salt production (drawing O. Weller).

ing, medication ...). Moreover, it has long been held that – just as with the production techniques of the Iron Age – salt exploitation was dependent only on the identification of vestiges or fired-clay structures collectively known as briquetage. Today, the variety of forms of exploitation recognised by both ethnography and archaeology (*Alexianu* et al. *2011; Brigand, Weller 2015; Cassen* et al. *2008; Cassen, Weller 2013; Fíguls, Weller 2007; Harding 2013; Hocquet* et al. *2001; Monah* et al. *2007; Nikolov, Bacvarov 2012; Pétrequin* et al. *2001; Weller 2002; Weller* et al. *2008*) allows us to return to the issue of the function of certain material remains, and to advance new hypotheses on the place of this irreplaceable substance also in the domestic, technical and socio-economic spheres.

The directly observable material remains of prehistoric salt production can sometimes be found in the form of wooden catchments or fittings, but most often it consists of accumulations of fired clay (or briquetage) comprising debris from ancient heating installations and fragments of salt pans, accumulations of charcoal and ashes, unearthed structures, or, in the case of rock salt exploitation, of stone tools. We should note that no such remains are known at present from salt marshes, and that such inventions should be dated to the Roman period (not the Middle Ages), as shown by the excavations from Vigo in Portugal (*Castro Carrera 2008*).

Spring catchment and fittings

The construction of catchment systems and retention basins around salt springs is difficult to ascertain in cases of heavy erosion or rapid sedimentation. However, French examples such as the spring at Moriez in the Alps, where researchers unearthed the frame of an ancient lathwork dated to around 5600 BC (*Morin* et al. *2008*), or that from Grozon in the Jura, where salt workers had erected a genuine horseshoe-shaped bulwark to protect the spring (*Pétrequin* et al. *2001*), suggest that the search for such structures should continue.

Many wooden structures have been observed during rehabilitation works or in capturing salt springs, but their dating is often problematic (missing elements, brief remarks at the moment of discovery *etc.*). The most eloquent are the 19 oak trunks at Fontaines Salées in Saint-Père-sous-Vézelay (Yonne, France)

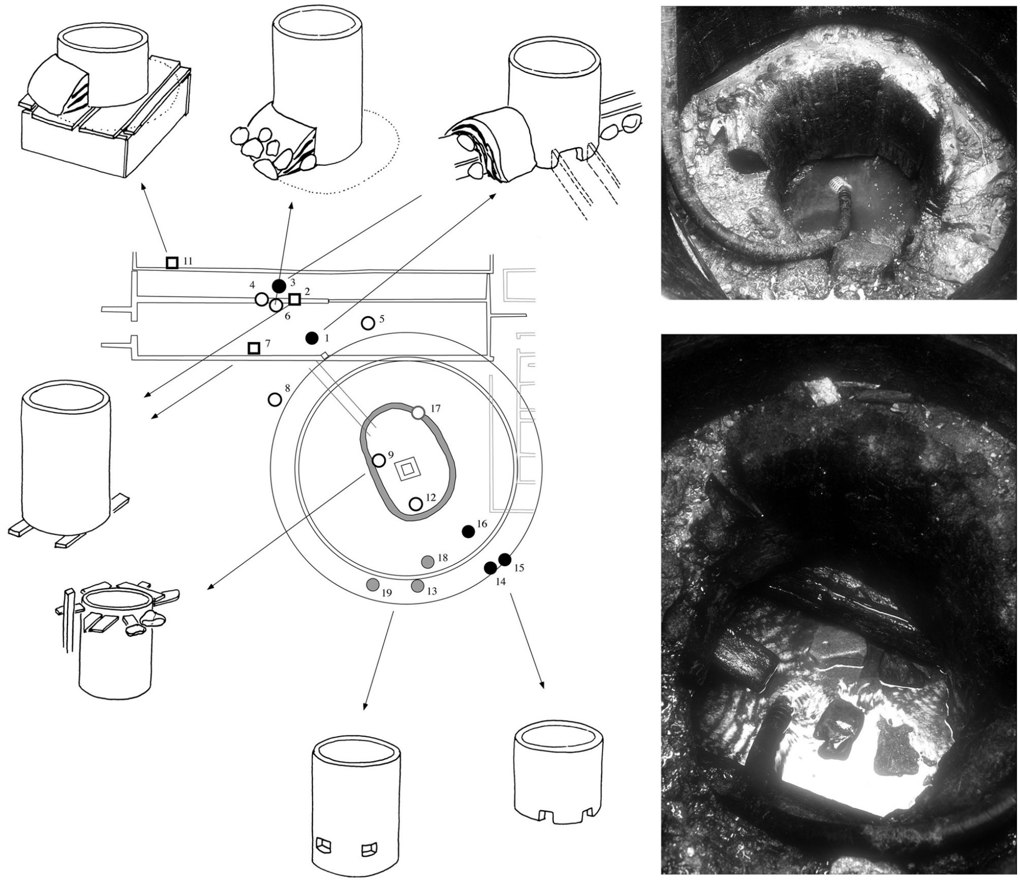

Fig. 2. Neolithic wooden wells from FontainesSalées, Saint-Père-sous-Vézelay, Yonne, France (drawing P. Pétrequin and photos O. Weller)

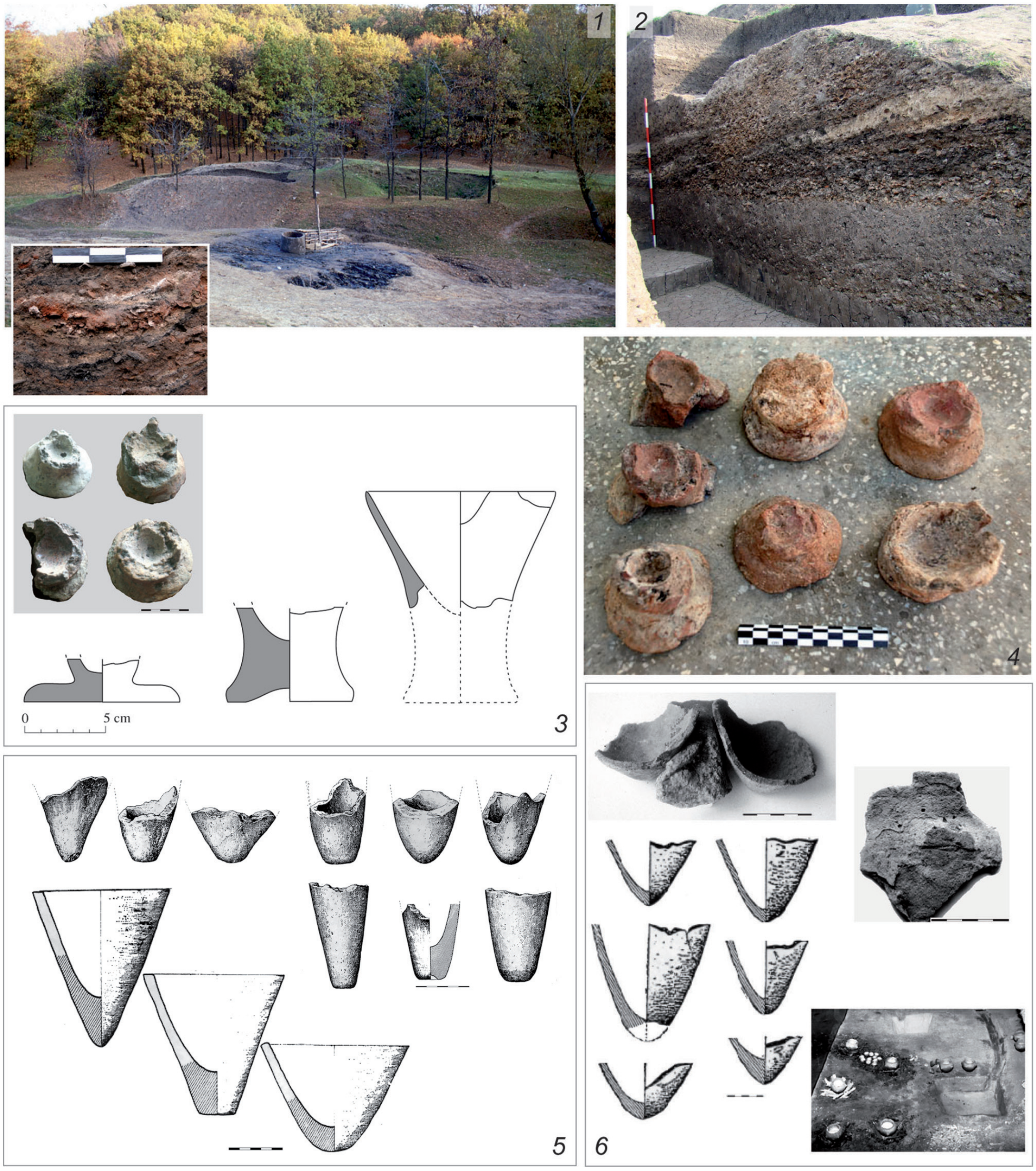

Fig. 3. Evidences of salt exploitation in Central and Eastern Europe between the 5th and 4th millenniums BC: 1 accumulation of firewood places from the Early Neolithic at Lunca-Poiana Slatinei (Romania); 2 succession of archaeological layers extremely rich in pottery from the Precucuteni and Cucuteni cultures at Tolici-Hălăbutoaia (Romania); 3, 4 briquetage from the Cucuteni culture (Lunca and Tolici, Romania); 5 briquetage from the Vinča culture (Tuzla, Bosnia and Herzegovina); 6 briquetage with an element of a stove, corroded ceramic and model from Barycz VII (Poland) (photos and drawings O. Weller except drawings 5 (**Benac 1978*****) and 6 (*****Jodłowski 1977*****).***

(Fig. 2), formerly attributed to the onset of the Iron Age, but nowadays re-examined and dated dendrochronologically to the 23rd century BC, that is to say contemporary with the Bell Beaker culture (*Bernard* et al. *2008*).

Fired-clay vessels (or briquetage)

The exploitation of salt during the Neolithic and Chalcolithic seems in some cases to have been particularly dynamic on account of the considerable quantities of fragments of ceramic moulds accumulated around certain salt springs, sometimes associated with combustion structures or residues (*Weller 2002a*). This is the case with salt springs in Little Poland, Bosnia-Herzegovina, Romanian Moldavia (Fig. 3.2–6), or, more recently, Bulgaria (Fig. 4), all exploited by means of fired-clay moulds during the middle of the 5th millennium BC. Around 3000 BC, on the Atlantic coast, the enclosures around the Poitevin Marsh in France produced a very large quan-

Fig. 4. Chalcolithic salt moulds accumulation in Solnitsata, Provadija, Bulgaria (photos O. Weller).

tity of briquetage (*Ard, Weller 2012*), while in Germany the salt springs from Halle furnish the first fired-clay moulds.

This specific ceramic ware, in all instances abundant and clearly distinct from domestic pottery, display the same general characteristics: clay of local provenance, numerous inclusions, sometimes accounting for a quite large share of the paste; abundant tempering (sand, plant matter, grog, *etc.*); open shape; crude fashioning from a clay lump or from coils, finger or plant imprints, traces of wickerwork on the base; the edges and outer walls are unfinished, but the interior is neatly smoothed. Fragmentation is nonetheless significant, due to deliberate breaking to extract salt cakes. Across different producing sites, the bases of the vessels, sometimes complete, constitute in some cases the majority of the ceramic harvest; the edges adhere to the salt cakes and can serve to trace distribution paths.

These salt moulds thus serve both as casts and crystallisers. If for some their function still remains at the level of hypothesis, such as the flat-based pots in the Carnac Mounds or the Cycladic 'frying pans' (*Cassen* et al. *2012*), we were able to confirm this for others through a series of chemical analyses based on an assay of chlorine (*Weller 2002a; Weller, Ard forthcoming*). Basically, the levels of chlorine in the salt moulds are 2 to 20 times higher than in domestic contexts. These values are greater still, as the rainwater infiltration is lower.

The use of ceramic moulds of practically identical shape and volume by each cultural group attests to the commitment to producing and packaging salt according to a predefined shape, in compact form and easy to transport. The production was not aimed at simply producing salt, but salt cakes of a standardised quality, size and weight. The salt cake thus becomes a social object, an identity marker of the producers. In this form, it will circulate conveniently, be divided without losing its use value, and be stored for many years.

It was in Central and Eastern Europe, in the Chalcolithic, specifically the middle of the 5th millennium BC, that the crystallisation and moulding of salt in vessels of fired clay developed (*Weller 2012*). The appearance of these chemical techniques alongside the first copper objects, similarly cast, reveals a new conception of the properties of matter, of making visible and malleable a substance that is initially invisible. Nonetheless, with the exception of a fragment of a furnace discovered in Little Poland, there are no known genuine combustion structures from this era, and Western Europe had to await the Bronze Age to produce such structures, and then the Iron Age for salt-works in the true meaning of the word.

Charcoal accumulations

For a long time, it was thought that in the absence of fired clay (ceramics, supports, accessories and fragments of furnaces or kilns), we could not demonstrate the exploitation of salt. However, other techniques of salt production do not necessitate the use of fired clay or kilns. The ethnographic studies conducted in New Guinea (*Weller* et al. *1996; Pétrequin* et al. *2001*) and the archaeological work in eastern France (Franche-Comté) revealed methods of exploitation that do not require the use of fired clay or furnaces, but other techniques involving the use of vegetal matter as raw material and which produce considerable quantities of charcoal and ash (*Pétrequin, Weller 2008*). Finding ancient accumulations of charcoal around salt springs or littoral marshes thus becomes a new challenge for the research on ancient forms of salt production.

To have an image, if not for the production of salt, at least for the approximate volume of charcoal and waste on the river basin, the case of Salins-les-Bains (Jura) is exemplary: the charcoal from the production of salt during the 18th century is visible in the alluvial deposits to a distance of up to 10km downstream from the salt-works; with respect to the charcoal produced during the Neolithic dated to around 3000 BC, it is still present in large quantities in the clogged meanders some 7km downstream from the salt exploitation area.

Over thousands of years, a massive quantity of fuel was consumed in order to produce salt. For instance, the longitudinal section of the Grozon basin (Jura) across 400m has revealed carbonaceous layers over 7m thick, dated to between the early 4th millennium BC and the Roman period (Fig. 5). The end of the exploitation during the Gallo-Roman era is marked by the entrenchment of the Romans around the salt springs (or the coastal marshes, respectively) presumably to put a halt to Gallic exploitation and to sell their own Mediterranean salt.

As for the paleoenvironmental approaches, palynologic and anthracologic analyses represent the most promising research directions. By studying the sedimentary sequences spread across the depressions near or immediately downstream of the salt exploitation points, it is possible to trace the management of the fuel and the history of deforesting (*Dufraisse, Gauthier 2002*). It is particularly possible to differentiate deforesting for agricultural purposes (where the pollen of certain crops are well represented) and deforestation associated only with the exploitation of salt, in the case of a spring located at that moment outside the area of permanent settlement and cultivated land. But the accuracy of the pollen charts is directly affected by the quality of the preserved pollen and the recording of the chronological sequences; this means that marshes and depressions with wet environments should be the prime targets of core boring and sample collecting.

With respect to exploitation techniques, in the light of our own ethnographic study in Indonesian New Guinea, following a re-examination of the ancient sources (mainly Pliny, Tacitus and Varro) and a series of life-size experiments (*Pétrequin, Weller 2008*), the extraction of salt without recipients is today better known for the Middle Neolithic of Eastern France, and similarly proved for the Early Neolithic of Romania (Fig. 3.1) (*Weller, Dumitroaia 2005; Weller* et al. *2008*). They involve the direct spillage of saline water over an incandescent pyre covered by a vegetal blanket meant to slow down the falling water. The saline water is concentrated along the running path, just as in the techniques used in the gradual-evaporation salt factories of 16th–19th century Germany and eastern France; in contact with the incandescent embers, the salt crystallises instantly. The small salt crystals are subsequently recovered from the ash and cinders, and packaged in a form that still eludes us.

The exploitation structures and buildings

Always built in the immediate proximity and view of the salt springs, according to the ethnographic data, the buildings and structures for exploitation are still largely unknown. Examples include the salt-works from Little Poland (pits, ditches and foundation post holes at the site of Barycz VII), the pits at Provadija in Bulgaria (*Nikolov 2008*), or the Neolithic pits at Sandun (Loire-Atlantique, France), rightly interpreted (*Cassen* et al. *2008*) as pits for filtering salty sand and collecting brine, just like the pre-Hispanic vestiges in Mexico (Fig. 6) (*Liot 2000*), or the Gallic sites in northern France (*Edeine 1970*). In the case of Sandun, therefore, the real function of the site which has thus far been considered a marsh-edge settlement that must be reconsidered. Serge Cassen also invites us to readdress the function of the different structures unearthed in several sites presumed to be settlements in France and Italy, or the so-called Cultura de los silos de Baja Andalucía, which he proposes should be reinterpreted as places for producing salt primarily by washing very fine sand: intriguing hypotheses which must be tested in the field.

The first Neolithic mining tools

The only salt mountain in Western Europe is found in Cardona in Catalonia, about 80km northwest of Barcelona. This varicoloured Muntanya de Sal reaches more than 140m in height. Despite the abundant research on Neolithic burials in the region in the early 20th century and the discovery of stone tools around the salt outcrops, the hypothesis of Neolithic extraction was hastily abandoned after the 1930s. Thereafter, this region in the foothills of the Pyrenees remained outside the large-scale research endeavours and archaeological campaign concentrated along the Catalan shoreline.

However, starting from a series of chance finds collected since the start of the last century by prospectors, farmers or workers from this salt mine, we were able to study several hundred stone tools comprising hammers, reused axes, pestles, and bush-hammers (*Weller 2002b; Fíguls* et al. *2013*). Their technological analysis showed that Neolithic workers used mining tools associated with the exploitation of rock salt in the form of an open quarry (Fig. 7). The salt blocks extracted from the outcrops were transported to the surrounding settlements to be transformed by mortar, and probably regularised, into blocks of salt of standard shapes and weights.

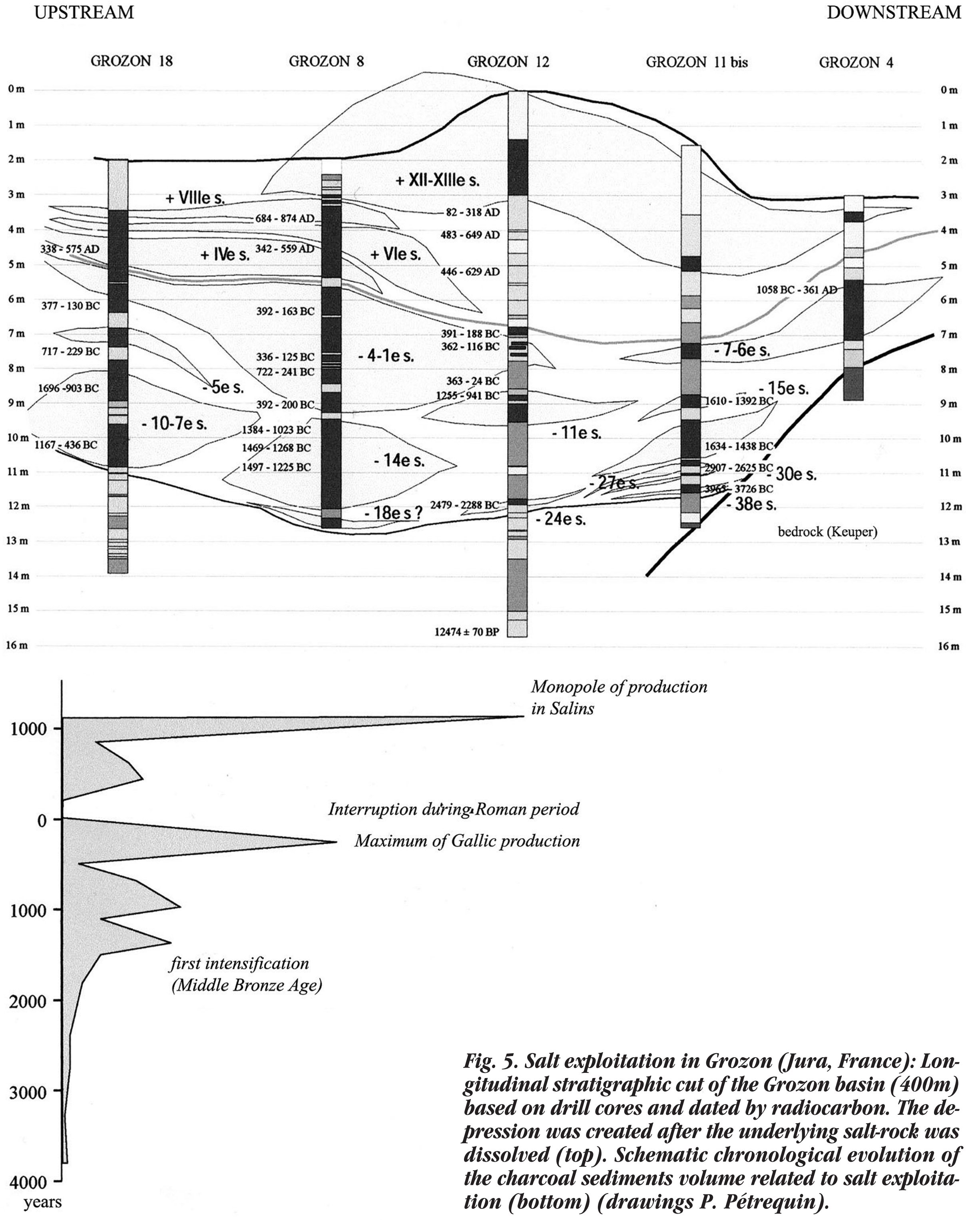

Fig. 5. Salt exploitation in Grozon (Jura, France): Longitudinal stratigraphic cut of the Grozon basin (400m) based on drill cores and dated by radiocarbon. The depression was created after the underlying salt-rock was dissolved (top). Schematic chronological evolution of the charcoal sediments volume related to salt exploitation (bottom) (drawings P. Pétrequin).

The socio-economic implications

Discerning the economic and social aftermath of the production of, and trade in, salt consists firstly of identifying, in the vicinity of the salt springs, the specific concentrations of settlements, and therefore of the population (*Brigand, Weller 2013; 2015*), or of valuables in the form of deposits (*Harding 2013*), imported goods or spectacular graves. But this is where interpretation is most difficult, particularly since the ethnographic model of chieftain societies specific to the highlands of Indonesian New Guinea is only one among many other examples of ways in which a society can be structured. Here, there are no buried treasures, no graves of momentarily prominent individuals, simply because the forms of power are transmitted equally through the exchange and redistribution of wealth. Other ethnoarchaeological models should be tested before attempting to characterise social behaviours founded on social inequality, such as those which around the middle of the 5th millennium BC engendered the monumental tombs from the Gulf of Morbihan (France), a particularly suitable area for the exploitation of salt (*Gouletquer, Weller 2002; Cassen* et al. *2012*).

On the question of the type of organisation and a conceivable specialisation of the crystallised salt industry by Neolithic groups in northern Catalonia (*Weller, Fíguls 2013*), the great portion of tools reused and manufactured from fractured polished axes, their distribution over an area of more than 20km around the salt deposit, their low degree of technical development, and above all the plausible absence of any major fortified control settlement, all suggest open exploitation, not one reserved to a single small group of local specialists. However, the relative richness of the graves of this group in goods imported from the coast (variscite pearls from Gavà, the largest ever known, bracelets and pearls from shells, yellow flint imported from Haute-Provence) suggests salt had an elevated position within a wider regional exchange network.

We may also mention the close spatial correlation observed in Germany between salt springs and the distribution of greenstone long alpine axes, which demonstrate that salt could have played a key role in the acquisition of these rich and ceremonial objects (*Weller 2002a*). Nonetheless, the age of the exploitation of these highly saline springs remains to be established; only fired-clay remains used since the late Neolithic have been subject of studies.

In any case, throughout Western Europe during the 5th millennium BC, certain saliferous resources, whe-

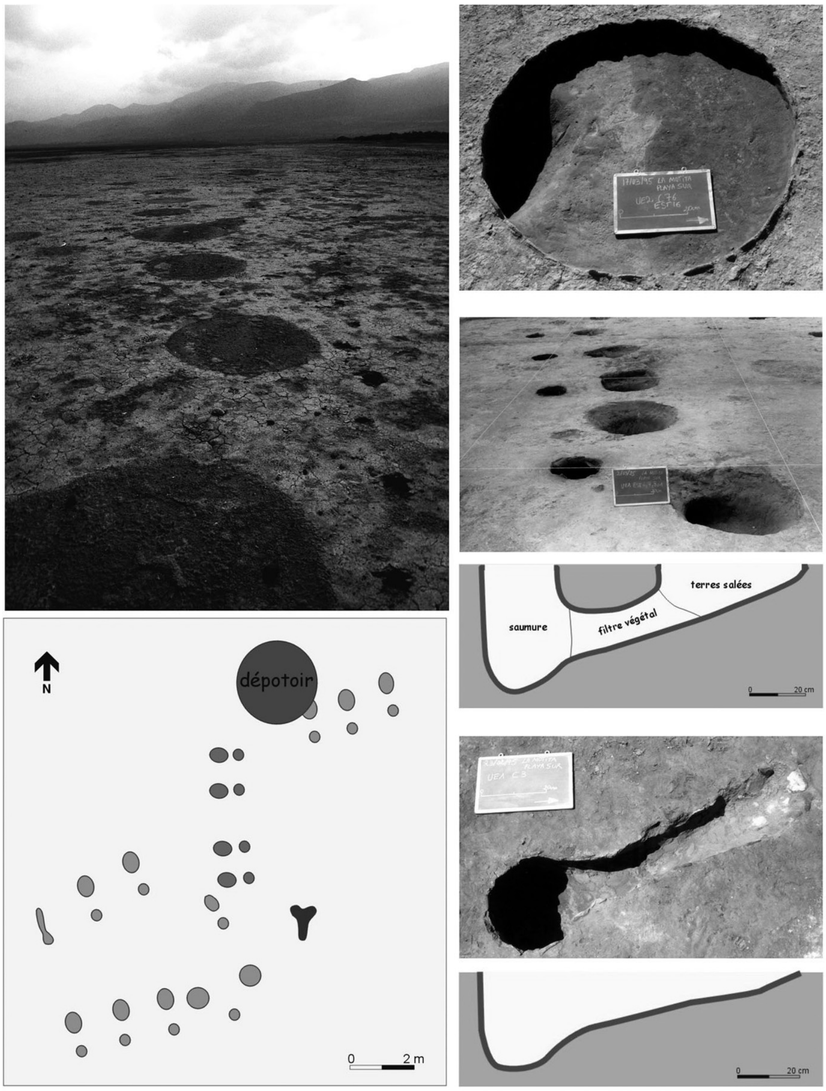

Fig. 6. Pits for leaching salty soils, with watertight facing, simple, double or multiple from the Pre-Hispanic salt production centre on the edge of the Sayula basin (Jalisco, Mexico) (photos O. Weller (left) and C. Liot (right), drawings C. Liot).

Fig. 7. Salt outcrops from the Vall Salina in Cardona (Catalonia, Spain) and mining tools for extraction (2) and shaped (3) the salt blocks (photos O. Weller).

ther inner-continental or coastal, appear to have acted as hubs capable of 'drawing' into their networks these large polished alpine axes with attached social value, while in Carpathian-Balkan Europe, the first copper and gold objects probably integrated such networks. It is thus necessary to turn decisively towards a political geography of salt.

Conclusions

Depending on the nature of the salt exploitation and the modes of occupation of territories rich in saliferous resources, this production was occasional, regular or heavily invested, and also modulated by the different uses and functions of the product. These different organisations responded to the different uses of salt, varying according to the social context, and salt most definitely did not have the same value irrespective of time and place. From this point of view, the circulation paths, the exchange pathways, and the social context were determining factors.

If the prevailing hypotheses on the function of salt during the Neolithic are primarily biological, in line with the ubiquitous adage 'salt is essential to humans', the substance further acquired other uses, more recently established: preserving foods, making dairy products, fixing dyes, hide processing, *etc.* However, the existence of idiosyncratic configurations of spatial organisation around saliferous re-

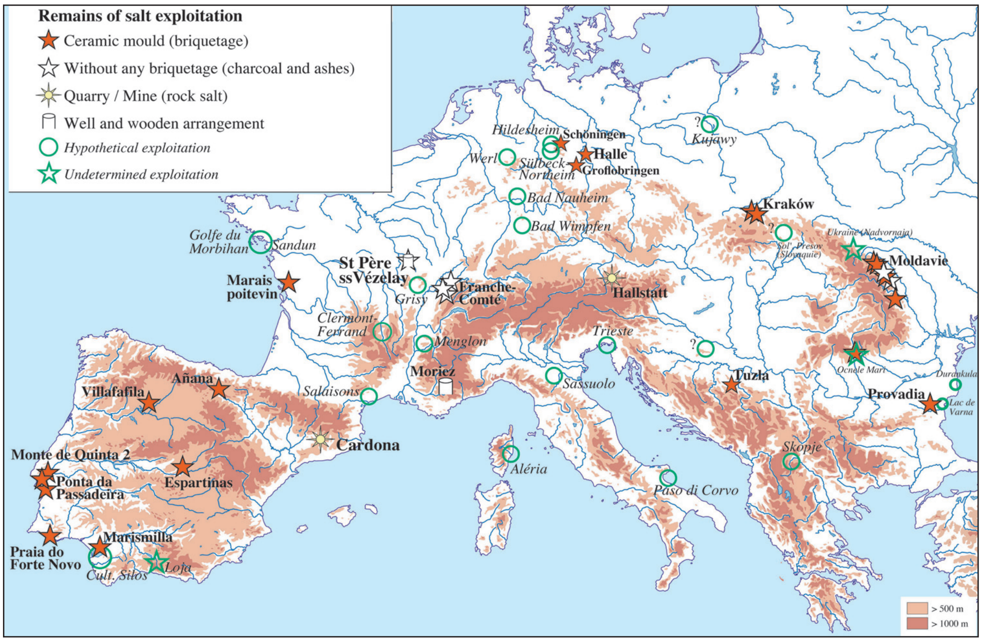

Fig. 8. An European assessment for the Neolithic and Chalcolithic periods (6000–2300 BC): the various archaeological evidences for salt production (drawing O. Weller).

sources opens the door to other hypotheses besides the strictly utilitarian or functionalist explanations so far sanctioned by pre-historians. The diversity of functions played by salt in contemporary traditional societies shows that its status cannot be reduced to that of a simple household and nutritional chemical substance, especially because during the 5th millennium BC it was the focus of a massive technical and economic investment, as evidenced by its being made into cakes in Central and South-eastern Europe.

The appearance of the first Neolithic moulds means that salt in the form of salt cakes became a standardised item, dividable, transportable and storable, or, briefly said, a socialised good, an identity marker, capable of enabling long-distance exchange networks. Besides its role in human and animal alimentation, salt could have played, in certain contexts, the role of an exchange good as a form of durable storage of a substance that is unique in terms of its qualities, of the areas suitable for its exploitation, and of its technical and economic charge.

We also notice that this intensification of exploitations of moulded salt in Central and South-eastern Europe coincides with periods of expansion of major groups such as the Lengyel (Poland), Vinča (Serbia, Croatia, Bosnia), Cucuteni (Romania), or Hamangia (Bulgaria) cultures. Salt cakes could have been one of the means by which social tensions generated by these population movements were defused. However, they were not necessarily used by all the expanding groups during this period of intensifying social relations, and were not routinely involved in all processes of social regulation. It was just one possible form of storing wealth, one of the ways of taking part in the exchange.

As for the present, we are moving towards a European-wide geography of techniques of salt production (Fig. 8), in which the technical investments, the economic and social status of this activity, and also the accompanying mental and social representations, can be pinpointed. It remains for us to define more precisely the forms of exploitation used in certain areas particularly suitable for extraction, for which only indirect evidence are available, but where the socio-economic contexts suggest remarkable production (the lagoon areas of Morbihan, the highly saline springs from Halle/ Salle and Bad Nauheim in Germany, the salt springs and saline lagoons of the Spanish interior *etc.*).

This study on an eminently soluble object is just the beginning, and future research should prioritise not only the search for undiscovered traces of exploitation (salt moulds, ceramics for boiling, filtration or storage structures, wooden catchment fittings, accumulations of ashes and charcoal, extraction implements and tools ...), but should also seek to characterise the social behaviours of the groups that manipulated this substance and the historical processes engendered by them.

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The beginnings of salt exploitation in the Carpathian Basin (6th–5th millennium BC)*

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ABSTRACT – *While there are ample data for salt exploitation in later prehistory, in the Neolithic,* i.e. *6th–5th millennium BC, archaeological data from Southern Central Europe remain scanty. The paper attempts to give an overview of Neolithic salt research in the Carpathian basin. Both the archaeological traces and the research of Neolithic salt extraction activity are rather uneven there. While the eastern half had close contacts with Transylvanian salt regions, the western part,* i.e. *Transdanubia, lacks salt sources of any kind. The obvious need for salt gave rise to the search for salt-rich areas within reach of the early LBK migration in Central Europe, and indeed, these groups had rapidly settled in three key salt regions in Western and Central Germany, as well as in Little Poland. One of the reasons for the rapid migration and long-term contacts with these zones might thus have been access to salt. In general terms, it is in many cases highly probable that some sites specialised in salt exploitation, and that certain regions served as settings for exchange networks.**

IZVLEČEK – *Kljub temu, da je na voljo množica dokazov za izrabo soli v pozni prazgodovini, je podatkov za južni del srednje Evrope v neolitiku (6. in 5. tisočletje pr. n. š.) zelo malo. V prispevku predstavljamo pregled raziskav neolitske izrabe soli v Karpatski kotlini. Tu so neenakomerni tako arheološki sledovi kot raziskave neolitske izrabe soli. Vzhodni del je imel bližnje stike s transilvanskimi ležišči soli, v zahodnem delu, Transdanubiji, pa virov soli ni. Potreba po soli je povzročila iskanje s soljo bogatih območij znotraj dosega migracij zgodnje LBK v srednji Evropi. Tako so te skupnosti hitro poselile tri ključne s soljo bogate regije v zahodni in osrednji Nemčiji, kot tudi v Mali Poljski. Eden ključnih vzrokov za hitre migracije in dolgoročne stike s temi območji je lahko bila prav sol. Zdi se, da so se v mnogih primerih posamezna najdišča specializirala za izkoriščanje soli in so nekatere regije igrale ključno vlogo v omrežjih menjave soli.*

KEY WORDS – *Neolithic salt exploitation; 6th–5th millennium long-distance networks; spread of farming; Central Europe*

Introduction

In focusing on the Neolithic, several salt regions were identified south and east of the Carpathian Ranges, above all in Bulgaria, Serbia and the Adriatic Carst (*Nikolov 2008; Gaydarska-Chapman 2007; Tasić 2000; Montagnari-Kokelj 2007*). However, this small paper attempts to give an overview of Neolithic salt research in the Carpathian Basin. Both the archaeological traces and the research of Neolithic salt extraction activity are rather uneven there. While in several cases it is highly probable that a site specialised in salt exploitation, or certain regions served as settings for exchange networks, there are hardly any archaeologically tangible finds to prove it. It is not possible to track salt exploitation with finds, especially in their find contexts, before the early 5th millennium; therefore, I begin by summarising the scarce results, starting with this period, the Carpathian Late Neolithic.

Going back in time, direct evidence from earlier Neolithic phases in the Central Carpathian Basin is still little more than hypothetical. Nevertheless, there is

* This paper is an extended version of a chapter published in *Harding, Kavruk 2013*.

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a fact that makes the acquisition of salt more than probable: salt is clearly necessary for maintaining human life, and it is even more essential when the proportion of meat and fish protein decreases and the basis of the diet turns vegetarian along with the appearance of the first domesticated plants; in other words: at the onset of the Neolithic transition (in the Carpathian Basin: 6000–5800 calBC), hunter-gatherer consumption gradually changed to a diet that was increasingly based on cereals. The Neolithic lifestyle also meant animal domestication. Sheep, goats and cattle were brought into the Carpathian Basin in an already domesticated form and it was necessary to supply them with salt. These physiological needs were, however, complemented by other reasons for having access to salt, such as the preservation of food and leather, or festive meals within the community; in other words, salt also had a social function (*Chapman, Gaydarska 2003.203*).

Thus, where there were no salt springs, salt must have been imported. It seems sensible to collect facts on settlement patterns and also parallel finds from other regions, especially salt regions in order to make a first attempt at reconstructing a possible early salt network. This network, which must have existed, may turn out to be a major key to understanding the different types of social and cultural development in the 6th and early 5th millennia BC. For this reason, it is worth trying to trace this network back to the earliest Neolithic centuries, and specifically to the Neolithic transition. Therefore, in the second part of this paper, I attempt to reconstruct a possible new salt route that may have played a role in the Neolithisation process from Transdanubia to Central Europe.

In order to avoid confusion by looking for finds that are not expected in a certain region, it is necessary to distinguish three types of activity that could have been connected with salt in the Neolithic. Firstly, it is pointless to look for finds, mainly pottery fragments, that were used for evaporating salt water anywhere else than in the immediate vicinity of salt springs. The second activity connected with salt was distributing it to salt-poor regions. In order to detect these routes, the network needs to be traced back with the help of mutual import finds or other indicators, such as local commodities and types of raw material. It is almost impossible to find out how the salt was carried; the objects may not have been vessels, but more probably, bags made of leather or textile; like salt, these are archaeologically invisible. Finally, of the third type of activity, *i.e.* the consumption of salt, there is also no direct archaeological indication. Logically, this third case should be seen in regions that have no salt springs, like the centre of the Carpathian Basin. Therefore, the present summary is an attempt to infer salt use and salt routes with the help of this tripartite approach.

Firm evidence for salt production and trade in the Late Neolithic

The technique for acquiring salt in the Neolithic may have consisted of nothing more than heating salt water in pots. More complicated techniques probably did not develop in the Carpathian Basin before the Middle or Late Bronze Age (*Harding, Kavruk 2013*).

In the Carpathian Late Neolithic, *i.e.* the first half of the 5th millennium BC, the Lengyel cultural group forms a large circle from Transdanubia expanding to the Munich Basin, Moravia and to the Malopolska area in South Eastern Poland. This latter is one of the major salt regions of Europe, and these are the first Lengyel sites with pottery that can be connected to salt production. Vessel types in the context of briquettage occur here (*Kaczanowska 2006.104–105; Fries-Knoblach 2001*). Given the well-documented cultural connection within the Lengyel circle in Central Europe, it is a probable that communities living in the huge Lengyel-Stichband-Moravian painted and Münchshöfen cultural area were connected with Malopolska salt production, and that the Lengyel communities there also traded in salt. Other commodities revealing the existence of dense cultural and exchange contacts are assumed by tracking the routes of finds such as marble arm rings (*Zápotocká 1984*). Similarly, in the East Carpathian salt area, ceramic finds associated with brine evaporation occur in the Cucuteni A culture (*Cavruc, Chiricescu 2006.202*).

The contacts, as seen from the archaeological point of view, were traditionally seen as having gone through Moravia. In the past two decades, however, it has become clear that another route can be reconstructed in addition to the Moravian valleys. Nándor Kalicz was able to range a series of Lengyel sites along the North East Hungarian Mountains that are linked to related sites and find complexes in East Slovakia (*Vizdal 1973; Kalicz 1994; Šiška 1995; Pavúk 1986; 1991*). In this way, the Lengyel settlement area of Western Hungary expanded through Eastern Slovakia (*Pavúk 2007; Vizdal 1986; Raczky* et al. *1994*) reaching the Wieliczka salt region around

Kraków (*Jodłowski 1977; 2000; Kamienska-Kozłowski 1990; Nowak 2007; 2009.90–93, 152, 692–693*).

By contrast, the cultural history of the east Hungarian Alföld groups further south does not seem connected with the Malopolska area. Much more probably, however, they had successful long-distance networks with the East Carpathian mountainous region and acquired salt from the springs there (*Sófalvi 2005.22–23*). The existing links and the exchange between late Neolithic Alföld cultural groups and their contemporary Transylvanian neighbours is proven by the many shared features and imported finds in the archaeological research of the past few decades (*Kalicz-Raczky 1984; Paul 1992; Ignat 1998; Ignat* et al. *2000 a; 2000b*).

Perhaps it was mainly these intensive and long-lasting contacts that were responsible for the fact that the distribution of middle and late Neolithic Alföld settlements remained stable. The late LBK regional groups, as well as the following Tisza-Herpály-Csőszhalom groups, remained within the original LBK distribution area and did not expand or move during the 6th–5th millenium BC. This stable, immobile geographic extension may not be independent of social changes, as some settlements became more central and important to such an extent that the first tell sites started to grow along with the formation of a settlement hierarchy consisting of significant centres in terms of economy, distribution, demography and rituals (*Chapman 1989.38–39; 1994; 1997.140–148; Bánffy 2002*). The settlement hierarchy in the East Hungarian Alföld seems to have formed parallel to the birth of a stratified society (*Raczky, Anders 2009; Bánffy 2007a; 2007b; Chapman, Siklósi 2010; Kalicz* et al. *2011*). I certainly do not mean that the contacts with Transylvania, and within this, access to salt springs there, were the only or even the main reason for the specific later cultural and social development of the later Neolithic Alföld culture. The processes may have been connected with the fact that within the Carpathian basin that was both ecologically and culturally divided southeast-northwest, Eastern Hungary rather belonged to the fringes of the Balkan Neolithic circle. Still, contacts and a dense exchange network formed part of this link. To what extent the salt trade was a reason or a result is a hard question to answer at the moment; nevertheless, salt seems to have played an important role in this development.

Access to salt at the beginnings of food production

As mentioned above, in the centuries before the late Neolithic Lengyel, Tisza and related cultures, direct archaeological evidence for the use of salt is lacking. However, there are some apparent links and contact zones that can be associated with salt. Areas within the Carpathian Basin reveal quite different possibilities, which lead us to infer different strategies to access salt.

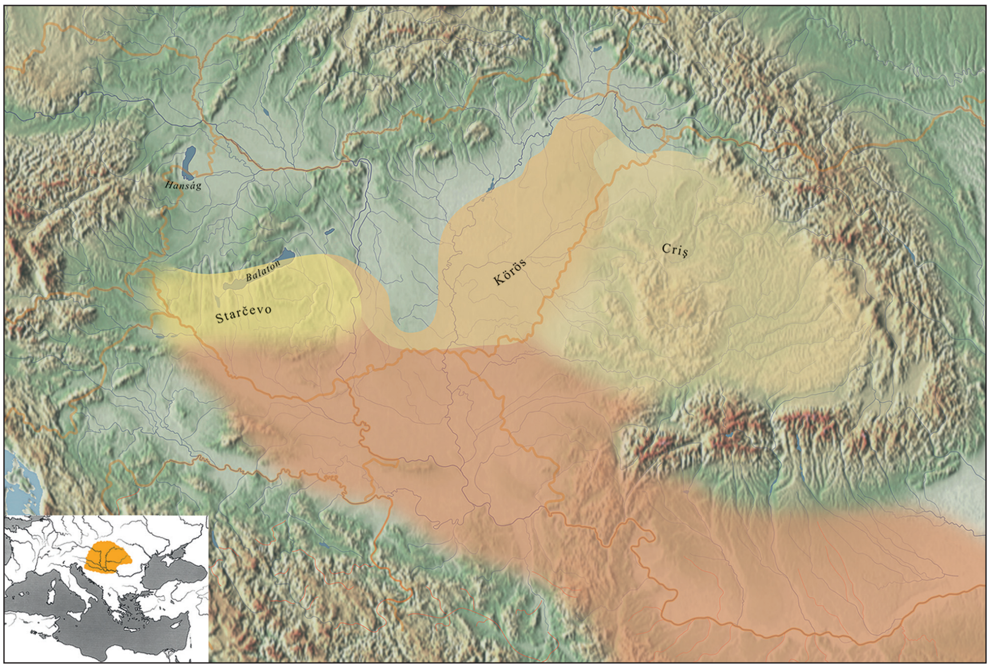

Fig. 1. Map showing early Neolithic cultural formations in the Carpathian Basin (E. Bánffy).

At the northern periphery of a large South East European cultural circle, three groups formed, the Starčevo, Körös, and Criş cultures, which occupy roughly the southern half of the whole basin (Fig. 1). Among many similarities, there are also some basic differences between the westwards expanding Starčevo and the Körös-Criş in the eastern half, *i.e.* the Alföld, and in Transylvania. The settlement pattern, the subsistence strategy and the long-range networks are the consequences of many environmental and cultural factors (*Bánffy, Sümegi 2011; 2012*), which in several ways differ in the three groups, although essential differences occur between the Starčevo culture in the western basin and the other two in the east. The various possibilities for access to salt may partially account for these differences.

The earlier research connected to the East Carpathian area focused mainly on tracking down salt springs and only secondarily on sorting out the historical and prehistoric periods during which they may have been in use. We now have firm evidence that salt waters were first exploited in the Eastern Carpathians, *i.e.* the almost 200 salt springs found in Romania and Moldavia, already at around 6000 BC (*Weller-Dumitroaia 2005; Weller* et al. *2011; Danu* et al. *2010; Munteanu* et al. *2007*). Pottery fragments of the Criş culture occur at Poiana la Lunca, Calabatoaia and Cucuieti within the context of or nearby salt springs (*Cavruc, Chiricescu 2006.195*). Some early Neolithic sites are known in Transylvania and in Moldavia which reflect a specifically close correlation with salt springs (*Ursulescu 1984.41; 2001*). Furthermore, some Neolithic sites have been investigated farther west in Transylvania, which, according to the excavators, may have been linked to salt (*Ignat 1983; 2001; Lazarovic, Lazarovici 2012*); one such settlement is Gura Baciului near Cluj.

The site Gura Baciului is located in the immediate vicinity of salt springs (*Maxim 1999; Lazarovici, Maxim 1995*). According to the excavators, the stratified site was inhabited for the whole period of the early Neolithic Criş culture with broad contacts within the East Carpathian Early Neolithic (*Lazarovici, Maxim 1995.346–352*). The radiocarbon sequence supports the long sequence of some 800 years (*Spataro 2008.92*). The site was thought to have played a role in salt exploitation and trade by the authors and also by Nenad Tasić (*2000.40*).

The latest sites connected to salt lie still farther west, at the Romanian-Hungarian border. The publication of Méhtelek and the Méhtelek group itself is seen as part of a whole regional sub-group within the Körös-Criş culture. According to a hypothesis based on the network of flint raw material, this group is connected with both the Körös and the Criş formations (*Mester, Rácz 2010*), but according to Nándor Kalicz, the Méhtelek group is mainly linked with the Körös tradition (*Kalicz 2011; 2012*). Kalicz explains his inference with the following arguments: "*During the past few decades … a series of Körös settlements have been discovered in County Bihar in Romania: the finds from these sites along the Ér, the Szamos and their tributaries have much in common with the Körös material from the Alföld. Farther to the north in the Szilágyság, sites yielding mixed assemblages of the southern Alföld Körös culture and the Méhtelek group can be noted, especially regarding figurines. The formerly enigmatic gap between Méhtelek and the southern Alföld Körös culture was thus bridged and it seems likely that the Körös communities advancing northward followed the Ér Valley and simply avoided the sandy region of the Nyírség … Three routes leading to the Upper Tisza region used by Körös communities could thus be distinguished: one along the Tisza, the other along the Ér Valley (in the Partium), and a third in the Szamos Valley. These routes clarify various aspects of cultural contacts*" (*Kalicz 2011.45*). As a consequence, the contact routes, bolstered by several finds, including the special flat 'slab' figurines so typical of the Méhtelek group, can be reconstructed convincingly between the East Hungarian and West Romanian Körös-Criş and the Transylvanian, Moldavian salt regions. Kalicz himself presumed that – apart from participating and forging the long-distance network of obsidian – salt may have played a crucial role within these contacts by considering it possible that the Méhtelek communities participated in salt trading (*Kalicz 2012.121*). Within Körös culture itself, a certain funnel-shaped, coarse pottery type (see *Ibrány-Nagyerdő, Kalicz 2012.Fig. 3.10*) is sometimes assumed to have been used for evaporating salt water (*Fries, Knoblach 2001.Taf. 6.1*). Similar types from later periods are considered indeed to have been used for briquettage. However, once it was presumed that it was pointless to seek pottery used for evaporation anywhere else than in the vicinity of salt springs where it must have happened, the argument about the importation of such pots from salt-poor regions in connection with salt exploitation is not useful.

The Méhtelek group, regarding its Körös cultural roots and its geographical position near Criş settlements, may have had a mediating role. According to recent information, it did not overlap with the period of the earliest Alföld LBK (in contrast with Pavúk's (*2004.74*) view), and the Transylvanian connections of the Szatmár group (early LBK) are quite uncertain. The implication that the salt network may have been continuous is only supported by the reviving connections between the Northern Alföld and Transylvania, when late LBK territorial groups formed, *i.e.* in the last centuries of the 6th millennium BC. The Esztár group in the eastern part of the Alföld, with its painted pottery, which is closely related to the Lumea Noua group in Western Transylvania, needs to be mentioned here (*Goldman, Szénászky 1994; Gligor 2009*).

After outlining possible long-distance connections between Transylvanian salt and the East Hungarian Körös culture, we need to draw attention to a newly researched and described branch, *i.e.* a Western expansion of the Körös culture in Southern Hungary: what resources might they have had for supplying themselves with salt? A small group of people of the Körös culture settled far away in a very limited area in the Danube-Tisza interfluve. In recent years, a dense settlement 'niche' has been detected along the left Danube bank: 50 Körös sites, all located in the floodplain (*Bánffy 2012; 2013; Kustár 2012*). The traces of the probably small settlements are – with two exceptions – known from surveys. It can be assumed that the large number of sites does not reflect a dense population; much more probably, some semi-mobile communities can be envisioned that left the traces of several sites through generations. The state of research of Körös settlements along the Danube has been summarised, but how these people could have been supplied with the necessary salt and the absence of sources for it are not touched upon.

According to maps showing the main salt resources in Europe (*Saile 2000; 2008; Tasić 2000; Fries, Knoblach 2001*), the central part of the Carpathian Basin (*i.e.* today's Hungary) is a region entirely lacking salt springs. The only chance to obtain salt in this area may have been to find and exploit some minor alkali ponds in the lowlands, *e.g.*, those close to Szarvas in the Alföld, but these were barely enough to meet even one village community's needs (Fig. 2). These ponds occur even more rarely close to the narrow settlement area along the Danube. The summarising publication (*Bánffy 2013*) contains some reflections on possible reasons for the Körös groups' abandoning the Danube. These implications involve climate conditions. In the marshy oxbows of the Danube, even a slight rise in the water level flooded the small arable islets or made them impossible to access.

Fig. 2. Alkali ponds in the Danube Tisza Interfluve region (R. Balázs).

Social problems were perhaps equally important: these groups were left in an isolated position with no apparent contacts to the west, where Transdanubian Starčevo groups were located; the contacts were even less possible to the more or less unsettled area to the north and south, and a sandy area to the east. After struggling to establish life on the Danube for some generations, this 'enclave' probably had good reason to return to the Alföld by the same routes by which they had arrived, *i.e.* the stream valleys crossing the sand back to the valleys of the Tisza and Körös rivers, where they could re-join their fellow communities. In this way, they may have chosen the advantages not only of the bigger community identity and wider kinship, but also easier access to commodities essential to life, like salt.

Access to salt played an important role in the Neolithic transition in Western Hungary and Central Europe

It is a fact that the Western Carpathian Basin, Transdanubia, is a region expressly poor in salt. Even the nearest salt deposits at Tuzla in Bosnia (*Tasić 2000*) are located far away, in a region with which the first Transdanubian farmers (the people of the Starčevo culture) did not have particularly close contacts. It has also become an accepted fact that the first farmers of Central Europe, *i.e.* the people of the LBK culture, formed in the Western part of the Carpathian basin, which was also the last transformation in Europe that happened with the major participation of 'colonisers' (*Zvelebil 2001*). A third fact is that these communities rapidly spread to today's Austria, Moravia and South Germany along the Danube, to the Halle/Saale region to the North and towards Southern Poland, probably both through Moravia and Germany. After some 150 years, a second wave of expansion followed. As a result, vast regions in Europe, from the Paris Basin to Ukraine turned to the LBK type of sedentary farming (Fig. 3). Let me scrutinise this process with regard to salt.

The first farmers of North Balkan origin (the people of the Starčevo culture), crossed the Drava River and occupied a wooded, hilly landscape until they reached the marshy Balaton region, where they must have met and mingled with local foragers (*Bánffy 2000; 2004; Bánffy* et al. *2007*). The expansion to the heartland of Central Europe was so rapid that it left no typological differences in the archaeological record (*Quitta 1960; Lüning 1988*) and – at least until the beginnings of the expansion – successive phases cannot be pinpointed with radiocarbon dates (*Gläser 1991; Lenneis, Stadler and Windl 1996; Lüning 2005.60–62. Bánffy, Oross 2010*). Flint provenance studies also bolster the idea of migration and direct contact (*Lenneis, Lüning 2001; Biró 2001; 2002; 2005; Pavlu, Vokolek 1992; Ramminger 2011*).

The LBK migration from Transdanubia was also recently confirmed by non-archaeological methods. New publications on ancient DNA analyses and also stable isotope analyses (*Smrčka* et al. *2008; Zvelebil, Pettitt 2008; Nehlich* et al. *2009; Szécsényi Nagy* et al. *2012; 2014; 2015; Haak* et al. *2005; 2010; Ammerman* et al. *2006*) have shed new light on the nature and tempo of the first farmers' mass migration. To date, the notion that population groups moved from Transdanubia towards the inner parts of Central Europe can be seen as a thesis supported by both archaeological and data from natural sciences.

In spite of growing knowledge about this dynamic mobility, the reasons are still not obvious. Several hypotheses have been suggested. One explanation based on a possible rapid population growth (based on examples from the Near East) proved mistaken (*Petrasch 2001; Bánffy, Oross 2010*). The archaeological evidence and the radiocarbon data indicate that the expansion from Transdanubia to Bavaria (*Lüning 2005; Nadler 2010*) and to the Saale River (*Kaufmann 1983*) took no longer than 50 to 100 years, or two to four generations at around 5600–5500 calBC. An explanation for this rapid expansion invoking population growth would call for a totally implausible 5.4% growth over four generations, whereas early LBK population growth could not have been more than 0.1% (a figure based on a consideration of infant and child mortality rates, generally bad health conditions and accidents). This low population growth correlates with the number of LBK settlements in Germany. Jörg Petrasch concludes that demographic growth was not the reason behind the rapid LBK expansion (*Petrasch 2001.21*).

In his discussion of the possible causes triggering migration, David Anthony offers several explanations. For me, his most important observation was that negative 'push' and positive 'pull' forces can be distinguished among the causes leading to migration (*Anthony 1990.898*). Consequently, one type of the causes that may trigger migration arises in the area of origin: overpopulation, climate deterioration, draught, famine and

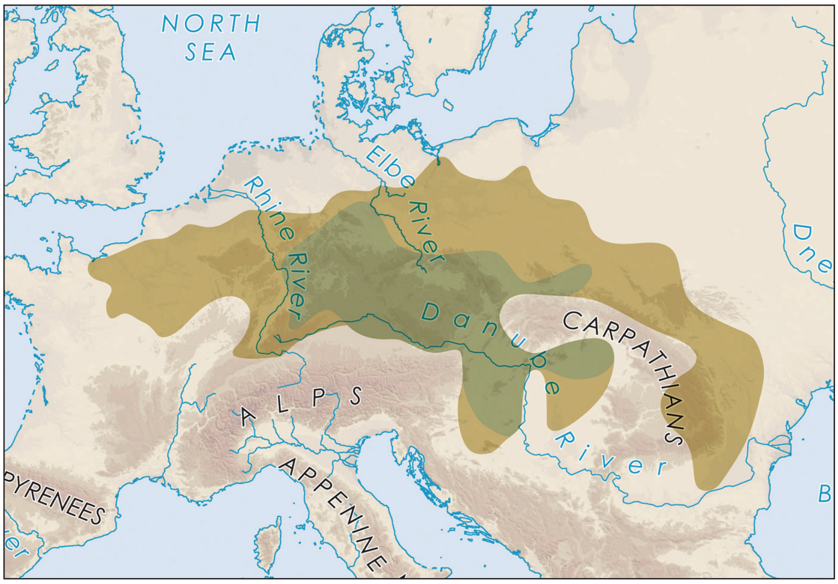

Fig. 3. Map showing the distribution of the first farmers (LBK culture) in Central Europe (S. Hansen, modified by E. Bánffy).

social tension. Several examples can be quoted for the other type, from history: one common feature of these is preliminary contact with the target area. Low population density, fertile soil, proximity to water, good climate, and possible raw material sources are all factors that make a particular new area attractive. If exchange relations can also be created and maintained, an area of this type usually attracts settlers.

'Push' forces in terms of overpopulation or climatic deterioration can be rejected in the case of the LBK expansion. In contrast, there is evidence for almost all of the 'pull' forces. The main emphasis is on the incentives that triggered the largest expansion in prehistory. Obviously, there were several different causes as "*migration is a social strategy*" (*Anthony 1997.22*).

An important new discovery provides the basis for implications for a better understanding of the LBK migration. Today, there is evidence for pre-Neolithic, hunter-gatherer communication and contact networks between Transdanubia and the regions to the northwest (*Mateiciucová 2004; 2008*). The survival of this subsistence strategy into the Neolithic becomes clear once the local Mesolithic population is supposed to have mingled with the first Balkan farmers in the Balaton region (*Bánffy 2004*). The causes for the migration may have ranged from the need for a common area where groups living at great distances from each other could exchange various commodities and ideas, to the need to pool efforts in order to perform certain tasks and to cultivate marriage alliances and other kinship ties. The presence of Szentgál radiolarite in Moravia and in Southern Germany, and of Danubian shells also in Germany are modest indications of these networks in the archaeological records.

In order to justify the idea that contact networks may (also) explain the Central European expansion, let us quote some arguments for similar prehistoric phenomena. As Curtis Runnels and Tjeerd van Andels have noted, the Neolithic expansion, together with its innovations, can be conceptualised as a trade commodity forming the basis of wealth, whose acquisition was probably an attractive option (*Runnels, van Andel 1988.102*). In Germany, the earlier, western contact network of the Mesolithic population was also exploited by the early farmers, and judging from the growing intensity of the contacts they probably improved and expanded it. A. Zimmermann has convincingly argued that the central places (ger. *Zentrale Orte*), whose emergence can hardly be dissociated from the settlement concentrations (ger *Siedlungskammer*) (*Zimmermann 1995.61–62*), were the main settings for down-the-line exchanges. The communal identity, the remarkably uniform material culture and the most likely similar social structure remained virtually unchanged for many generations. This would suggest that the contact networks remained in place until the time of the later LBK groups in Transdanubia and the Flomborn phase in Germany, perhaps even for some time afterwards. What remains to be explored is the mutual interest that formed the basis of these contact relations. What commodities were traded between these distant groups?

As to the Transdanubian formative LBK groups moving northwest and keeping contact with the 'pioneer' inhabitants for a longer time, archaeologists have already detected, researched and published many kinds of similarities in settlement types, architecture, burial habits, object types *etc.*, documenting contact between different regions. However, these are necessarily restricted to artefacts and other finds made from non-perishables, such as various stone raw materials and clay. To date, there are three types of find that verify the existence of the earliest LBK route: pottery, unified clay figurines and the Transdanubian red radiolarite. These occur over distances of more than 1000km, *e.g.*, in the Wetterau region in West-Central Germany. The clay objects reflect a strong tradition, but the raw material of flint must be seen as proof of a direct long-distance network. Yet there is still no firm reason to see these objects as targets of exchange; much more possibly, they simply moved along with people.

Obviously, the actual range of traded commodities must have been much wider and no doubt included wares that leave no trace in the archaeological record, such as furs, textiles, leather and leather articles, as well as foodstuffs. I shall not discuss other possible aspects of these contacts, such as the possible exchange of craftsmen, of individuals introducing a new technology to a particular region, or marriage and kinship ties between groups. These contacts will perhaps never be detected unless many more LBK cemeteries containing well-preserved skeletal remains are uncovered.

The idea that the commodity received for the wares of Transdanubian origin may also have been salt first occurred to me when I visited the Bad Nauheim-Niedermörlen settlement. The finds from this site reflect surprisingly strong ties with Transdanubia. The Mörlener Bucht area is rich in haematite deposits (*Schade, Lindig and Schwitalla 1999.28*), although, this red paint is not rare enough to form the basis of exchange relations. However, Bad Nauheim lies in an area rich in salt. Excavations conducted near Niedermörlen have brought to light the unique remains of extended Celtic and Roman salt mining. Wendelin Leidinger, who studied the remains of Neolithic salt production in more northerly regions (Westphalia), has described in detail how the earliest Linear Pottery communities in that area produced salt by evaporation and cleaning (*Leidinger 1983; 1996; 1997*). Therefore, it is possible that this easily transportable and valuable commodity, essential to the diet, for food preservation and for feeding livestock, was exchanged for commodities from the Danube valley. Tasić considered salt and access to salt deposits, regions having soils rich in salt and briny waters, as major factors in the Neolithisation of the Balkans (*Tasić 2000*). Trade in salt played an important role in the cultural development of this region and also in its contacts with other areas in later periods (*Monah 1991*).

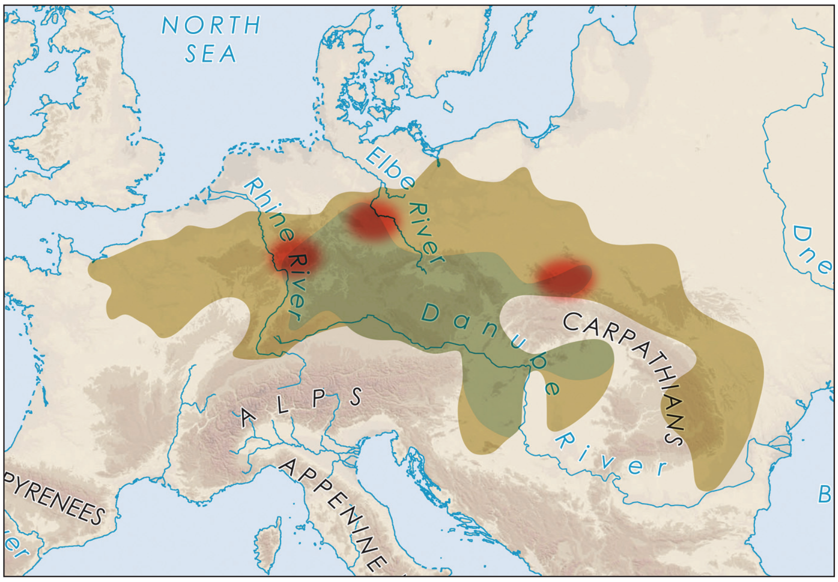

Fig. 4. Map showing the distribution of the first farmers (LBK culture) in Central Europe, with the three major salt regions marked (S. Hansen, adapted by E. Bánffy).

A negative statement must be made to complete the picture of migration connected with salt. The Hallstatt region near Salzburg in the Salzkammergut, the Upper Austrian region, is rich in salt deposits and lies closer to Transdanubia, so why would the first farmers have gone so far for salt? The distribution of the Early Neolithic sites indicates that the migration route led along the north bank of the Danube, through the Munich Basin to southwest Germany. In spite of the shorter distance, the salt mines in Hallstatt were unknown in the 6th millennium BC and can thus be rejected as a possible source. This fact probably enhanced the importance of the Wetterau and Aldenhoven regions.

One of its archaeological indicators is the striking typological resemblance between the find assemblages from Transdanubia and Germany; another is the use of Szentgál radiolarite in some areas, although good quality stone was available locally (*Gehlen, Zimmermann 2012.669*); yet a third is the long-term contact relations spanning not one, but several generations, as reflected in the finds from Bad Nauheim.

It may become possible to detect salt (sodium chloride) in the matrix of pots that were used for salt production (*Horiuchi* et al. *2011*). However, in the Neolithic briquetage would only be found where salt production occurred, *i.e.* near salt springs. How salt was transported from salt-rich areas to the salt-poor central Carpathian Basin is hard to say, but, as assumed above, it was not only the salt that was perishable, but the bags or sacks that may have been used to carry it would have left no archaeological traces.

I find it more useful to consider the distribution map of the first farmers in Central Europe. In Figure 4, where the darker patch shows how far the first wave of the LBK reached, it becomes apparent that the three most distant, ending in West Germany, in the Elbe Saale region and in Malopolska, are three major salt regions. Was this pure chance?

To connect salt and the Central European migration at the onset of the Neolithic today is hardly anything more than speculation, a hypothesis. This is hardly surprising, given that it coincides with the scarcity of data on the Mesolithic-Neolithic transition and the actual process of Neolithisation itself. Future research, with new archaeological and scientific methods can test the hypothesis of the relationship between the Neolithic transition and access to salt.

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Salt exploitation in the later prehistory of the Carpathian Basin

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ABSTRACT – *Salt is a necessity for humans and animals, today as in the ancient past. The ways in which salt was produced in ancient times vary from area to area, and could use briquetage, deep mining (as at Hallstatt), or the technique specific to Transylvania, based on wooden troughs, perforated in the base. How these troughs functioned is still uncertain. In the Iron Age a different technique was employed, involving deep shafts dug down to the rock salt surface. As well as technological considerations, it is crucial to understand the social and economic importance of salt in the ancient world.*

IZVLEČEK – *Tako kot sol potrebujemo danes, so jo potrebovali ljudje in živali tudi v preteklosti. Pridobivanje soli se je v preteklosti med regijami razlikovalo. Lahko je vključevalo tehniko briketiranja, rudarjenje (kot v Halštatu) ali pa posebno tehniko, značilno za Transilvanijo, ki je temeljila na lesenih, na dnu perforiranih koritih. Še vedno ni jasno, kako so ta korita delovala. V železni dobi je bila uporabljena drugačna tehnologija. Vključevala je kopanje globokih jaškov do plasti kamene soli. Poleg poznavanja tehnologij pridobivanja soli, je potrebno tudi razumevanje družbenega in gospodarskega pomena soli v preteklosti.*

KEY WORDS – *salt; Carpathian Basin; briquetage; mining; wooden troughs*

Introduction

Common salt, sodium chloride, is widely recognised as a crucial commodity for ancient communities, just as it is for modern ones. Although in our modern world a very small proportion of the salt produced is used in the preparation and consumption of food, it is that use which we tend to think of when we speak of salt. In practice, it is for industrial purposes and road clearance in winter that most salt is used today. In the ancient past, things were very different. There were some industrial applications of salt, such as tanning, but in all likelihood by far and away the most significant application was in the storage and preservation of foodstuffs. Today, and in the recent past, even developed societies use salt for food preservation; in peasant societies, especially those without electricity and therefore refrigerators, salt is crucial for people to store cheese, vegetables, and meat. It has other uses in such communities too, for instance in therapeutic purposes for both humans and animals.

Humans and animals need a certain intake of salt in order to preserve the metabolic balance of the body; without it, serious health problems can occur. While the minimum needed for human health is relatively small (2g per adult per day is regarded as a reasonable figure), when one adds in the needs of animals, the amounts required become more substantial. Taken all in all, we can presume that in prehistory, as in early history, steps were taken to ensure the availability of salt by all communities – but especially by those who were not fortunate enough to live on or near salt sources.

This raises important archaeological questions. If salt was moved around Europe, it was a trade com-

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modity; and trade (or more accurately exchange) was an important part of the ancient economy, whether in the Bronze Age, the Iron Age, or any other period. The questions therefore include this one: can we identify not only salt production methods and places in prehistory, but also the evidence for its movement around Europe?

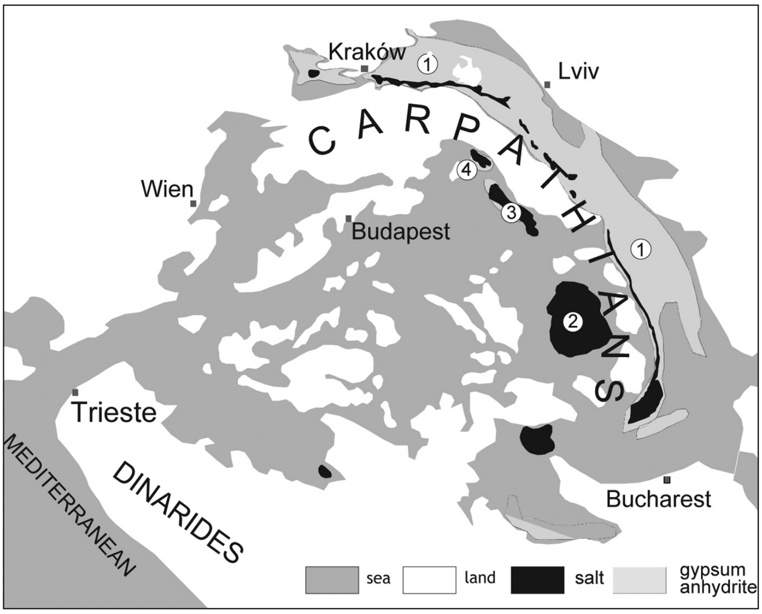

Fig. 1. Distribution of salt, gypsum and anhydrite in the central Paratethys Sea during the 'Badenian salinity crisis'. 1 Carpathian Foredeep. 2 Transylvanian Basin. 3 Transcarpathian Basin. 4 East Slovakian Basin (after **Bukowski 2013).**

There could in theory be two ways of tackling that question: one, by archaeological means, such as identifying the containers in which the salt was moved; the other by analytical means, by identifying the compositional pattern of particular salt sources. Unfortunately, neither method is currently possible, at least in the Carpathian Basin. Containers for salt have not been found from prehistoric contexts, other than the coarse pottery known as briquetage (see below); nor is it currently possible to separate salt sources analytically except within very large limits, and at present the consensus among chemists and geologists is that it will not be possible to go to the level that archaeologists would find useful, the separation of individual sources within a single region. In the analysis of common salt, the chlorine signal is so dominant that tracing impurity patterns, or isotopic variations in other elements, becomes impossible. In addition, salt is highly soluble, so it neither survives in solid form (with rare exceptions, below) nor as an element in other artefacts such as pottery or bone.

Salt in the Carpathian Basin

Many parts of the Carpathian Basin are rich in salt, which geologically speaking is an evaporite (a mineral created through the evaporation and chemical precipitation of salts contained in seawater or salt lakes). This applies particularly to areas within the Carpathian mountain ring (or just outside it, as with Moldavia,[1] Galicia or Little Poland), and especially to Transylvania. Thus many localities in eastern and northern Slovakia have salt, as do many parts of central, northern and eastern Romania. There is also salt further south, at Tuzla in Bosnia, and one should not forget the sources in the eastern Alps, most notably Hallstatt and the Dürrnberg near Hallein, though strictly speaking these do not lie in the Carpathian Basin. But they were undoubtedly significant for areas within the Basin, notably present-day Hungary, which today has no salt at all.

Salt deposits are present in four main areas (Fig. 1): the Carpathian Foredeep (from Kraków through Ukraine to Moldavia), Transylvania (the Transylvanian Basin), the Transcarpathian Basin (the Maramureş and adjacent areas of Ukraine north of the Tisza) and the East Slovakian Basin. It is primarily the latter three that concern us here.

The salt deposits of the Carpathian Basin were described recently by Krzysztof Bukowski (*Bukowski 2013*). The deposits are of Miocene age, and result from the presence of the Paratethys Sea, which covered much of central and eastern Europe, including what is today the Black Sea. The salt arose as a consequence of the 'Badenian Salinity Crisis', a major climatic and environmental change that brought about a continuous series of evaporite deposits (not only salts, but also gypsum and anhydrite). The salt is apparent not only in rock massifs, but also in the brine springs that occur throughout the area. Precipitation (*i.e.* rain) passes through the ground and dissolves the salts, which then flow back to the surface in the form of salt springs. It is the brine from these springs that has been so important for much of the exploitation we see in historical and modern times.

1 'Moldavia' in this article refers only to the north-eastern province of Romania, not to the Republic of Moldova.

Archaeological evidence for salt exploitation in the Carpathian Basin

Traditionally, salt archaeology has concentrated on two forms of exploitation: evaporating brine or seawater, and deep mining. The latter is mainly known from the Austrian Alps (Hallstatt and Hallein), and until fairly recently was thought to be a phenomenon of the Iron Age; in the last 30 years it has become apparent that there was a major Bronze Age phase of exploitation at Hallstatt as well (*Kern* et al. *2009*). These sources are not our main area of concern here, however. The exploitation of salt water can take place either in lagoons or salt lakes, which leave little or no archaeological trace, or by artificial means of evaporating the brine, through the use of heat. In the latter case, the brine was placed in coarse ceramic containers known as briquetage, and the containers were placed on furnaces or ovens. Originally defined at the massive Iron Age sites in Lorraine, eastern France, briquetage also turns up elsewhere in western Europe in Bronze and Iron Age contexts, notably in Germany.

Within the Carpathian Basin, there are few (if any) indisputable finds of briquetage, of any age. There are, however, notable finds in Moldavia of Neolithic date (*Andronic 1989; Ursulescu 1977*), and ceramics thought to be briquetage near Wieliczka in southern Poland (*Jodłowski 1971*), and in Bosnia (*Tasić 2002*), of similar age. Curiously, such finds are not repeated in later periods, nor inside the Basin itself; the situation has recently been discussed by Eszter Bánffy (*2013*). So, if not through evaporation using briquetage, what? How was salt obtained in the Carpathian Basin in prehistory?

The first answer to this question would be that solar evaporation helped to provide at least some of what was required. In the heat of summer, the numerous salt springs and streams dry out, leaving a crust of salt crystals on the surface; these can be picked off and used, though a further wash in fresh water improves the taste of the salt.

Waiting for the sun to evaporate salt water could be avoided by utilising other means; in many parts of temperate Europe, including the Carpathian Basin, the sun would only be hot enough at the height of summer to produce any reasonable quantity of salt. Alternative methods would have been necessary. Here we come to a rather extraordinary phenomenon that has only become properly known in the last ten years. The story has been told in detail before, but a short summary of the situation will suffice here. In the early 19th century, a curious set of wooden objects was found in a salt mine shaft in what is today Transcarpathian Ukraine, at the time part of Hungary. The finds included a ladder, ropes, mallets and, most notably, a hollowed out wooden trough with a set of perforations in the base which were filled with wooden pegs or plugs. The finds were described 60 years later (*Preisig 1877*), and illustrated in the catalogue of the Hungarian State Geological Institute, published in 1909 (*Vezető 1909*). After that, they disappeared from sight, only being rediscovered in 2008 in the Central Mining Museum in Sopron, western Hungary, where they have now been studied and republished (*Harding 2011*).

Meanwhile a similar trough and other wooden objects were found in the 1930s at Valea Florilor, north of Turda in Transylvania (*Maxim 1971*). These finds came into particular prominence when work began on the Băile Figa site in northern Transylvania near Beclean; a trough of the same kind was extracted in

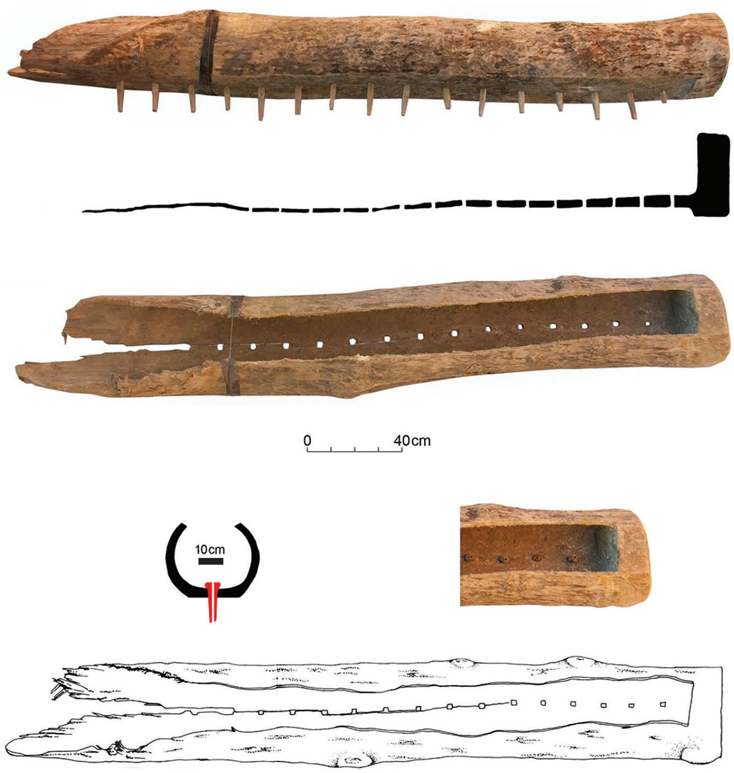

Fig. 2. Wooden trough from Băile Figa, Beclean.

2005 by the local museum geologist, followed by further examples from excavation starting in 2007 (*Chintăuan 2005; Harding, Kavruk 2013*) (Fig. 2). Subsequently, another object of this kind was discovered not far from Figa at Caila, and there are indications that the same technology was used in other places in the same area. There are thus six sites now known where the trough technique was used; all lie in the Carpathian Basin, and most lie within Transylvania. At present, there is no indication that this technology was used further east, in Moldavia, or further north, in Galicia and Poland, but if it was a successful method of obtaining salt, it would seem unlikely that it was restricted to the relatively small area that is currently known to be its home. Especially in Moldavia there other indications of ancient salt working that closely resemble what is known from Transylvania (*Monah 2002*); it might be surprising, therefore, if the trough technique does not eventually turn out to have been used there as well.

The troughs vary in detail, but can be up to 3m in length; none of those that survive is intact, so it is not certain that both ends were enclosed (*Harding, Kavruk 2013.194–198*). The perforations in the base can be round or square, the pegs shaped accordingly. There are indications from the dating evidence that round holes gave way to square ones, presumably because the pegs in round holes could twist around and become separated from the trough; square pegs in square holes could not rotate. The pegs that survive are themselves perforated, and in a few instances the perforation is known to have been filled either with twisted cord, or with a wooden needle. At Figa, one of the troughs was found partially supported by posts (Fig. 3); thus it would appear that they were raised up above the ground surface on some kind of structure.

As well as the troughs, many other wooden installations were used. The excavation evidence from Figa is particularly rich in this respect, though still hard to understand in detail. A common feature was the creation of roughly circular areas varying in size from 2–3m across to as much as 10 x 13m, enclosed by wattle fences; these were probably brine storage ponds (Fig. 4). A complex sequence of constructions using both wattle and split oak timber was also present at Figa, though how these worked is not yet clear. What is clear, however, is that the technology is mainly Bronze Age: of the 66 radiocarbon dates so far obtained, more than 40 fall between 1600 and 800 calBC (*Harding, Kavruk 2013. 116–117*). A very few are earlier (and there is Early Bronze Age pottery from the site that may corroborate this), and some are later, falling into the Dacian Iron Age (more of this below).

What, then, was the technology involved? Here, different opinions have been expressed, and there is no certainty about the matter, though some facts may be stated. The excavations at Figa and the indications from early finds have shown that the troughs do not seem to come singly, but in pairs or groups. In Trench XV at Figa, for instance, five troughs have been found in or near one single area, four in a straight line (*Cavruc* et al. *2014*); in Trench I, there are two troughs; at Valea Florilor, there seem to have been three. Thus whatever the technology involved, it probably utilised multiple troughs, either in parallel or in line. If the latter, they may have worked in sequence, perhaps to concentrate the salty water to the extent that salt crystals would form quickly, for easy removal by hand; if the former, the intention was presumably to maximise output.

The publisher of the very first trough to be discovered, Eduard Preisig, suggested that the function of the troughs was to allow water to drip slowly onto the rock salt, creating depressions in the rock surface, which would facilitate the removal of blocks of salt (*Preisig 1877*). This technique was recreated experimentally by my colleague Valeriu Kavruk and his team (*Buzea 2010*). After several attempts, it was

Fig. 3. Trough from Băile Figa as found, showing post supports.

found to work satisfactorily, provided that fresh water was used, and the installation was allowed to run for several hours. At Figa, the rock salt is very hard and cannot easily be broken up by hand. Even modern cast-iron tools have difficulties in detaching more than small pieces of rock. So a method of speeding up the process would appear to be a solution to the problem, and perhaps gives an indication of how the troughs were used.

Fig. 4. Wattle fences around a possible brine storage pond at Băile Figa.

This does not, however, solve all the problems presented by the installations found at Figa and elsewhere. It does not, for instance, explain why the troughs should have been found in pairs or groups, unless this was simply a factor of several troughs having been used at once, or of one succeeding another as one went out of commission and another was needed in order to maintain the supply of salt. Nor does it explain the function of the wattle-framed ponds and other built constructions, which I have suggested above were created in order to store brine. Perhaps most likely is the idea that once pieces of rock had been broken off the parent body, they were put into the wattle ponds to dissolve, the brine thus concentrated then being used as it was or allowed to dry out to form crystals. The technique of turning rock salt into crystalline salt by dissolving it in water is known from other places, notably Hallstatt.

The Iron Age and Roman periods

In the Iron Age, further technological innovations came into use at Figa. In the south of the site, shafts and pits were dug down to reach the rock salt, one of them being lined with split timbers placed one above the other to form a box-like construction; another was a simple pit (of unknown depth), access to which was by means of a ladder (*Harding, Kavruk 2013.198–199*) (Fig. 5). Since the bottom of these shafts lies below the present-day water table, it is not known how the salt was extracted at the working face, but presumably the intention was to obtain lumps of rock salt for later processing. Some 14 of the 66 radiocarbon dates from Figa date to the Iron Age, so activity at the site in this period must have been more than cursory. It is not impossible, however, that the troughs continued to be used at the bottom of these shafts, though there is no evidence for this, and all the dated troughs belong to the Bronze Age.

At least one other site has definite evidence for Iron Age activity: Sânpaul in Harghita county, in the south-east of Transylvania (*Harding, Kavruk 2013. 43–47*). This locality was already known as the site of a Roman fort and vicus, and of a Roman altar referring to M. Caius Iulius Valentinus, who is described as *conductor salinarum* (*Piso 2004–2005 (2007)*). In a stream running down from a brine well lie timber posts; these have been dated (Fig. 6).

Fig. 5. Wood-lined shaft of Iron Age date at Băile Figa.

Fig. 6. Timbers in the salt stream at Sânpaul, Harghita county, Romania.

There was evidently a Roman saltworks at this place, though of the four radiocarbon dates obtained, three belong to the early modern period and one to the Iron Age. Clearly, the area was one of continuing and long-lasting activity, whatever the situation in the Roman period.

Elsewhere in Transylvania, the evidence for Roman salt production is again largely circumstantial, derived from the proximity of Roman sites to known salt sources, and from the presence of inscriptions recording similar *conductores* (*Russu 1956*). Mining technology, both for metal minerals and for salt, is extensively known in Dacia (*Wollmann 1996*), notably from such well-known mining areas as Roşia Montana in Alba county.

The importance of salt in the prehistoric economy

Salt was only one commodity in the range of materials that were exploited in the Carpathian Basin in prehistory; many would imagine that the metal minerals were more important than salt, since Transylvania is rich in such minerals, and must have supplied the metal-less Hungarian plain with them. Yet salt is easily underestimated as a desirable commodity, which people have traditionally gone to great lengths to acquire. As explained above, the unequal distribution of salt sources meant that an area like Transylvania would have been in a prime position to provide supplies to those without. But this raises the question of the scale of the operation at the production sites. Kavruk and I have considered the matter in some detail (*Harding, Kavruk 2013.209–217*). In a Bronze Age context, when briquetage sites around Europe were relatively small, and in the Carpathian Basin more or less absent, we have argued that the scale of production on such sites was limited to the domestic sphere; the volumes were simply too small for anything else. With the massive installations uncovered in and near Transylvania, on the other hand, it is likely that the technology involved enabled many kilograms per day to be produced, which must mean that most of the salt was destined not for local consumption, but for transport to the salt-less areas to the west and south. Seen in this light, the salt production of at least this part of the Carpathian Basin takes on a new dimension. It becomes, like Hallstatt, a major producer of an essential commodity.

It is impossible at the moment to chart the movement of that salt to areas outside Transylvania. Salt is highly soluble and generally does not survive; only a couple of examples are known from prehistoric contexts, one from western Hungary (*Németh 2013*), probably emanating from Alpine sources, and the other from Crete (*Kopaka, Chaniotakis 2003*). Briquetage and coarse pottery containers were used in western Europe to transport salt in cake form, but not in central and eastern Europe, at least, not in the Bronze and Iron Ages. Any reconstruction of a salt trade must therefore depend on proxy sources, such as what is known from the medieval and modern salt trade (*Marc 2006*).

Even though the produced salt is effectively invisible archaeologically, we need be in no doubt about its importance in the prehistoric economy. It joins a number of other commodities, such as textiles or wooden handicrafts, for which we have to assume a presence without usually being able to demonstrate it. Given its known importance in historical times, for food preservation, for human and animal health, and for a range of industrial processes, salt can take its place as a major driver of commercial and technological enterprise in prehistory, just as it has in modern and historical periods.

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Foodways architecture: storing, processing and dining structures at the Late Neolithic Vinča culture site at Stubline

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ABSTRACT – *The paper presents an analysis of storing, processing and dining structures from the Vinča culture site at Stubline. Numerous clay structures found in houses were associated with everyday activities related to food. We argue that these structures were not only important in subsistence strategies, but were also profound symbolic agents involved in complex symbolic practices related to the conceptualisation of social spaces in Vinča culture houses.*

IZVLEČEK – *V članku predstavljamo analize struktur, povezanih s shranjevanjem, pripravo in uživanjem hrane v kulturi Vinča na najdišču Stubline. V hišah so bile najdene strukture, ki jih lahko povežemo s hrano in vsakodnevnimi aktivnostmi. Trdimo, da so strukture enako pomembne v subsistenčnih strategijah in kompleksnem simbolnem delovanju pri oblikovanju socialnega prostora v hišah kulture Vinča.*

KEY WORDS – *storing; processing and dining structures; Stubline; Late Neolithic; Vinča culture*

Late Neolithic Vinča culture site at Stubline

Stubline is a Late Neolithic Vinča culture settlement near Serbia's capital Belgrade, built on an elevated slope around 4850/4800 BC. The plateau, 16ha in area, was surrounded by two watercourses. The Stubline site lies in a small micro-region, with several contemporary Late Neolithic Vinča culture settlements in the immediate vicinity. The first excavations at the site were carried out for one month in the late 1960s (*c.f. Todorović 1967*). Systematic excavations were renewed in 2006, and have continued since then on behalf of the Belgrade City Museum (*c.f. Crnobrnja* et al. *2009; Crnobrnja 2012*).

Based on the current excavation and prospection data, the Neolithic settlement is exceptionally well preserved, with more than 200 above-ground houses arranged in rows (Fig. 1), with linear communications, open spaces, and circular ditches surrounding the settlement (*Crnobrnja* et al. *2009; Spasić 2012a*). As in many other Neolithic villages in the Central Balkans, the ground plan of the settlement at Stubline clearly illustrates settlement growth dynamics. We do not know which house was the first to be built in Stubline or who its first inhabitants were, but over time, the settlement extended, and two ditches were dug out at the far western part, either as a symbolic division of space, or in order to protect the inhabitants and their possessions (*c.f. Spasić 2012a.16*). As time passed, the community grew, and as a result, the two ditches were filled in order to provide the additional space needed to build houses. The houses were again erected in rows, in the same direction as the earlier ones. This layout of new buildings enabled the persistence of former communications. New Stubline shows continuity with earlier organisational ideas, which, on a broader scale, reflects that the settlement narrative was an enduring, long-term process, rather than an event or point in history, a true case of *longue durée*.

Three above-ground houses were discovered during the 2008, 2010 and 2014 excavations (*Crnobrnja* et al. *2009; Crnobrnja 2012*). The excavated houses were rectangular, with exceptionally well-preserved

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house inventories that offered unique insights into Neolithic housing. The house from the 2008 field season is rectangular in form, with no discernible subdivision into rooms. The household inventory consists of two ovens, one quern, and one clay structure for cereal storage, dozens of ceramic vessels, 43 anthropomorphic figurines and 11 miniature tool models (Fig. 2). Among other finds, one portable clay *bucranium* was found in the central part of the house. The second house was also rectangular, again with no discernible subdivision of interior space (Fig. 2). The house had a massive clay floor and numerous well-preserved structures and finds (two ovens, one clay structure for cereal storage, a clay table, one quern, a large number of storage vessels, *etc.*). Two *bucrania* associated with a large oven in the north-eastern part of the house were found facing the floor. A third *bucranium* made entirely of clay was found in the mass of collapsed wall fragments in the heavily damaged southern part of the house (*c.f. Spasić 2012b.300–301, Fig. 10–11*). The latest investigated house was also rectangular, and had two discernible phases in its history. During the earlier phase, the house had a single room, and one oven,

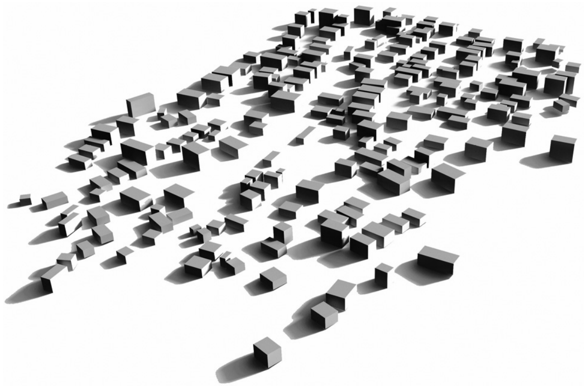

Fig. 1. 3D reconstruction of Vinča culture settlement in Stubline.

while in the later phase the interior was reorganised by raising a partition wall, and changing the position of the oven. Besides the confirmation that numerous activities were carried out in Vinča culture houses, as well as clear evidence that the houses were both sacred and everyday places, the houses in question revealed the way in which their inhabitants conceived their natural environment, community, and foreigners. Up to a certain point, their houses reflected themselves.

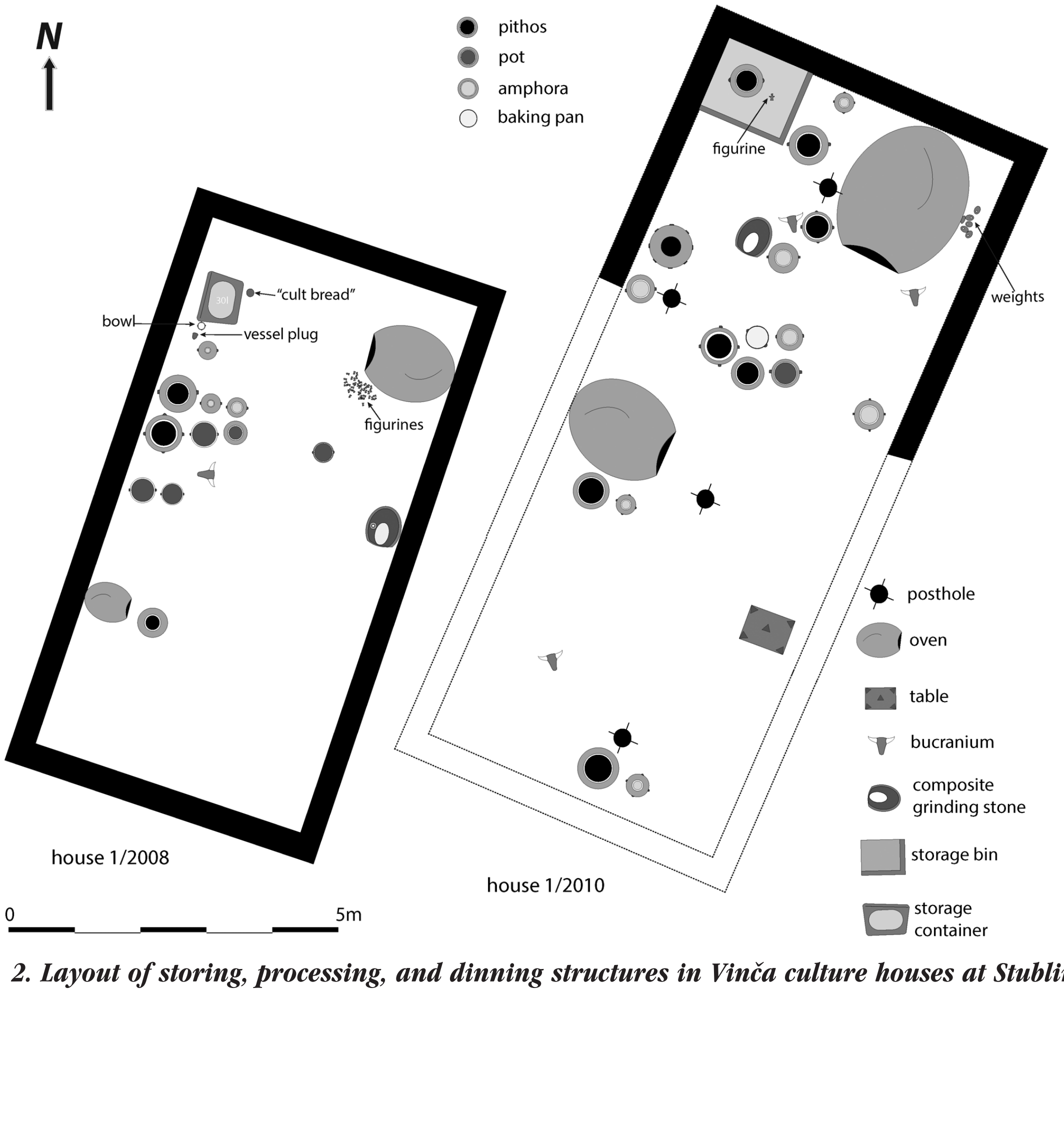

Fig. 2. Layout of storing, processing, and dinning structures in Vinča culture houses at Stubline.

Storing, processing, and dining structures at Stubline

Architectural structures associated with storing and processing food, as well as for dinning were found in all the excavated Neolithic houses at Stubline (*c.f. Crnobrnja* et al. *2009; Crnobrnja 2012*). Common to all the excavated structures is that they were made of unfired clay and that they were more or less fixed constructions not intended to be moved around the house. Two architectural storage facilities, two composite clay quern structures, and three fragmented clay tables were found, besides more ordinary objects used for storing, processing, and dining (such as clay vessels, grindstones and others). Such clay structures have been identified also at several other Vinča settlements (*Bogdanović 1988; Todorović, Cermanović 1961; Todorović 1981; Tasić* et al. *2007; Tripković 2007; 2011*). Since these structures (especially storage and processing ones) were not intended to be moved, a certain part of the house and floor area must have been occupied for longer periods. Thus, we see great significance in these structures, both in relation to the house inventory and in analyses of house histories.

The inventory of houses 1/2008 and 1/2010 included two clay structures/querns for food processing (*i.e.* grinding). Both querns are composite shell-shaped structures consisting of a shallow clay receptacle with an upright clay base for a grindstone. The quern in house 1/2008 (Fig. 3) was found near the eastern wall, around 3m from the northeastern corner of the house (*Crnobrnja* et al. *2009.13, 17, Fig. 5/4*). The quern in house 1/2010 (Fig. 4) was also found in the northern part of the house, approx. 5m to the east of large oven 1 (*Crnobrnja 2012.48, 55, Fig. 3/8*). Both structures have an ovoid shell-shaped receptacle, 15cm deep, with an opening at the lower end. The conical walls of the receptacle are 5–7cm thick with a diameter of approx. 50–55cm. Oval 30 x 20–25cm upright-modelled clay platforms are 12–13cm high, and have a shallow recession for positioning an oval grind. When worn out, the grindstone inserted in the bedding of the platform was replaced. The basic form of the querns was built using traditional coil-building technique, after which additional layers and coatings of clay were applied. The clay quern in house 1/2008 was probably built directly over the house floor and was fixed, while the quern in house 1/2010 had a solid flat base and could have been repositioned in different parts of the house. The fixed structure of the first quern has the great advantage of compactness and stability of construction, while the benefit from the portability of the second quern should not be neglected. The portable clay structure of the quern from house 1/2010 could have been further stabilised by fixing it to the floor through two holes in its base.[1] Both structures were heavily secondarily burnt in the fire that ended the lives of the houses.

A question remains as to whether the querns were built of unfired clay. When it comes to the quern from house 1/2008, it could be concluded with great certainty that the structure was not fired, while the one from house 1/2010 was probably fired in order to make the quern portable.

Two clay structures for food storage were discovered in houses 1/2008 and 1/2010, besides numerous large-sized vessels of *pithoi* and amphora type that were intended for the same or a similar purpose. A trapezoidal storage structure, 80 x 65cm, in the form of a shallow oval receptacle was identified in the north-western part of house 1/2008 opposite oven 1 (Fig. 5; *c.f. Crnobrnja* et al. *2009.16, 17, Fig. 5/3, Fig. 12*). The height of the receptacle walls varies

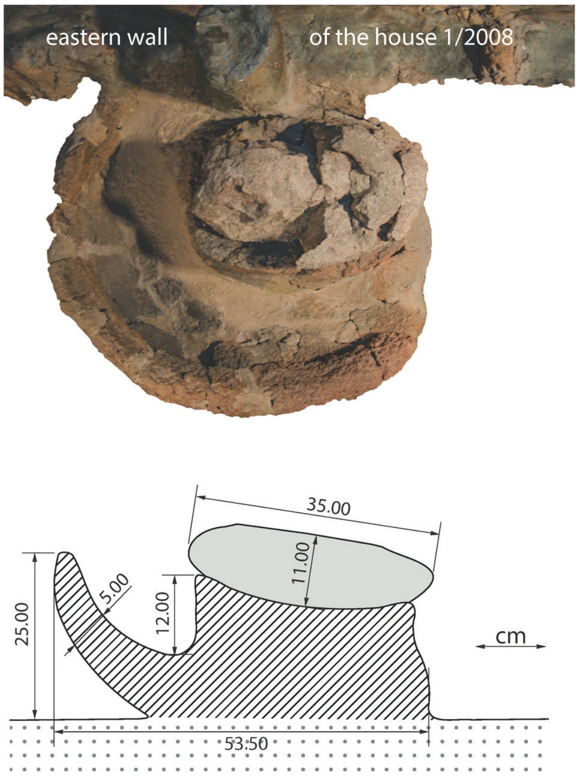

Fig. 3. Composite grinding structure from 1/2008 house in Stubline.

1 Small holes for attaching the quern structure were also observed near the floor area where the quern was found.

from 8–12cm, while its rear is 35cm high. The full capacity of the structure is approx. 30 litres. This storage container was constructed directly over the house floor, and built by erecting 5–15cm thick walls made of unburnt clay. Several flat curved objects of fired clay, a vessel plug (Fig. 6) with textile impressions, and another shallow bowl with a false spout, another conical bowl and a storage vessel of amphora type were found around the container.

The second clay storage structure was discovered in house 1/2010 (*Crnobrnja 2012.48, 54, Fig. 3/6*). The structure in question is a shallow rectangular storage bin, 140 x 120cm (Fig. 2), unearthed in the northwestern part of the house opposite the large oven. The bin was formed as an enclosed space, the northern and western walls of which were actually house walls, while the remaining two walls were built on the house floor. The walls of the storage bin were preserved to a height of approx. 12cm. It should be noted that the floor of the bin had a substructure comprising three layers of pottery sherds and clay coatings that resembled the floor-building technique for thermal structures (*Crnobrnja 2012. 48, 54*). A large amount of pottery fragments, most of which were from a single *pithos*, and one anthropomorphic figurine were found inside the storage bin (*Crnobrnja 2012.54, Fig. 14*).

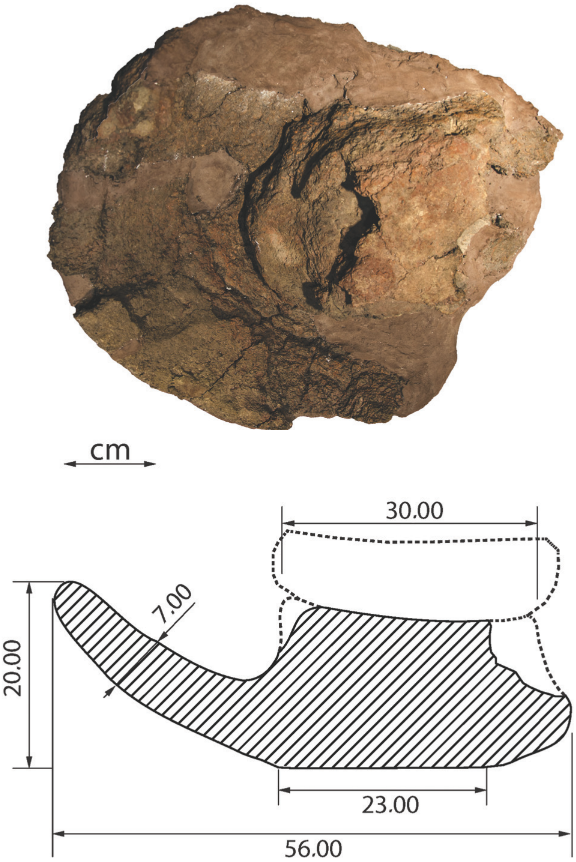

Fig. 4. Composite grinding structure from 1/2010 house in Stubline.

Three fragmented clay-dining structures in form of a low table were discovered at Stubline. The table from house 1/2010 was almost completely preserved (*Crnobrnja 2012.54, 55, Fig. 12*). It was positioned in the southern part of the house near its eastern wall (Fig. 7). A rectangular table slab, 70 x 50cm, was modelled on five short triangular legs, one at each corner of the table, and one in the centre (Fig. 7). The table was approx. 20cm high. A typical Vinča biconical bowl was found placed on the table. The remaining two heavily fragmented tables were found in two refuse pits during the 2014 campaign. The infill of these pits consisted solely of densely packed daub fragments (*i.e.* wall and floor fragments), charcoal, and ash. Only one leg and part of a clay table slab were preserved from both table structures. Their morphology is similar to the table from house 1/2010; even the dimensions roughly correspond (Figs. 8, 9). One of these tables has a rather different slab: it is rectangular, with a low oval wall around it. Thus, the surface of the table resembles a shallow oval receptacle (Fig. 9).

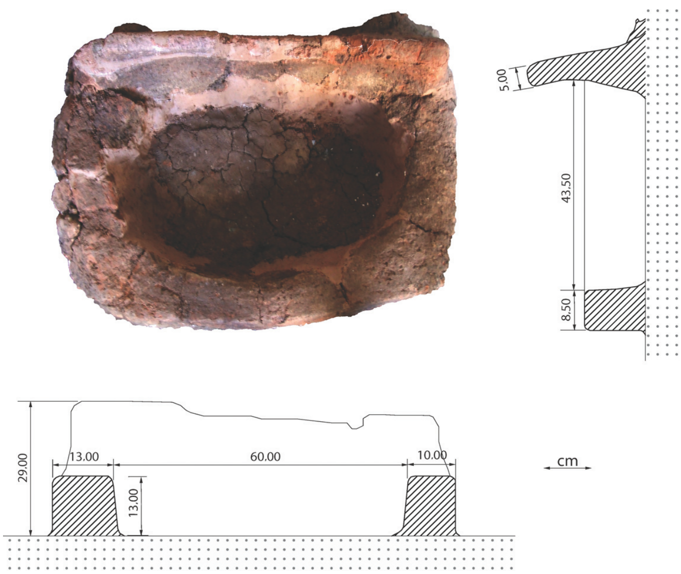

Fig. 5. Storage container from 1/2008 house in Stubline.

The construction technique of table structures at Stubline could be nicely observed on one of the finds from the 2014 campaign. The cross-section of the fragmented table leg clearly shows that whole structure was built in steps. Rough clay core resembling the final structure was first formed, followed by successive applications of clay coating, 1.5–2 cm thick, on the core (Fig. 8).

Discussion

The last decade of scientific research into the household and spatial organisation of Vinča settlements has seen an immense advance in the comprehension of the everyday lives of Late Neolithic communities in the Central Balkans. Boban Tripković made an initial breakthrough in this field, analysing various aspects of household activities in his seminal books on the household and settlement organisation of Vinča settlements in the Central Balkans (*Tripković 2007; 2013*). Regarding the question of cereal storage and related household activities and facilities, Boban Tripković righty perceives it as one of the most important aspects of household/settlement organisation (*Tripković 2007.27–31*).[2] Based on the current data, various types of clay structure for storing, processing and dining have been identified at numerous Vinča settlements (Figs. 10, 11), such as at Divostin (*Bogdanović 1988*), Vinča (*Tasić* et al. *2007*), Banjica (*Todorović 1981; Tripković 2007*), Opovo (*Tringam* et al. *1985; 1992*), Beletinci (*Brukner 1962; Chapman 1981*), Pločnik (*Radivojević* et al. *2013; Radivojević, Kuzmanović-Cvetković 2014*), Čučuge (*Anđelković-Despotović, Redžić 1992*), Grivac (*Bogdanović 2008*), Gomolava (*Jovanović 2011*), Jakovo (*Jovanović, Glišič 1961*), and Uivar (*Schier 2006*). Until very recently, such unfired clay structures have often been neglected in studies of Neolithic household organisation because of the poor state of preservation.

New and more meticulous excavation methodologies have brought to the light several such structures, which resulted in a renewed interest in the topic, as well as a reappraisal of old finds. All of the described storing, processing and dining structures are of great importance for the study of household organisation. Besides their functional value, their main characteristic is that they are more or less fixed structures occupying a certain area of the house floor, thus enabling a profound analysis of various household activities that transpired in Vinča houses.

The function of composite clay querns as structures for processing cereal is now indisputably confirmed, after more than three decades of uncertainties regarding the definition of their purpose. Since the

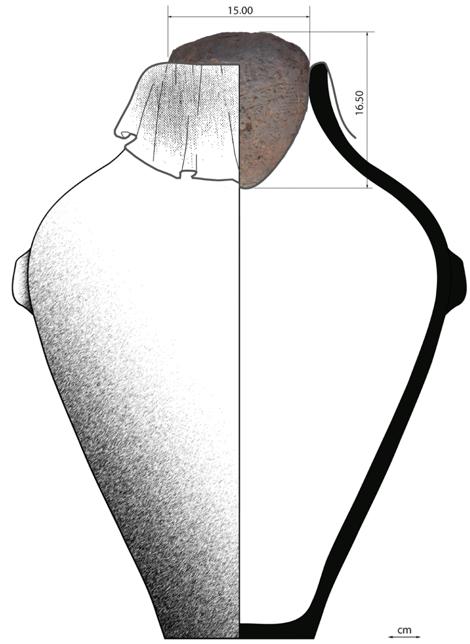

Fig. 6. Reconstruction of vessel plug usage.

discovery of one in a Vinča house at the Banjica site (Fig. 12), misconceptions about its usage brought to light anecdotal interpretations that defined them as equipment for processing dairy products (*Todorović 1981.16*). After the discoveries of composite clay querns at the sites at Vinča (*Tasić* et al. *2007*), and Stubline (*Crnobrnja* et al. *2009; Crnobrnja 2012*) their function as structures for processing cereal is unquestionable. Further confirmation of this interpretation is assured through the discovery of several grains of *Triticum diccocum* near a composite clay quern at Vinča (*Tasić* et al. *2007.214, 219,*

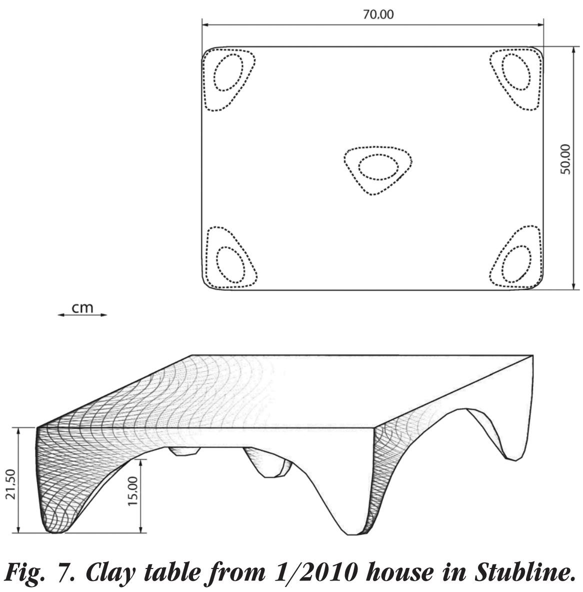

Fig. 7. Clay table from 1/2010 house in Stubline.

2 Another seminal book devoted solely to the history of cereal storage in Balkan prehistory appeared almost simultaneously, providing a solid basis for understanding the topic (*c.f. Jevtić 2011*).

T. II/2). On the other hand, spatial distribution also clearly indicates that these structures were mainly associated with thermal structures, clay vessels and other structures for storing cereals (*c.f. Tripković 2013.106, 159*). Similar composite clay querns were later identified in the corpus from older excavations (Fig. 11), such as from house 2/79 at Banjica (*Todorović 1981*), house 13 at Divostin (*Bogdanović 1988. 51, 79, Figs. 5, 26 B*), and houses IV/1956 and 3/1980 at Gomolava (*Jovanović 2011.25–26*). Outside the zone of Vinča culture, composite clay querns for processing cereal were also identified at sites at Liga in Northern Bulgaria (*Merkyte 2005.16*).

Two different types of clay storage structures were identified in the northern zones of houses 1/2008 and 1/2010 at Stubline (Figs. 2, 5). The storage bin from house 1/2010 (Fig. 2) is actually an enclosed part of the house that was formed by separating the northwestern corner of the house from the rest of the floor surface with small partition walls. On the other hand, the storage container from house 1/2008 is an autonomous structure with a well-defined receptacle (Fig. 5). Storage bins are recorded at numerous Vinča culture houses: in house 1/06 at Vinča (*Tasić* et al. *2007*), in house 2/79 at Banjica (*Todorović 1981.14/D; Tripković 2007.89–90*), in house 2 in Opovo (*Tringam* et al. *1985.431; 1992.356*), in house 1 at Beletinci (*Brukner 1962.90; Chapman 1981*), in houses 13, 14 and 17 in Divostin (*Bogdanović 1988*), and in one of the Vinča houses discovered at Uivar in Romania (*Schier 2006.Fig. 5*). The enclosed space in house 4/1980 at Gomolava could most probably also be defined as a storage bin (*Jovanović 2011.27–28*). On the other hand, the type of storage structures discovered in house 1/2008 at Stubline, marked here as a storage container, have so far been identified in only few Vinča houses (Fig. 11). Such and similar clay containers were found in house 21 at Grivac (*Bogdanović 2008.170, 189, Fig. 8.58*), in house 1 at Jakovo (*Jovanović, Glišić 1961. 131, 135*), and in house 15 at Divostin (*Bogdanović 1988.61*). The clay structure from the house in Pločnik, interpreted as some sort of thermal structure, could also be identified as a storage container (*Radivojević* et al. *2013.1032–1033; Radivojević, Kuzmanović-Cvetković 2014.19*).[3] Structures very similar to our storage containers were also discovered in house 13 at Divostin (*Bogdanović 1988.53*), and at the Čučuge site (*Anđelković-Despotović, Redžić 1992.94*). The finds from house 13 in Divostin

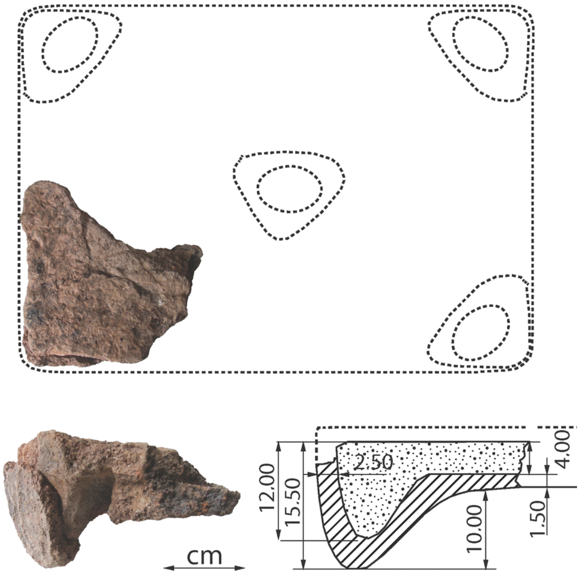

Fig. 8. Fragmented, secondary deposited clay table from a garbage pit discovered during 2014 excavations in Stubline.

and the one from Čučuge are clay containers modelled on clay legs, and are the only portable structures of this type discovered so far.

Clay structures analogous to those presented here and associated material culture assemblages from

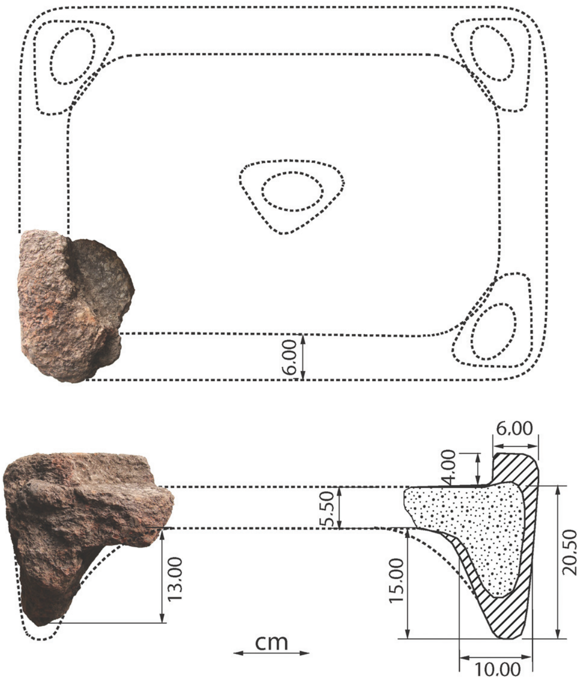

Fig. 9. Fragmented, secondary deposited clay table with shallow recipient from a garbage pit discovered during 2014 excavations in Stubline.

3 The authors were provided with field documentation from Pločnik excavations thanks to the kindness of Duško Šljivar, the director of the excavations, and museum counselor.

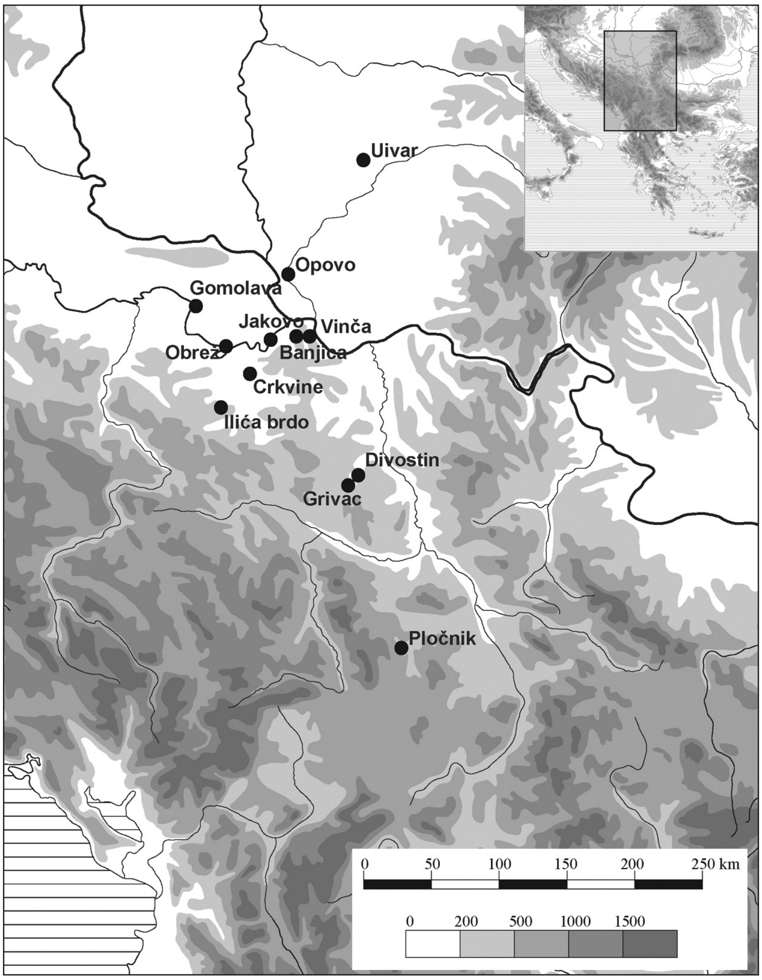

Fig. 10. Vinča-culture settlements mentioned in text (base map courtesy of M. Milinković).

other Vinča-culture houses suggest that their association with food storage is indisputable (*Tripković 2013. 79*). An impressive contribution to the analysis of storing inside Neolithic houses was made through the discovery of almost all the known types of storage structure, as well as 225kg of burnt grain in the Neolithic house at Slatina in Bulgaria (*Nikolov 1989*). Still, these structures were given other interpretations also. The storage bin from the house 2/79 at Banjica was identified as a space for tanning calf skin (*Todorović 1981.16*), while various storage containers from Macedonian Neolithic houses have been associated with leavening dough (*Čausidis 2010.147*). Storage containers have also very often been related to cult practices and interpreted as cult altars (*c.f. Kitanovski, Simoska, Jovanović 1990.107–112; Mitkoski 2005. 35, 38; Jovanović, Glišić 1961.131–134*). Any use of the clay bins and containers that infers a use of water and some kind of liquid should probably be ruled out, since all of the described structures were made from unfired clay, which is soluble and porous in contact with liquids. The considerable formal and technical/structural variation in both storage bins and storage containers could also point to the different types of food stored in them. It is also intriguing to note that the storage container from house 1/2008 in Stubline had a total capacity of not more than 30 litres, and that in the same house, numerous much bigger large-scale vessels for storing both liquids and cereals were found (Fig. 2). The same could be said for house 1/2010, whose inventory consisted of several vessels with a capacity of more than 100 litres (Fig. 2). One can only speculate why, alongside storage vessels that served the basic need for in-house storage well, Neolithic communities of the Central Balkans built storage bins and containers that permanently occupied a substantial area of house floors. As a way to understand this matter, we infer two possible explanations. It could be assumed that both storage bins and containers were not as permanent as it has been presumed. They could easily be torn down and rebuilt seasonally when in-house storage demanded more capacity than vessels.[4] Their function could also have changed from time to time. On the other hand, perhaps clay bins and clay containers met some storage conditions that other vessels could not.

Besides Stubline, the only clay dining structures in the form of modern-day tables in Vinča culture houses have been found at Divostin (Fig. 11). Total of eight tables was found at Divostin, four of them were before recovered from house 13. Seven were oval, while the eighth was rectangular. Their state of preservation varies. The largest one was found in house 18, and had a table slab around 60 x 40cm (*Bogdanović 1988.68*). It is important to mention that all the Divostin tables were found in houses which had been in use for a very long time (*i.e.* house 13–15), and also that they were found in rooms which were additionally built in later phases of houses. As at Stubline, clay bowls and other objects (*i.e.* weights, small

4 House histories in Vinča culture were very dynamic and frequently marked by numerous changes in house organisation.

clay altars, miniature vessels) were found on the top of some of the tables (*Bogdanović 1988.53, 63*).

There is no observable pattern in the spatial distribution of storing, processing and dining structures in different houses across the whole Vinča culture *oecumene*. On the other hand, there are some noticeable patterns at intra-settlement levels. The main activity areas associated with food storage and processing in Stubline are concentrated in the northern parts of the excavated houses (Fig. 2). Thermal structures and numerous vessels for grain and liquid storage were associated with northern areas of the houses, as well as storage and processing structures. A similar tendency towards more intensive use of northern house areas is also observed at Divostin, while at Banjica, Gomolava, and Jakovo, this density of various activities is noticeable in the central rooms/parts of the houses (Fig. 11; *c.f. Tripković 2013.126*).

To store and process grains or to retain and understand ways

Based on the various household data, we argue that storing, processing and dining structures were not only important in subsistence strategies, but that they were also profound symbolic agents included in complex symbolic praxes related to the conceptualisation of social spaces in Vinča culture houses. We infer that there are two possible strategies in identifying the role of clay structures in conceptualising social spaces and symbolic reproduction in Vin-

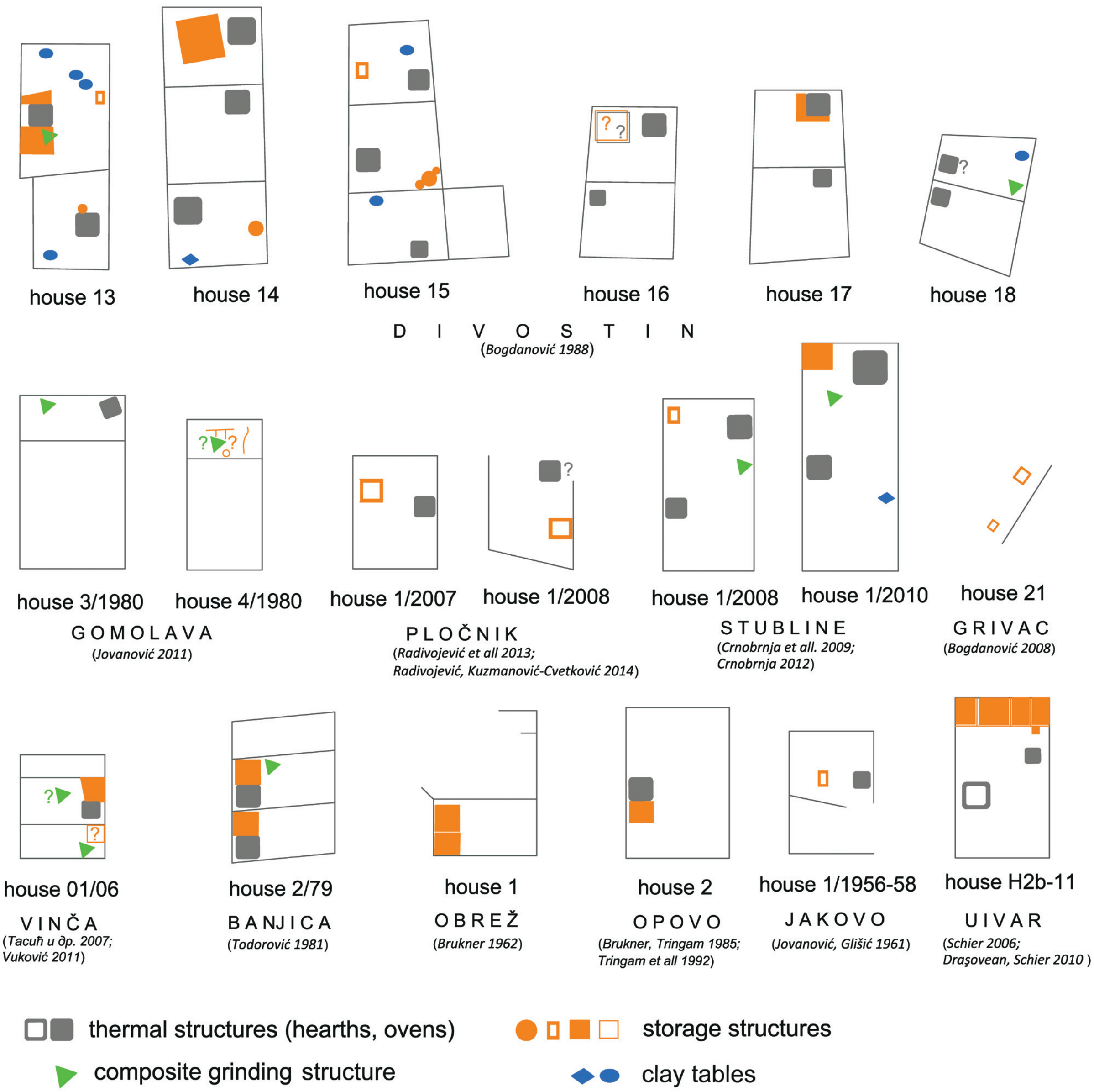

Fig. 11. Schematic layout of storing, processing, and dinning structures in Vinča culture houses.

ča houses. The first one includes already discussed role of the structures themselves, while the other employs analyses of their associations with other important material agents. As shown above, all of the structures were clearly connected to food management, especially to grains. However, several of these structures have clear symbolic potency through animal symbolism. The storage container from the site at Jakovo, and one of the clay tables from Divostin have horn-like protrusions (*c.f. Jovanović, Glišić 1961.131–134; Bogdanović 1988.53*). The fact that the storage container from Jakovo was decorated and had horn-like protrusions led to misconceptions in interpretation, so until very recently the object was thought to be a cult altar. There are numerous other associations of storing, processing, and dining structures with material culture imbued with animal symbolism. The storing and processing structures from the house 1/2010 at Stubline were found near a large oven and two clay *bucrania* (Fig. 2; *c.f. Spasić 2012b.300–301, Figs. 10–11*). The storage container at Jakovo was also associated with a *bucranium* placed on a wooden pole in front of it, while one hybrid human/animal figurine and so-called amulet with two hybrid *protomae* were found immediately beside it (*c.f. Jovanović, Glišić 1961; Spasić 2012b.299–300, Figs. 6–7*). In one of the storage bins from house 2/79 at Banjica, an almost complete bull skull with horns was found (Fig. 13; *c.f. Todorović 1981*). On the other hand, there are also clear associations of our structures with human imagery. A complete anthropomorphic figurine was found deposited in the storage bin in house 1/2010 at Stubline (Fig. 2), while a set of 43 anthropomorphic figurines associated with an oven were found in the vicinity of the composite clay quern in house 1/2008 at Stubline (Fig. 2; *Crnobrnja 2011; Spasić 2014*). A bowl with eight highly stylised protomae and small three-footed vessel were found near the composite clay quern in the house 1/2010 at Stubline (*c.f. Crnobrnja 2012.57, Fig. 14; Spasić, Crnobrnja 2014*).

The fact that some of the storing, processing and dining structures had clear symbolic value, and that most of them were associated with other objects with great symbolic potency should be examined on a larger scale. We maintain that these structures formed part of larger symbolic assemblages associated with Vinča household narratives. Various symbolic agents were present inside these houses, and were closely associated together. As already described, all of the clay structures concerned were used at some stage in processes related to storing and processing grain. Grain had powerful symbolic value, which is seen on a far lesser scale in the Vinča material culture.[5] On the other hand, most of the discussed structures were closely related to animal symbolism (*i.e. bucrania*, horn-like protrusions, amulets, figurines). Human imagery was also present together with animal imagery, the combination of which was somehow connected with dining structures and structures used for storing and processing grain. Thus, Vinča household activities incorporated all the major symbolic aspects of Neolithic life. We argue that these houses were powerful symbolic are-

Fig. 12. Composite grinding structure from 2/79 house in Banjica.

Fig. 13. Storage bin from 2/79 house in Banjica.

5 Several dozen so-called cult breads from Vinča culture could be indirectly associated with grain symbolism (*c.f. Petrović* et al. *2009. 162–163*). Clear grain symbolism exhibited in clay grain models is present in the preceding Middle Neolithic Starčevo culture (*c.f. Nikolić, Zečević 2001.4, 8, 21; Greenfield, Jongsma 2014.8, 10, Figs. 9–10*).

nas, where structures for storage or processing grain were connected with potent animal and human symbolism: a genuine example of Hodder's oppositional structuring (male: female; wild: domesticated; plants: animals).[6]

Clay storing, processing, and dining structures are also of considerable importance for understanding Vinča culture household narratives. Several contextual examples convince us that these structures were part of important events in household histories. As described earlier, storage bins, containers and clay tables were frequently erected or placed in newly built adjoining parts of the houses (*i.e.* Divostin). Whether the reason for the rebuilding and the increase in the size of Vinča culture houses was because of physical or material expansion, or symbolic, social or physical reproduction, the structures used for dining, storing and processing clearly denote these events in house histories. Several of the last chapters of Vinča culture house histories were marked by storage and processing structures also. Three sets of bull heads with horns on the floor of house 2/79 at Banjica could probably be interpreted as house closure deposits placed there when the house was abandoned. One of the three bull heads with horns was left in the storage bin (Fig.13; *c.f. Spasić 2012b.299*). We argue that a similar example of house closure depositions can probably be observed in house 1/2010 at Stubline, and that storing and processing structures were also included in it. A composite clay quern structure for processing grain was found in an inverted position, facing the floor. Several large inverted grindstones were found nearby. While the position of the later ones could be interpreted because of house destruction or post-depositional processes, or the position of composite quern clearly indicates that it was intentionally positioned in that way. Thus, we see it as clear evidence of house closure deposition during the abandonment of the house. The complete anthropomorphic figurine found in the storage bin in house 1/2010 was probably left there during the same time event.[7] An almost complete *pithos* and several fragmented serving vessels were also found in the same storage bin. Not all vessels in the storage bin were heavily secondarily burnt, like the majority of structures and vessels from house 1/2010. Therefore, the deposition of vessels found in the storage bin probably occurred after the abandonment and destruction of the house. The anthropomorphic figurine discovered in grain silo A at Selevac could also have been deposited upon the closure of the house (*Tringham, Stevanović 1990.59–61, Fig. 4.4/a, d*).

Closing remarks

Clay storing, processing, and dining structures are important elements of Vinča culture houses. The elaboration of their functional characteristics in the future should include an analysis of their use. We observed great morphological, structural and technological variability in all three categories, so the question is whether this variation corresponds with functional variation. Future analysis should seek to discover if there was difference in the use of storage bins and containers that have more solid floors. What are the main advantages of storage inside fixed storage containers of rather small capacity compared to large capacity vessels? Are there differences between the oval and rectangular clay tables? Are there functional differences between clay tables with a flat slab and those with some kind of wall around the slab? So far, we have succeeded in understanding that clay storing, processing, and dining structures were important features of subsistence in houses, but also that they are important elements for understanding Vinča house narratives.

6 *c.f. Hodder 1990.20–92; 1992.23–27*. The concept of binary oppositions has been much debated recently (*c.f. Thomas 1991.14; Whittle 2003.93; Russell 2012.246–247*). Despite some shortcomings and limitations, the concept has enormous interpretative potential.

7 Complete anthropomorphic figurines were occasionally found in Vinča culture houses (*i.e.* Divostin, Stubline, Jakovo, Grivac, Selevac ...); their appearance in the houses has recently been interpreted as possibly representing closing deposits (*c.f. Porčić 2012. 823–824; Porčić, Blagojević 2014.94*).

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Forms, function, and use of Early Eneolithic pottery and settlement structures from Zgornje Radvanje, Slovenia

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ABSTRACT – *This paper discusses the use of ceramic objects in daily life in the Early Eneolithic period, based on ceramic assemblages from the settlement at Zgornje Radvanje in Maribor. The possible function of individual pottery types was studied through typological analysis, pottery production methods, traces of secondary burning and carbonized residues, and ethnographic parallels. The function of different types of settlement structure is discussed on the basis of statistical comparisons of the composition of ceramic assemblages.*

IZVLEČEK – *V članku razpravljamo o uporabi keramičnih predmetov v vsakdanjem življenju v obdobju zgodnjega eneolitika, na podlagi keramičnih zbirov iz naselbine Zgornje Radvanje v Mariboru. Funkcijo posameznih keramičnih tipov smo raziskali s pomočjo tipoloških analiz, analiz načina izdelave keramike, sledov sekundarnega gorenja in karboniziranih ostankov ter tudi z iskanjem etnografskih vzporednic. Na podlagi statističnih primerjav sestave keramičnih zbirov pa razpravljamo o funkciji različnih tipov naselbinskih struktur.*

KEY WORDS – *Early Eneolithic; settlement; Zgornje Radvanje; settlement structures; pottery; functional analyses*

Introduction

The use of ceramics, mainly vessels, became a popular topic in Slovenian archaeology of the Neolithic and Eneolithic periods in the last ten years. These investigations are primarily based on biochemical studies, mainly of lipids absorbed by pottery (*Ogrinc, Budja 2005; Šoberl* et al. *2008; 2014; Ogrinc* et al. *2012; 2014; Mlekuž* et al. *2012; 2013; Budja* et al. *2013*), and also on analysis of visible charred residues deposited on the vessels surface (*Ogrinc* et al. *2012.340–342; Šoberl* et al. *2014.155, 158; Kramberger 2015*). Biochemical studies may give us direct links between the vessels and the contents they originally held and thus can help not only to explain the actual function of individual ceramic finds, but also various other questions concerning pottery use.[1] In parallel, the analysis of morphological characteristics of vessels, analysis of pottery manufacturing technology (techno-functional analysis), analysis of use-alterations, studies of archaeological contexts (*e.g., Ashley 2001; Wilson, Rodning 2002; Braun 2010; Boudreaux III 2010*), as well as ethnographic analogy (*e.g., Costin 2000; Hegmon 2000; Eerkens 2005. 86*), although it may be unrecognised initially, can give us further indications about the intended use of prehistoric ceramics (see also *Henrickson, McDonald 1983; Schiffer, Skibo 1987; Rice 1987.207–232; Eerkens 2005.85–87, 96–97; Urem-Kotsou* et al. *2002*). Yet, until recently, Slovenian archaeologists placed relatively little emphasis on such approaches (*Mlekuž* et al. *2012.331–335; 2013.133–139; Šoberl* et al. *2014.150–164*).

In this paper, we contribute to the continuous study of the use of ceramics in the Neo/Eneolithic period with a case study based on ceramic assemblages obtained at the Early Eneolithic settlement at Zgor-

1 For the methodological approach to biochemical studies of organic residues on pottery and possibilities that such an approach may offer, see, for example, Mihael Budja (*2014*).

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nje Radvanje. The research has two objectives: firstly, to define the pottery types and their possible function intended by potters (*Rice 1987.207–232*). Our considerations are based on analyses of vessel shapes and dimensions, of ceramic manufacturing technology, use alterations (traces of secondary burning, remains of carbonised residues) and ethnographic parallels. The second objective concerns the function of the different types of settlement structure excavated at Zgornje Radvanje; the discussion is based on statistical comparisons of the composition of ceramic assemblages.

The site and its ceramic assemblage

The Zgornje Radvanje site, situated in northeastern Slovenia, was excavated between 2007 and 2008, and in the year 2010. There is evidence showing that the area of the site was intermittently inhabited from the Eneolithic to the Early Modern Period, however, the biggest and the most prominent settlement dates to the Early Eneolithic Lasinja Culture (*Koprivnik* et al. *2009.16–18; Kramberger 2010; 2014.241–242, Fig. 15; Murko 2012.141–142; Arh 2012*). The settlement of the Lasinja Culture was probably circular in form and consisted of around 23 settlement structures, some of which were clearly pit houses. Numerous smaller pits dating to the same period were found in their vicinity.

According to the radiocarbon dates, most of the Lasinja settlement, which was excavated in 2007 and 2008, existed for a short period around *c.* 4300 BC, while a single ^{14}C date of a sample from a post hole is somewhat younger, indicating activity on the site at the end of the 5th and beginning of the 4th millennium BC (*Kramberger 2014.242–244*). Part of the Eneolithic settlement, excavated in 2010, also dates to the 4th millennium BC (*Arh 2012.Figs. 10, 40, 61, 65*).

For the present study, we have chosen the ceramic assemblages from 17 different structures. These structures differ in their size, number of post holes and the presence/absence of fire places and hearths; therefore, it can be assumed that they were built in different ways, and perhaps served different purposes. The first type of structure is characterised by a deepening of a trapezoidal shape and a hearth or fire place (structures 17, 22 and 5; see also *Kramberger 2010.311–312, Fig. 4; 2014.241, Fig. 16*). Only a few post holes were found on the edge of the pit, and because they were mostly very shallow, we assume, that they supported the roof (Fig. 1). The second type of structure also contained a fireplace; however, it is also characterised by deeper post holes (structures 9 and 20), which delineate a rectangle with at least two rooms (Fig. 2).[2] Other structures chosen for our study did not contain fireplaces. Structures 8, 6 (*Kramberger 2014.Fig. 17*), 7 (*Ibid. Fig. 19*) and 4 (*Ibid. Fig. 18*) were about the same size as the buildings with hearths and fireplaces; structures 3, 11–15, 1 (*Ibid. Fig. 20*) and 19 were significantly smaller. Each structure was usually connected with a single deepening of a rectangular or oval shape, and post holes were found in the pit itself or on its edge. The only exceptions are small rectangular structures 11–15, because all of them relate to only one deepening and the cultural layer found in it, and were therefore probably contemporaneous.

Part of the Lasinja settlement excavated in 2007 and 2008 in Zgornje Radvanje yielded 26 408 ceramic fragments (almost 300kg; *Ibid. Fig. 26*), while in the studied structures, a total of 14 021 were found; yet we can recognise that they were found in each structure in a varying quantities (Fig. 3).[3] The number of ceramic fragments became significantly smaller after joining fragments during the reconstruction process, and eventually it was possible to determine

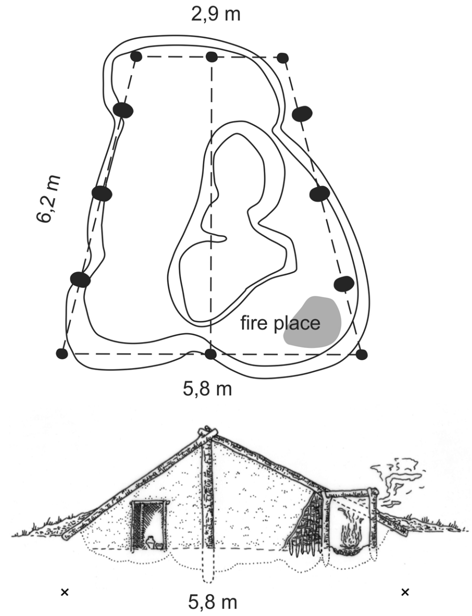

Fig. 1. Zgornje Radvanje. Reconstruction of the building (structure 22) with trapezoidal deepening and hearth.

2 In structure 20, the fireplace was found in the deepening of a structure, while in structure 9, in its vicinity.

3 Most of the ceramic fragments not included in our study originate from less well-preserved structures, structures which were only partly excavated, or from smaller pits, but also from alluvia, palaeochannels and top soil.

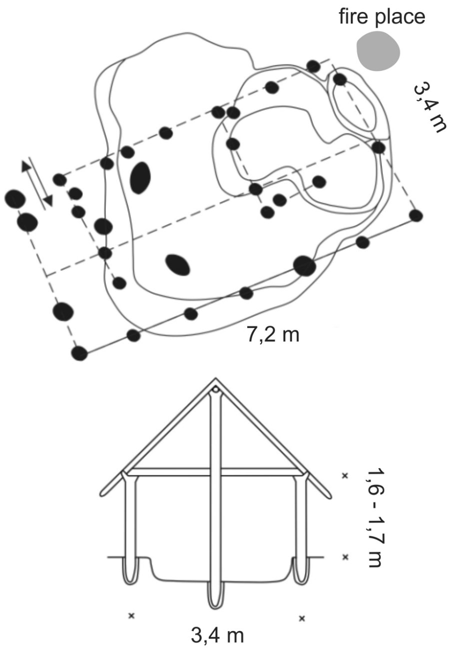

Fig. 2. Zgornje Radvanje. Reconstruction of the rectangular building (structure 9) with a fire place.

the basic shape of 699 ceramic finds, which form the basis for our study. These appear in 15 different basic types, which differ from each other in shape, size, the size of the opening in comparison to the maximum diameter, and in additional elements (*i.e.* feet, handles, appliqués, and spouts).

Vessel shapes/sizes and function

Ethnographic studies indicate that there is often a relationship between vessel shape and its use (*Braun 1980.172; Hally 1986.268; Henrickson, McDonald 1983.630; Smith 1988.912*). These studies have shown that people produce vessels of different shapes for particular purposes, because a vessel's morphology affects its performance in the daily activity in which it is used. The most important functional variables that affect a vessel's morphology are assumed to be the frequency with which a vessel's contents need to be accessed and the degree to which these contents need to be contained (*Braun 1980.172*). In general, vessels with larger openings are produced when frequent access is of concern, and more restricted vessels when containing the contents is important (*Ibid. 172; Henrickson, McDonald 1983.630–634; Smith 1988.914; Boudreaux III 2010.10*). Thus, the first recognised pattern in our analysis of vessel shapes that needs to be pointed out is that there are two main groups of vessels, based on the relative size of their opening: vessels with necks, with openings smaller than 80% of the maximum diameter of the body, and vessels without necks, and openings bigger than 85% of the maximum diameter.

First, we present the group with openings smaller than 80% of the maximum diameter. The most common vessels in this group are larger two-handled vessels described as pots, which according to their size and quantity (31.76%) could have been primarily as storage vessels (Fig. 4.L; see also *Kramberger 2014.Pl. 7.122, Pl. 8.131, Pl. 9.146, 152; 2010.Pl. 2.9, 12, Pl. 3.13–15, 18, Pl. 7.47–49, Pl. 8.50–52, Pl. 9.52*). There are three different groups of pots, based on their size. The first group consist of vessels with volumes between 12.1 and 15.4 litres; in the most common second group are vessels of volumes between 3.5 and 5.5 litres, while the third group consists of vessels with volumes between 0.8 and 2.3 litres (Apps. 1–2). The use of pots as storage vessels is also indicated by the biochemical analysis of organic residues preserved on similar pots from the Neo/Eneolitic site at Moverna vas in Bela Krajina (*Šoberl* et al. *2014.164, Fig. 13*). Namely, these analyses showed that some pots have one of the highest preserved lipid concentrations, which indicates that they were probably used to store fatty foodstuffs over an extended period.

Only five examples of bottle-like vessels, which have smaller openings than pots,[4] and appliqué instead of handles appeared in the settlement structures (Fig.

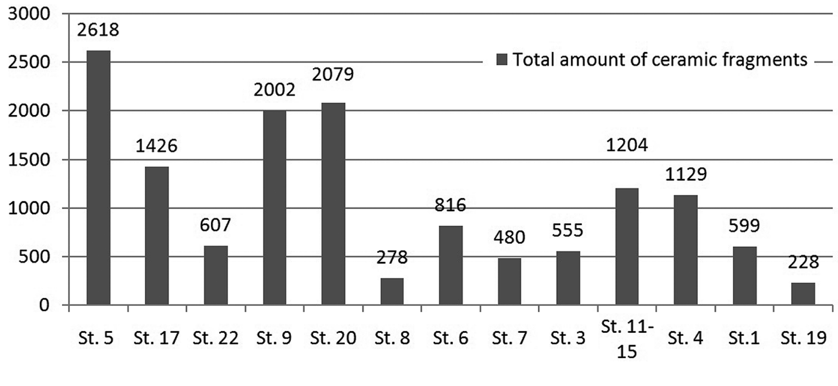

Fig. 3. Zgornje Radvanje. Total amount of ceramic fragments obtained from the settlement structures.

4 The minimum diameter of pot necks is always greater than half of the maximum diameter of the vessel, while bottle-like vessels have narrower necks.

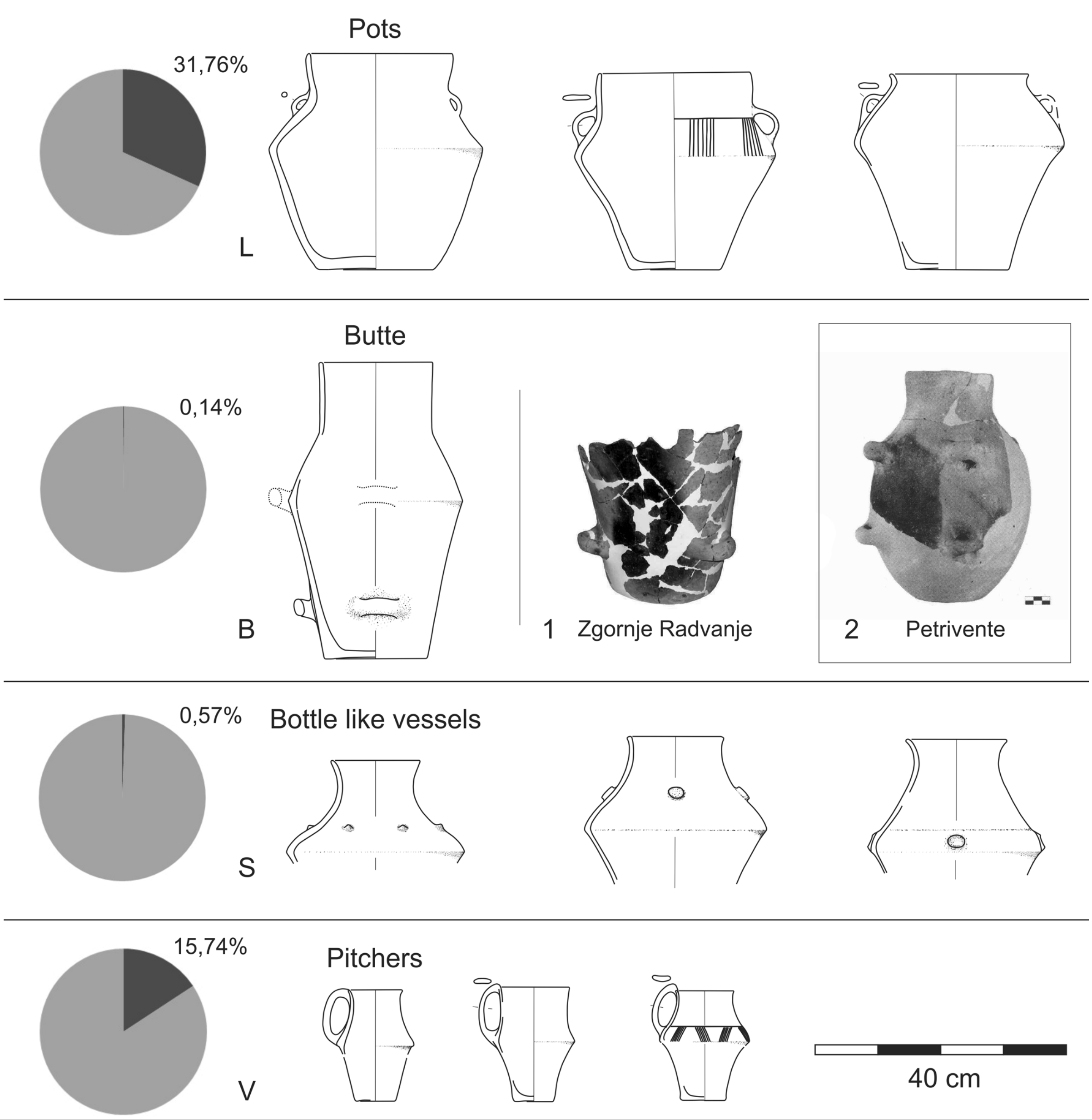

Fig. 4. Pots, a Butte, bottle-like vessels, pitchers and their percentage within the typologically defined finds. Photos of Butte vessels: 1 Zgornje Radvanje, 2 Petrivente (after* Kalicz *et al.* 2007.Fig. 4.14*).

4.S; see also *Kramberger 2014.Pl. 7.118, Pl. 8.130; 2010.Pl. 3.17, Pl. 9.55*). Although they were only partly preserved, it is evident that they occur in two different sizes. While four specimens can be compared with the size and volume of pot group 1, a single bottle-like vessel may match the pots in group 3 in terms of volume. Given the smaller openings and the length and shape of the necks, the bottle-like vessels could have been used to store liquids, but since they are rare, we could expect that vessels or barrels from organic materials were also used for this purpose. According to Prudence M. Rice, vessels used for storing liquid usually have narrow necks to prevent the liquid from spilling and to control pouring, while "*a tall, flaring neck acts much like a spout and also serves as a funnel in filling the vessel.*" Dry material such as grains and seeds are usually stored in wide-necked vessels (see *Rice 1987. 241*). Nevertheless, at this point, the possibility that pots and bottle like vessels were used also for other purposes cannot be excluded, since ceramic products may serve variety of needs (see *Rice 1987.293–301*). The biochemical analysis of the organic residues from a contemporaneous site at Ajdovska jama, for example, showed the presence of mid-chain ketones in three pots, which suggests these vessels were used for heating foodstuff. Two of them were larger pots with a relatively small opening, similar to our pots (*Šoberl* et al. *2014.160, Fig. 5.72AJ, 4AJ; compare with Kramberger 2015.Pl. 9.152*).

A tall vessel with a volume around 13.5l (Apps. 1–2), with horizontal handles on the belly and on the transition to the upper part, for which we use the German name *Butte* here, because there is no English name for this specific form, has been identified only in a single case (Fig. 4.B). However, the fragments of such vessels are also known from some other locations in Slovenia,[5] and they are a common find at Neolithic and Eneolithic sites in central and south-eastern Europe. In central and south-eastern Europe *Butte* vessels appear in the Starčevo (*e.g., Marić 2013.Fig. 6.7a–b*), Körös (*e.g., Domboróczki 2010.Fig. 7*), Linear Pottery (*e.g., Neugebauer, Schöfmann 1981.Fig. 165*), early Sopot (*e.g., Dimitrijević 1979.275*) and early Vinča cultures (*e.g., Garašanin 1951.Figs. 17–18*). They are also characteristic of Lengyel culture (*e.g., Kalicz 1983/1984. Fig. 8.1*) and its variant Moravian eastern Austrian group of painted pottery (*e.g., Ruttkay 1976.143*), of the Bisamberg-Oberpullendorf group (*e.g., Stadler, Ruttkay 2007.Pl. 8.11*), the Münschöfen culture (*e.g., Neumair 1997.Fig. 17*), Balaton-Lasinja (*e.g., Kalicz 1992.Fig. 7.11*), Ludanice (*e.g., Pávuk 1981. Fig. 15.16*), Jordanów (*e.g., Podborský 1970.Fig. 15. 11*), and Salcuta cultures (*e.g., Sălceanu 2008.Pl. 10.13, Pl.79.1*) and also the Late Neolithic period in Greece (*e.g., Urem-Kotsou* et al. *2002.Fig. 2.5, Fig. 5*). Such vessels are mostly undecorated. However, at Early Neolithic Starčevo sites, they appear with barbotine (*e.g., Marić 2013.Fig. 6.7a–b*), at Linear Pottery sites they are sometimes decorated with incised motifs (*e.g., Lenneis 1999.Fig. 4.9–10, Fig. 15. 10; 2010.Fig 4.113*), and in the Moravian group of painted pottery, decorated with painted motifs (*e.g., Rakovský 1986.Fig. 4.6*).

Firstly, it is important to note that the *Butte* vessel from Zgornje Radvanje was secondarily burnt and that the traces of secondary burning are preserved in a regular vertical line between the handles (Fig. 4.1). The comparison of this phenomena is documented for the further example of such vessel from Petrivente in Hungary (Fig. 4.2), which was attributed to the Sopot culture (*Kalicz* et al. *2007.33–36*); the possible explanation could be that the vessels were tied with a rope to a wooden construction (perhaps to the wall of the house) which burnt down.[6] The reason for tying the vessel to the wall

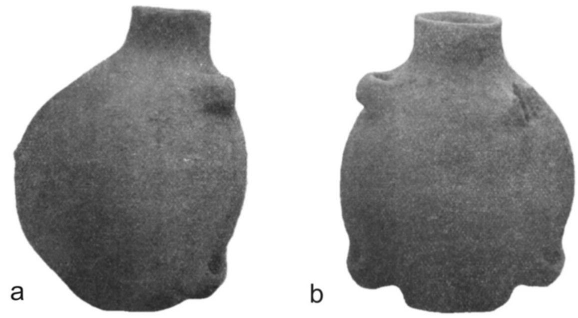

Fig. 5. The irregularly shaped* Butte *from Hungary: a – side view; b – front view (after* Nagy Gyula 1911. Fig. F/a*).

of the house could have been to protect food or liquid from ants, rats and other pests; another possible explanation is better access to the content (like water).

Secondly, it has to be mentioned that the forms of *Butte* vessels are sometimes very irregular. For example, the vessel from Hungary published by Kisléghi Nagy Gyula in 1911 is clearly flattened between the handles (*1911.Fig. F/a;* Fig. 5). Further examples of significant irregular form come from Bisamberg (*Ruttkay 1974/1975.Pl. 10.3*; Bisamberg-Oberpullendorf group) and Falkenstein-Schanzboden (*Stadler, Ruttkay 2007.Pl. 4.13*; Moravian east Austrian group of painted pottery), both located in Austria. In my opinion, the flattened body between the handles could make the vessel from Hungary more appropriate for carrying it on the back – probably to carry liquid, given its shape. This is further supported by the chemical analysis (GC-MS) of a black substance preserved on the bottom of a four-handled *Butte* vessel from the Neolithic site at Makriyalos in northern Greece. The analysis showed that the black substance is birch bark tar, which was probably used to seal the vessel's surface (*Urem-Kotsou* et al. *2002. 114*). A variety of post-firing treatments are used by potters in different societies to reduce permeability and make the vessels more suitable for holding liquids (see *Rice 1987.163*).

Carrying loads over long distances is still a regular activity in many societies in the developing world; there are two common ways of loading the burden: head-loading and back-loading (see, for example, *Lloyd* et al. *2010.1*). In rural Africa, for example, car-

5 They were found at Late Neolithic sites at Andrenci (*Pahič 1976.Pl. 4.57, Pl. 7.100, Pl. 8.115*), Bukovnica (*Šavel 1992.60*) and Čatež-Sredno polje (*Tomaž 2010.91*), at the Neo-Eneolithic site at Ptujski grad (*Korošec 1951.119, Fig. 55*), and at Early Eneolithic sites, such as Pri Muri pri Lendavi (*Šavel, Sanković 2011.find no. 25*), Turnišče (*Tomaž 2012.finds nos. 116, 190, 575*), Gorice pri Turnišču (*Plestenjak 2010.find no. 11*) and Šafarsko (*Šavel 1994.Pl. 12.1*).

6 For example, in the Hessisches Landesmuseum, Raetzel Fabian presented a reconstruction which showed Butte vessels hanging on the wall of a Neolithic house (*1988.Fig. 93*).

rying water is an important daily activity of women and girls (*Fahy Bryceson, Howe 1993.1718–1719*). Traditionally, this is done with water jars made of ceramic (Fig. 6). According to Rice, pottery is in principle likely to be preferred only for carrying liquids, because it is very suitable for holding them; for dry goods, baskets have the advantage of being robust and light (*Rice 1987.208–209*).

Pitchers comprise the remaining type of vessel in the group of vessels with necks and an opening that is smaller than 80% (Fig. 4.V; see also *Kramberger 2014.Pl. 7.116, 121, Pl. 8.127–129, 135–136, Pl. 9.144, 149; 2010.Pl. 7.41–45*). They are fairly common in the pottery assemblage (15.74%), with a shape similar to the bottle-like vessels, but significantly smaller: two reconstructed vessels have volumes around 0.4l, while another two objects around 0.2l (Apps. 1–2).[7] They also have only one handle, so it seems reasonable to assume that they were used for drinking.

Fig. 6. Ethiopia. Woman transporting water in a water jar (www.unesco.org/water/wwap, 12, photo M. Marzot).

The group of vessels without necks is comprised of dishes, bowls and pedestal dishes, with openings bigger than 85% of the maximum body diameter. All types are relatively frequent: 5.6% of the fragments from the total amount are of bowls (Fig. 7.C; see also *Kramberger 2014.Pl. 8.126, Pl. 9.148; 2010. Pl. 1.3–4, 6–7, Pl. 4.23, Pl. 5.27, 30–31*), 8.99% of dishes (Fig. 7.E; see also *Kramberger 2014.Pl. 7.111, 113, 115, Pl. 9.143, 145; 2010.Pl. 1.8., Pl. 6.34, 39*), 11.1% of dishes or bowls and 14.7% of pedestal dishes (Fig. 7.En; see also *Kramberger 2014. Pl. 7.109, 112, Pl. 8.124, Pl. 9.142, Pl. 9.147; 2010. Pl. 5.25, 28, Pl. 6.33, 37*). Bowls and dishes differ only in the proportion between the opening and the height of the vessel.[8] Both forms can occur with handles, grips, appliqués and relatively often also with spouts. On the other hand, pedestal dishes, besides the feet, have characteristic tongue-like appliqués attached to the body.

The dishes, bowls and pedestal dishes found in the studied structures are characterised by inverted or straight lips; different variants are exceptional (see *Kramberger 2014.Pl. 5.24*). The volumes of reconstructed dishes range from 1.2 to 6.8 litres, but no clear groups can be discerned on the basis of capacity. On the other hand, three different groups of bowls can be identified: the first consists of vessels with volumes from 7.4 to 11.1 litres, the second with volumes between 4.1 and 4.4 litres, and the third with volumes between 0.4 and 0.9 litres. The capacity of pedestal dishes was relatively standardised, and their volumes range between 1.5 and 2.5 litres (Apps. 1–2).

The size of the better preserved examples, the relative size of orifices and their percentages in the ceramic assemblage, suggest that some dishes, bowls and pedestal were used for serving food, but the size of openings suggest they were also appropriate for cooking. These suggestions are also supported by the results of researchers in Northern America. A functional study of the Coweeta Creek pottery assemblage in North Carolina, for example, showed that one vessel of a specific type of carinated bowl (*i.e.* with an inverted lip)[9] has a circular zone of pit marks on the base and lower wall of the interior. Elsewhere, the surface was intact, and according to the authors, it is therefore probable that the pit marks are the result of the bowl's contents being scooped out with a ladle (see *Wilson, Rodning 2002. 33, Fig. 10b*). Moreover, similar patterns of use of

7 It is important to note that there is also a larger group of pitchers with volumes which, judging from the upper parts, were significantly bigger, but unfortunately not easy to define precisely.

8 The diameter of openings of bowls, according to our criteria, is equal to between 1 to 2 times of their height, while the diameter of openings of dishes and pedestal dishes is equal to between 2–4 times of their height.

9 In this paper, 'lip' refers to a segment located between the body and opening in the case of dishes, bowls and pedestal dishes. Such bowls/dishes are sometimes also referred to as carinated (*Wilson, Rodning 2002.33*) or restricted (*Mlekuž* et al. *2013. 134–136*).

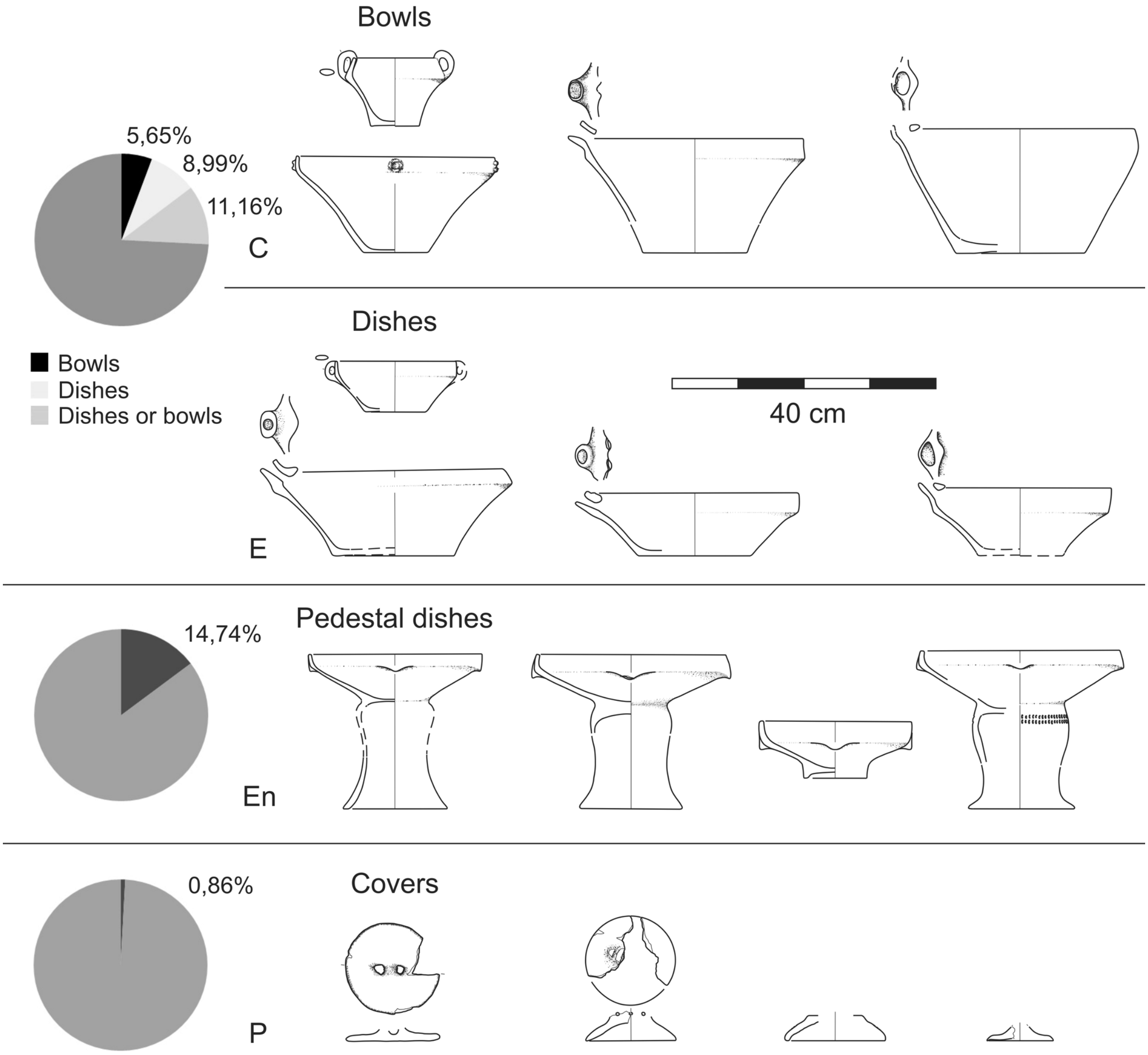

Fig. 7. Bowls, dishes, pedestal dishes, covers and their percentages within the typologically defined finds.

carinated bowls were also recognised by researchers of Lamar-period carinated bowls in Northern Georgia (*Hally 1983a; Shapiro 1984*) and, consequently, such bowls are interpreted as communal serving vessels (*Hally 1983a; 1983b; 1986; Henrickson, McDonald 1983; Wilson 1999; Boudreaux III 2010.21–22*). However, another similar bowl from Coweeta Creek had a two-centimetre-wide ring of soot encircling the vessel's base indicating that it was placed over a low fire, which could mean that it was used for both cooking and serving (see *Wilson, Rodning 2002.33, Fig. 10c*).

To come back on the ceramic assemblage from Zgornje Radvanje, the last ceramic objects that are probably associated with the storage, preparation, relocation, and probably food consumption are the ladles (Fig. 8.Z), covers (Fig. 7.P) and small vessels with massive walls, named as mortars (Fig. 8.MO). Ladles were more common (4,4%) than mortars (0.6%) and covers (0,8%).[10] It can be assumed that the larger ladles, which have volumes around 0.1 litres (Apps. 1–2) were used for transferring food, and smaller ones for eating, perhaps. Small ceramic vessels with massive walls could have been used for grinding. In addition to finds which may have been associated with the food-related activities, small vessel that mimic the shape of the larger ones (Fig. 8.M), a special find that, given the traces of secondary burning and biochemical studies of visible organic residues, can interpreted as a lamp (Fig. 8.O; *Kramberger 2015*), spindles (Fig. 8.Ua), weaving weights (Fig. 8. Ub) and seals (Fig. 8.D) also appeared in the settlement structures.

10 Based on the small amount of the ceramic covers, we could therefore also expect covers from organic materials.

Techno-functional analysis of pottery

Clearly, it is not only the form that determines vessels' suitability for particular uses. The use of different clays and tempers for different function classes is widely known ethnographically (*Rice 1987.113–167*) and is also likely to be characteristic of prehistoric societies since the Neolithic period (*Borowski* et al. *2015*). Furthermore, types of surface treatments and firing may affect the particular task for which a vessel is used (*Rice 1987.226–227; Horejs 2010.18; Lis 2010.239*). In the framework of our discussion of the function of individual pottery types in daily food and drink-related practices, we therefore compared their manufacturing technology by looking at the characteristics: the granularity of fabrics, surface treatment techniques and firing atmosphere.

The manufacturing technology is described with macroscopic standards (after *Horvat 1999*). Dishes and bowls were treated together, because we could not say to which type many pieces belong and because the analysis has shown that there are no significant differences in the manufacturing technology between both types (Fig. 7.C–E). Furthermore, since there is only one example, the *Butte* was not included (Fig.

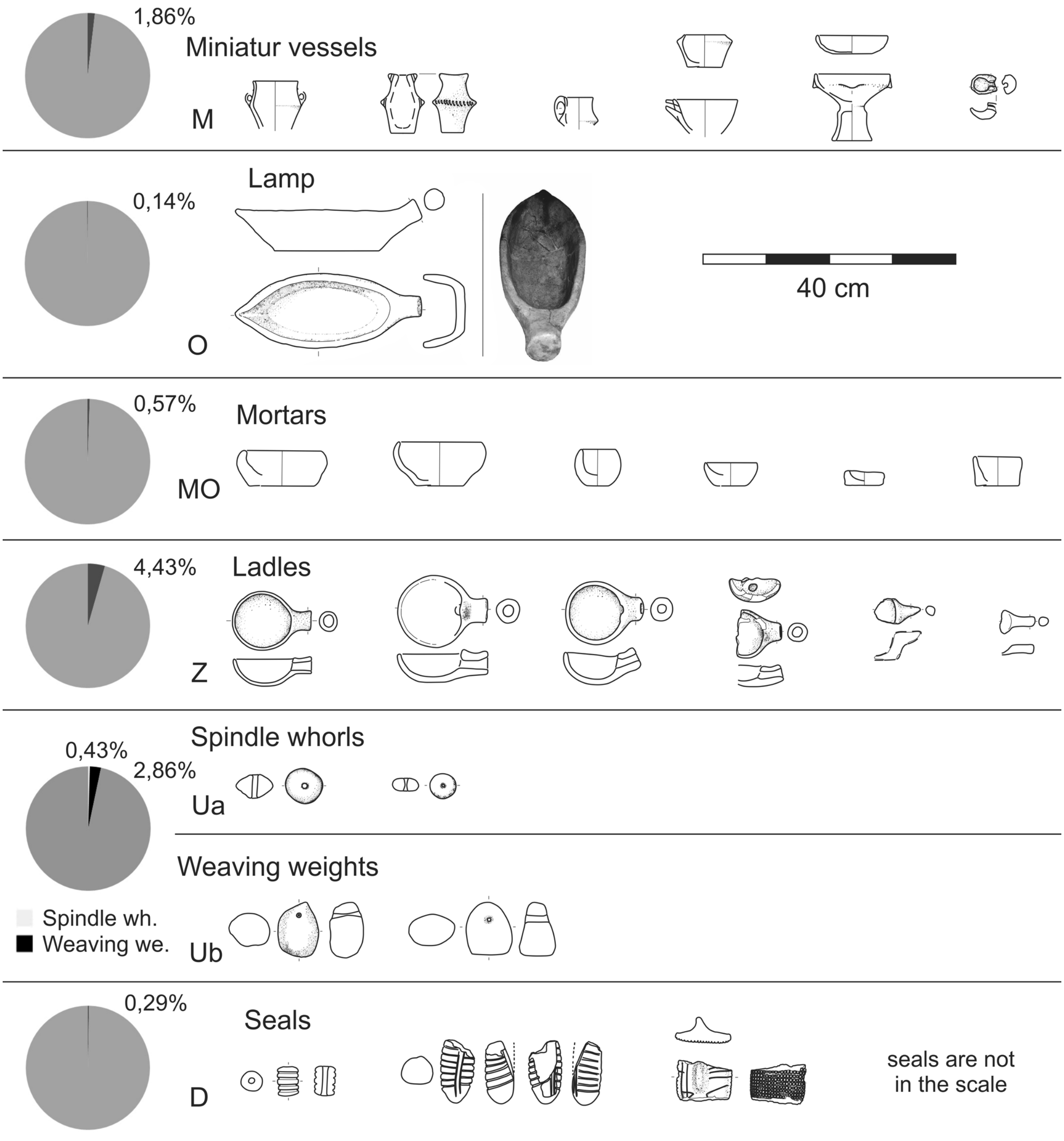

Fig. 8. Miniature vessels, a lamp, mortars, spoons, spindle whorls, weaving weights, seals and their percentages within the typologically defined finds.

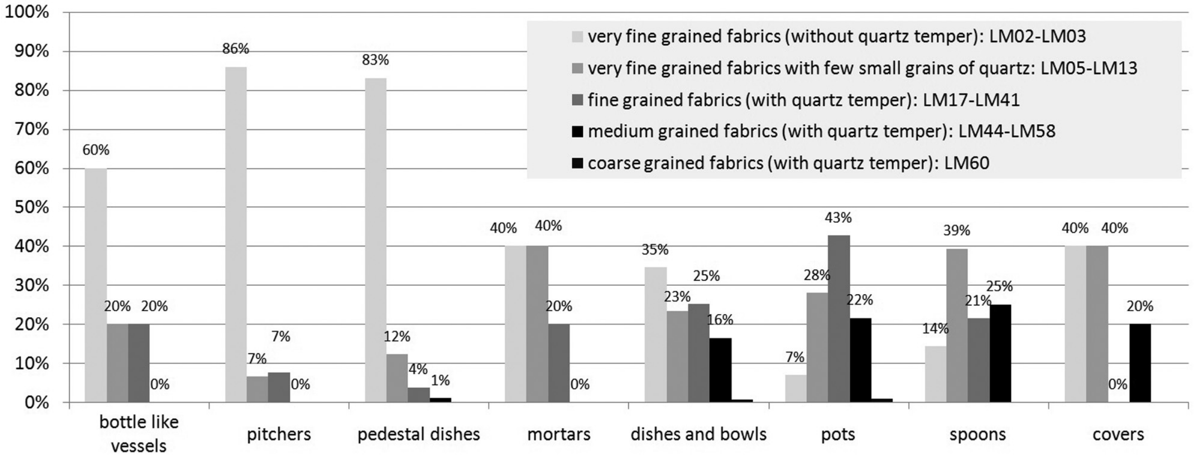

Fig. 9. Granularity of fabrics by vessel type.

4.B), and the data on bottle-like vessels (Fig. 4.S), mortars (Fig. 8.MO) and covers (Fig. 7.P) needs to be treated with caution, since there are only a few examples.[11]

The fabrics that were used for pottery production in Zgornje Radvanje contained quartz, mica and iron oxides, while whitish undefined grains and partially burnt organic material were found in only a few items (*Kramberger 2014.245, App. 1*). Mica, iron oxides, quartz and organic material (impurities) are common inclusions in ceramic bodies in the region and beyond; but there are differences in the sizes of grains and their frequency, especially of quartz. The comparison of the granularity showed that in most cases bottle-like vessels (60%), pitchers (86%) and pedestal dishes (83%) were made of the most fine-grained fabrics. On the other hand, bowls, dishes, pots, ceramic ladles, lids and mortars were often made of more granular fabrics with more quartz (Fig. 9).

Most often the surfaces of all types of vessel are matt and smooth, which means that these vessels were sponged before firing to remove irregularities from the surface. This was carefully done, perhaps when the surface was still wet, because there are usually no traces of a tool or hand. Only a smaller number of vessels appear with different surface treatment. The surface of mortars (33%), pots (6%), spoons (12%) and covers (17%) was sometimes partly uneven and rough, so it was probably smoothened before firing. Dishes, bowls (both together in 2%) and pedestal dishes (2%) rarely appear with this type of surface, while other types were not treated in this way at all. On the other hand, in some cases, the surfaces of pitchers (16%) and pedestal dishes (10%) were partly or completely polished. This was probably done with a soft object when the surface was leather-hard, and the result is a completely smooth and shiny surface. Vessels with this surface are also present among dishes, bowls (3%) and pots (1%),

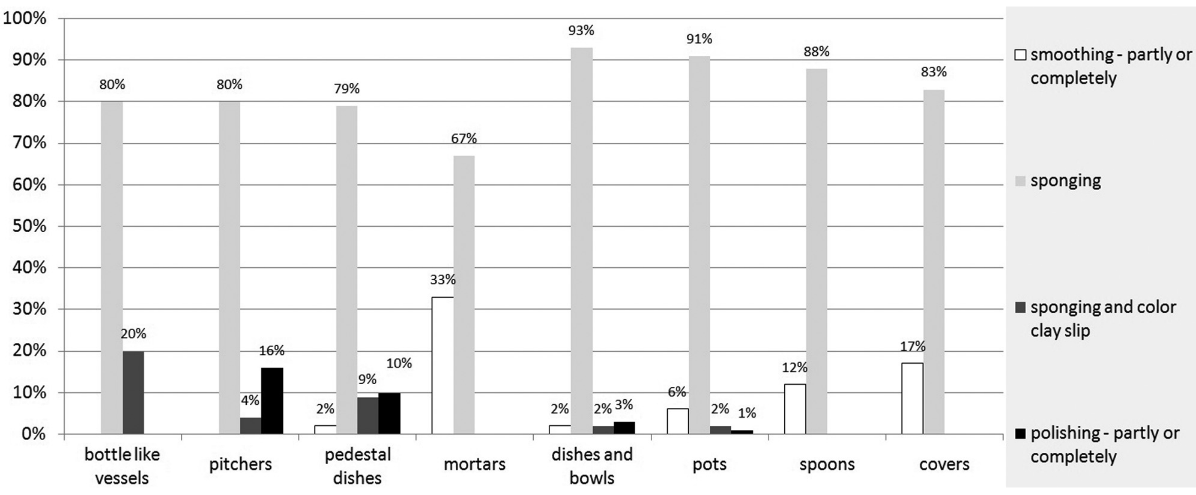

Fig. 10. Surface (finishing) treatment techniques by vessel type.

11 There are only five examples of bottle like vessels, four mortars – one of them without original surface – and six covers.

but relatively less often. Moreover, in comparison to dishes, bowls and pots, the surfaces of pedestal dishes (9%), pitchers (4%) and bottle-like vessels (1 example, 20% in total) were more often treated with sponging and a colour clay slip, while mortars, spoons and covers do not appear with a slip at all (Fig. 10).

The firing atmosphere differs from vessel to vessel, whereby we may divide firing conditions into two main groups: types of conditions which result in a greyish/dark greyish surface and firing conditions which result in a bright coloured surface. A comparison of both groups of firing conditions within different pottery types showed that the bottle-like vessels (60%), pitchers (85%) and pedestal dishes (60%) were mostly burned in incomplete oxidizing or oxidizing conditions with a reducing atmosphere at the end. Consequently, the surface of these vessels is often greyish/dark grey. In contrast, in most cases, dishes and bowls (71%), pots (94%), ceramic ladles (83%), lids (92%) and mortars (100%) were fired in incomplete oxidizing or oxidizing conditions, so the surfaces are brightly coloured (Fig. 11).

Finally, the differences in the granularity, surface treatment techniques and firing atmosphere are further indices that different vessel types served different purposes. According to Rice, the amount, size and shape of inclusions in fabrics influence porosity and density and, therefore, a vessel's suitability for holding liquids (*Rice 1987.231*). This means that vessels made of less granular fabrics (in our case, bottle-like vessels, pitchers and pedestal dishes) may have been more appropriate for this particular purpose. Different surface treatment techniques (burnishing, sponging, polishing, clay slip) can also reduce the penetration of moisture into a vessel (*Ibid. 231*). Moreover, besides clear visual differences between vessels that were fired in an oxidising/incomplete oxidizing atmosphere with a reducing atmosphere at the end and vessels fired in incomplete oxidizing or oxidizing conditions, there might be a similar reason for using both methods, since, according to Rice, charred organic material remaining in the walls may reduce porosity (*Ibid. 231–232*).

Opening diameters and function of dishes, bowls and pedestal dishes

As mentioned above, according to their shape some dishes, bowls and pedestal were perhaps used to serve meals. In our opinion, this is more likely, especially in the case of pedestal dishes, since the technical/functional analysis showed they are similar to pitchers: both types are usually made of very fine-grained fabrics, surfaces were treated with sponging, polishing or clay slip and were mostly fired in incomplete/complete oxidizing conditions with a reducing phase at the end of firing. Biochemical investigations of ceramic assemblage from the Neo/Eneolithic site Moverna vas showed that pedestal dishes have the highest preserved lipid concentrations of all the vessel types, even higher than pots and small cups, which means that they were probably used in food-related practices over an extended period (*Šoberl* et al. *2014.163–164, Fig. 13*). Furthermore, beside pots, the pedestal dishes in Moverna vas proved to be unique vessel types associated with birch-bark tar (*Ibid. 164*). Birch-bark tar can be used for many purposes, including as already mentioned, to seal the vessel's surface (*Ibid. 164*; see also *Urem-Kotsou* et al. *2002.114*).

Based on the foregoing, and if we accept the hypothesis that pedestal dishes could have been used to

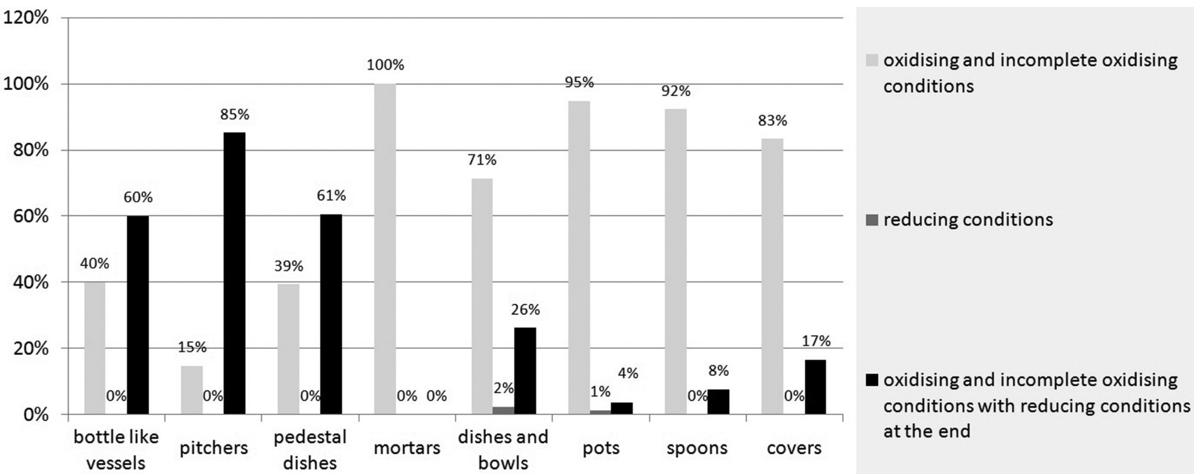

Fig. 11. Firing atmospheres by vessel type.

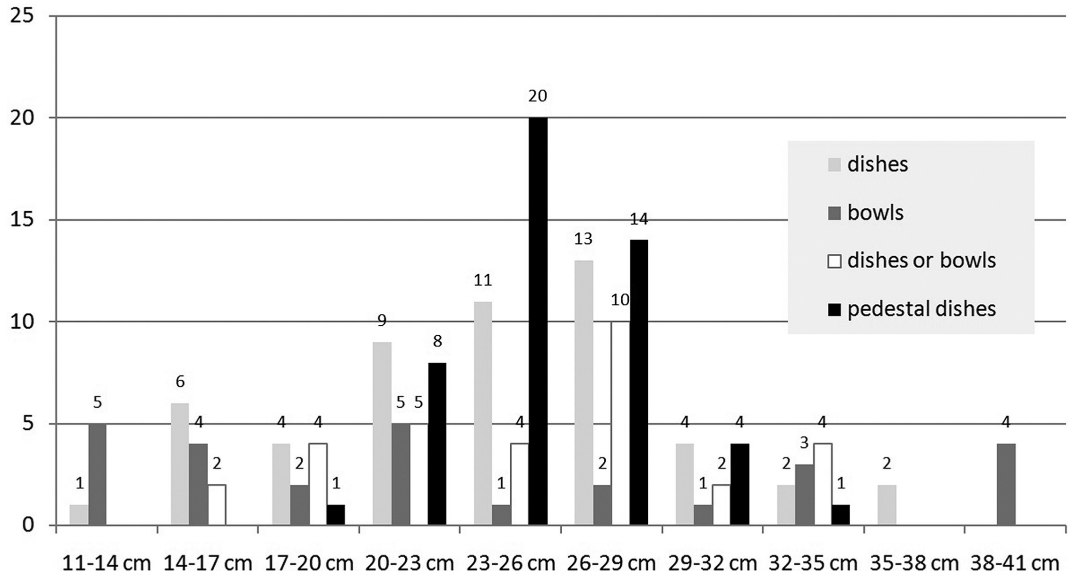

Fig. 12. Opening diameters of pedestal dishes, dishes and bowls showing size classes.

serve meals, the question arises as to how precisely food consumption could have been carried out? In order to try to understand the dining habits at the site, a statistical comparison of the size of openings of dishes, bowls and pedestal dishes was planned. For this purpose, all 153 ceramic objects pertaining to these vessels from structures 5, 17, 22, 9, 20, 8, 6, 7, 3, 11–15, 4, 1 and 19 were selected; 52 examples were from dishes, 27 from bowls, 31 from dishes or bowls and 48 from pedestal dishes.

The analysis revealed that only one smaller group of vessels have openings between 11 and 20cm; most these are dishes and bowls (30); only one pedestal dish has an opening diameter of around 19cm (see *Kramberger 2014.Pl. 9.147*). The reconstructed vessels which fall into this category have volumes between 0.4 and 0.9 litres, which could mean that they were appropriate for individual food consumption (Apps. 1–2). On the other hand, a large quantity of bowls and dishes have larger dimensions and so could not be used for individual consumption. The size of openings of such pedestal dishes, bowls and dishes is most often between 20 and 29cm (59 dishes and bowls; 42 pedestal dishes), some are even bigger, and the biggest bowls and dishes may have openings between 35 and 41cm (Fig. 12)). Taking into consideration completely reconstructed vessels, such bowls range in volume from 4.1 to 11.1 litres, dishes between 1.2 and 6.8 litres, and pedestal dishes between 1.5 and 2.5 litres (Apps. 1–2).

It is of course likely that vessels made from wood and other organic materials were also used in food-related practices, and therefore they could also have been used for serving meals at the site, but they do not appear in our statistics, since wooden objects have not survived. However, there is some possibility that the lack of vessels with smaller diameters on the one hand, and a larger amount with larger diameters on the other, to some extent indicate dining habits.

From ethnographic studies in Slovenia it is well known that even in the recent past families often ate meals from one vessel. According to Gorazd Makarovič, for example, eating meals from one dish was very common in Slovenian territory until the end of the 19th century and still often during the period between the two world wars (*Makarovič 1988–1990.170*). According to Meta Sterle, dishes used for group dining had a special name, '*čpine*' (*Sterle 1987.*

Fig. 13. At lunch in the Poljana meadows near Korensko sedlo (Slovenia), mid-20th century (from photo library of Gorenjski muzej).

110). Only wooden spoons were widespread cutlery items, but were also not always used; many meals were eaten only with the hands. According to written sources, paintings and photographs, people from different regions of Slovenia – Prekmurje, Bela Krajina, Dolenjska and Gorenjska – ate from one large dish. Even the size and shape of preserved dishes from the 19th century testify to the fact that they were intended for eating meals by a group of people; they are relatively big, usually with slightly inverted rims on which a spoon can be rubbed (*Makarovič 1988–1990.169–172*). As mentioned above, researchers in Northern America identified traces of spoon-scratches on bowls with inverted rims, indicating that this shape was well suited to spooning out food. It is perhaps for a similar reason that bowls, dishes and pedestal dishes from the studied site have slightly inverted lips.[12] Moreover, restricted bowls and dishes are also ideal as serving vessels because their slightly inward sloping walls are advantageous for containing contents during serving.

According to Irena Keršič, even chairs were rare in the Slovenian peasant homes in the 19th century in some regions (*Keršič 1988–1990.353*); only individual farmers had tables (*Ibid. 354*). Various objects could be used to serve food; in some cases, they used so-called '*menterge*' that were otherwise used for mixing bread. Elsewhere, they may also have used shelves above the hearths and benches without backrests, which normally served for placing water vessels, or benches along the wall of the house, as well as hearths and ovens (*Keršič 1988–1990.352–358*). While dinning during traditional hand haymaking, for example, a group of people may have used only a bundle of dried grass for easier access to the food (Fig. 13). This particular purpose may have been served pedestals on pedestal dishes, and it is possible to imagine a similar type of food consumption at the studied site and during prehistoric periods in general.

Carbonized organic residues and traces of secondary burning

"*Vessel shape, size and manufacturing technology give archaeologists an indirect basis for hypotheses about vessel use, or at least suggestions about the functions for which a vessel was particularly well suited*" (*Rice 1987.232*). However, traces of secondary burning and carbonized organic residues, as direct indications of use are also available in our ceramic assemblage. Traces of burning can appear on the interior of vessels, but are more often documented on the exterior; on the other hand, in most cases, visible carbonized organic residues are encrusted on the interior of the walls. This suggests that vessels with both features were used for cooking (*e.g., Ashley 2001.136–139; Braun 2010.84–85*). However, we may not completely exclude other possibilities, since the vessels could also have been exposed to uncontrolled fire, such as when the house in which a particular vessel was burnt down, as in the case of our *Butte* from Zgornje Radvanje. Something similar holds for visible carbonized organic residues encrusted on vessel surfaces, because each pattern is more the result of one of the last events, than of multiple cooking episodes (*Oudemans, Boon 1993.222; Budja 2014.196*), so some specimens may have been subjected to uncontrolled fire.

Based on the above, single cases of vessels with traces of secondary burning and carbonized residues may not allow us to draw a final conclusion in the interpretation of their use. Thus, in the following analysis, we try to test how often traces of secondary burning and carbonised residues are present on the pottery and if these are actually related to particular vessel types. Analyses showed that a special variant of dishes and bowls – dishes and bowls with a spout (60%) – most frequently bore traces of secondary burning. Moreover, organic residues are most often preserved on the interior of these vessels (44%). Carbonized remains (18%) and traces of secondary burning (6%) are also sometimes found on dishes and bowls without a (surviving?) spout, while they rarely occur on the other ceramic forms (Fig. 14). According to this, we believe that bowls and dishes with spouts were connected with cooking or heating up food. Similar observations were made, for example, by Dushka Urem-Kotsou, Kostas Kotsakis and Ben Stern while studying the function of Neolithic 'cooking pots' from a Neolithic site at Makriyalos in Northern Greece (*Urem-Kotsou* et al. *2002. 112–113*) and by Keith H. Ashley while making a similar analysis of the San Pedro pottery from a North Beach site on the coast of north-eastern Florida (*Ashley 2001.136–139*). Moreover, mid-chain ketones, which are used as biomarkers for exposure to high temperature, were observed in bowls and dishes from the partly contemporary site at Moverna vas, showing with a high probability that these vessels were used for cooking (*Šoberl* et al. *2014.163*). Ne-

12 See, for example, *Kramberger 2014.Pl. 7.109, 112, Pl. 8.124, Pl. 9.142–143, Pl. 10.155, 159, 161*.

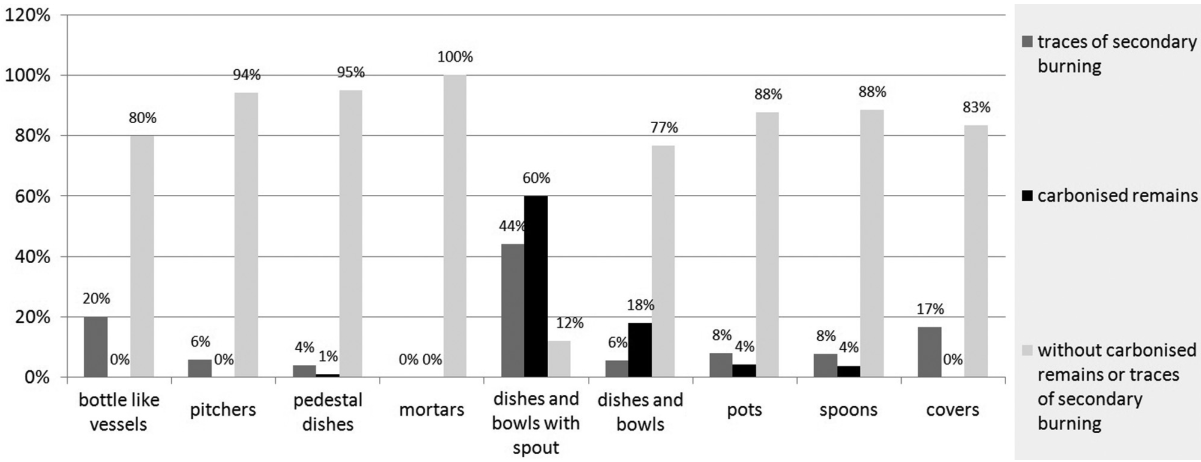

Fig. 14. Traces of secondary burning and carbonized remains by vessel type.

vertheless, at this stage of research, we cannot completely exclude the possibility that the visible black residues preserved on our dishes and bowls are associated with post-firing surface treatment techniques; firstly, because the study is based only on 25 pieces of dishes and bowls with spouts, and secondly, because analyses of other sites have shown that charred organic residues can be either food remains or birch-bark tar (see *Šoberl* et al. *2014.150–151, 158, Fig. 10*).

Settlement structures and the ceramic assemblages

The study of the composition of the ceramic assemblages of different types of structures at the settlement of Zgornje Radvanje gives us interesting evidence about the storage, preparation and consumption of food and drink. It was found that the composition of these ceramic assemblages is not homogeneous and that it relates to the type of structure. The first deviation was noted within trapezoidal structure 5. It was found that the smaller pits excavated at the bottom of the feature (structure 5 – phase 1) contained more of the larger pots (51.8%). Most were relatively well preserved, so if it is accepted that larger pots were primarily used for storage, these pits may be interpreted as storage pits (see *Kramberger 2010.312*, *Figs. 2–3, Fig. 23,*[13] *Apps. 1–2*). In addition, these pits contained fragments of dishes and bowls (25.9%), fragments of a pedestal dish (3.7%) and a single bottle-like vessel (3.7%). In phase 2 of structure 5, defined by the remains of a trapezoidal house, pots (27.5%), dishes, bowls (a combined total of 13.7%), pedestal dishes (6.9%), pitchers (15.6%) and ladles (3.7%) are common. A similar composition of the pottery was found in other buildings with a deepened trapezoidal plan and a fireplace or hearth, as well as in both rectangular houses with fireplaces, the only difference being that the latter also contained weaving weights. It is also interesting to note that the only *Butte*-type vessel was found in structure 20 and that bottle-like vessels were found in other structures with fireplaces: two in structure 5 (the second example is from phase 2), one in structure 17 and one in structure 22. These are all larger examples of bottle-like vessels found on the settlement; only one small bottle-like vessel has been found (Fig. 15).[14]

In features without fireplaces, basically the same types of vessels as in buildings with fireplaces were found, with only a few exceptions. The composition of the ceramic finds suggests that the smaller feature (19) was used for weaving, since in addition to the rectangular buildings with a fireplace it is the only other structure in the settlement in which weaving weights were recorded, and even in a large quantity (37.5%, *i.e.* at least 12 different objects). The smaller features 4 and 1 differ from the others in containing spindle whorls. However, the remaining features yielded a similar composition of finds as the features with fireplaces or hearths, and the only difference is that they are based on the percentages of different ceramic forms, less standardized. As a result, their purpose is more difficult to interpret on the basis of ceramic finds alone (Fig. 16).

13 The bottle-like vessel was recognised later as a special vessel type, and in the first publication it was treated as a pot; therefore, there is a small difference in the percentages of pots in phase 1 between the former and this publication.

14 This bottle-like vessel is similar in size to some pitchers and also has similar decoration (*Kramberger 2014.Pl. 8.130*).

Conclusion

The Eneolithic settlement at Zgornje Radvanje shows a wide range of vessel types, of which some were related to the storage, preparation and consumption of food and drink, while others were connected with various daily activities such as textile production. Pots and bottle-like vessels were the largest vessels at the settlement. For the biggest pot specimens we can calculate volumes between 12.1 and 15.4 litres, which makes them well suited for storage. Bottle-like vessels could have been used for storing liquids, although we should note that they are rare in the settlement, so we also have to consider the use of barrels or leather bags for storing liquids. The pitchers of different sizes and varying smaller volumes served as drinking vessel.

Techno-functional analyses showed that bottle-like vessels, pitchers and pedestal dishes were often produced to different standards than pots, dishes, bowls, mortars, lids and ladles. The first were in most cases made of the most fine-grained fabrics, fired in incomplete oxidizing or oxidizing conditions with a reducing atmosphere at the end, and their surface before firing was carefully treated (sponging, colour clay slip, polishing). On the other hand bowls and dishes, pots, ceramic ladles, lids and mortars were often made of more granular fabrics with more inclusions of quartz and mostly fired in incomplete oxidizing or oxidizing conditions. Their surface was most often sponged before firing, and they appear with shining polished surfaces and a colour clay slip rarely. The different surface treatments and granularity of fabrics influences the vessels suitability for holding liquids, while the reducing atmosphere at the end of firing process produces the greyish/dark greyish surface. Based on these, we may conclude that one of the most important factors in the production of pitchers, bottle-like vessels and pedestal dishes was to prevent liquids from penetrating the ceramic, and so these vessels were well suited for storing and serving liquids or perhaps a liquid food (pedestal dishes).

Some vessels give further clues as to their use. In this connection, we can mention the dishes and bowls with spouts, which of all vessel types had the most frequent traces of secondary burning, showing that they were associated with the preparation of food, cooking or heating up meals. Preserved carbonized residues appeared most frequently on their inner surfaces, which could be interpreted as food remains. However, such interpretations based solely on visible residues may be misleading, since something that looks at the first sight like food remnants could be something else – for example, the result of a post-firing treatment technique to produce a more liquid-resistant surface. Therefore, some chemical analysis of carbonized residues needs to be done to test our assumption.

Concerning the use of the vessels, especially interesting is the so-called *Butte*, a vessel type well known in the Neolithic and Early Eneolithic in central and south-eastern Europe, which characteristically have horizontal handles on the belly and either on the transition to the upper part of the body or on the shoulders. On the one hand, the shape of this vessel with a small opening and a voluminous body indi-

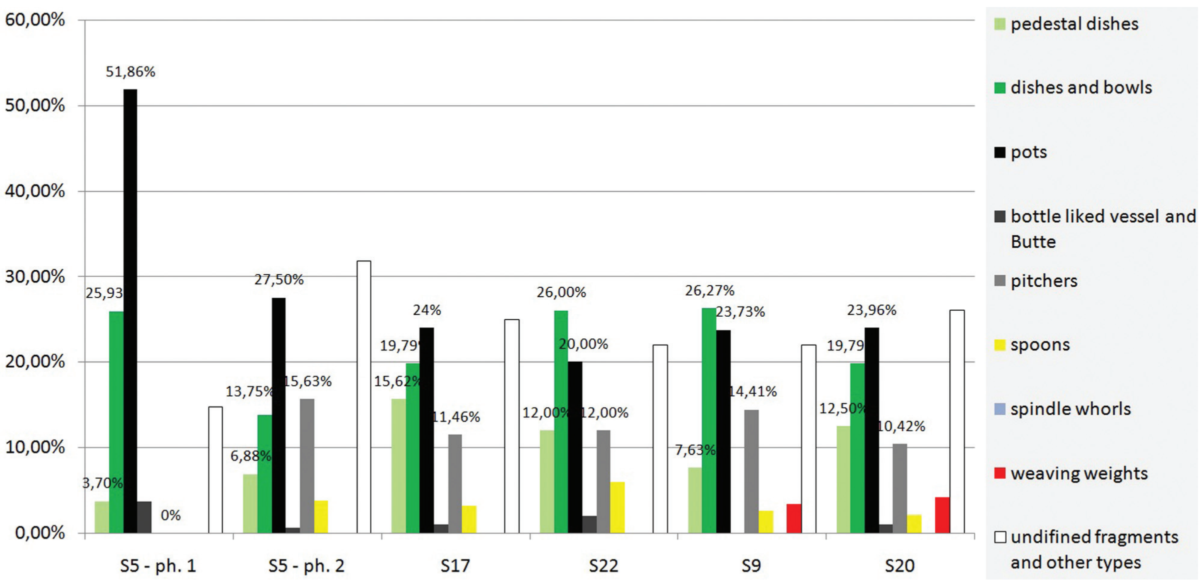

Fig. 15. Structures 5, 17, 22, 9 and 20 (with fireplaces). The composition of pottery assemblages.

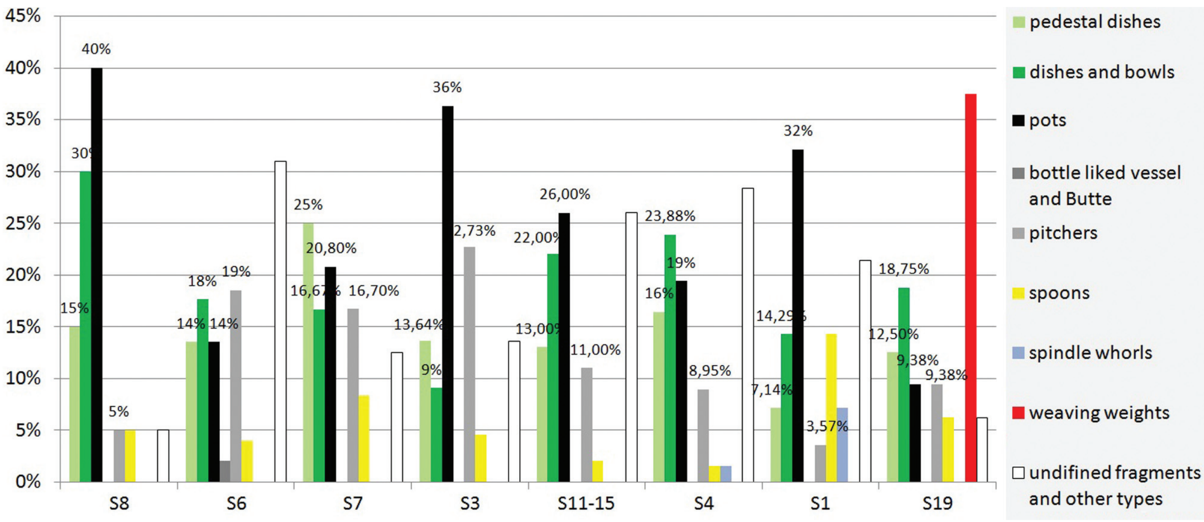

Fig. 16. Structures 8, 6, 7, 3, 11–15, 4, 1 and 19 (without fireplaces). The composition of pottery assemblages.

cates that it was used in connection with the storage of liquids; on the other hand we know from ethnographical parallels, that similar vessels with handles are used as a kind of 'backpack' for transporting water over large distances.

Pedestal dishes and perhaps also dishes and bowls without spouts, may have been used for serving meals. Smaller ladles could be used as a form of cutlery, while bigger ones were suited for transferring food. Most pedestal dishes, dishes and bowls are relatively large, which means that they could contain more food than was needed for one person. Consequently, this could mean that they were intended for more people, which is also known from ethnographic parallels, and on the territory of Slovenia, for example, was still common until the Second World War. Pedestals may have made access to food easier, while the inverted lips of such vessels could have simplified spooning up the food.

Besides the analysis of the form and function of the vessels from Zgornje Radvanje, we also studied the distribution of pottery in different settlement structures. In this connection, it is interesting to mention that this analysis shows indeed some differences between the various settlement structures. We can conclude that the ceramic assemblages which were obtained from the single-roomed trapezoidal houses and double-room rectangular buildings are relatively standardised in their composition. Hearths or fire places were found in these features, so it may be assumed that they served as residences and places where food was prepared. The smaller pits excavated at the bottom of structure 5 served perhaps as storage pits, because larger pots that can be interpreted as storage vessels were predominant in them. It should be mentioned, of course, that structures with fire places also served for other activities, as they contained, among other things, weaving weights, seals and a special find which can be interpreted as a lamp. On the other hand, the ceramic assemblages in other features are less standardised in their composition, so they probably served other purposes; although for most of them it is not yet clear which. To solve this problem, at first the fragmentation of ceramic assemblages and the comparison of stone tool assemblages within the features need to be examined. Almost 500kg of stone tools and stone implements were found at the site, and concerning that, the settlement at Zgornje Radvanje diverges significantly from other known Eneolithic sites in Slovenia.

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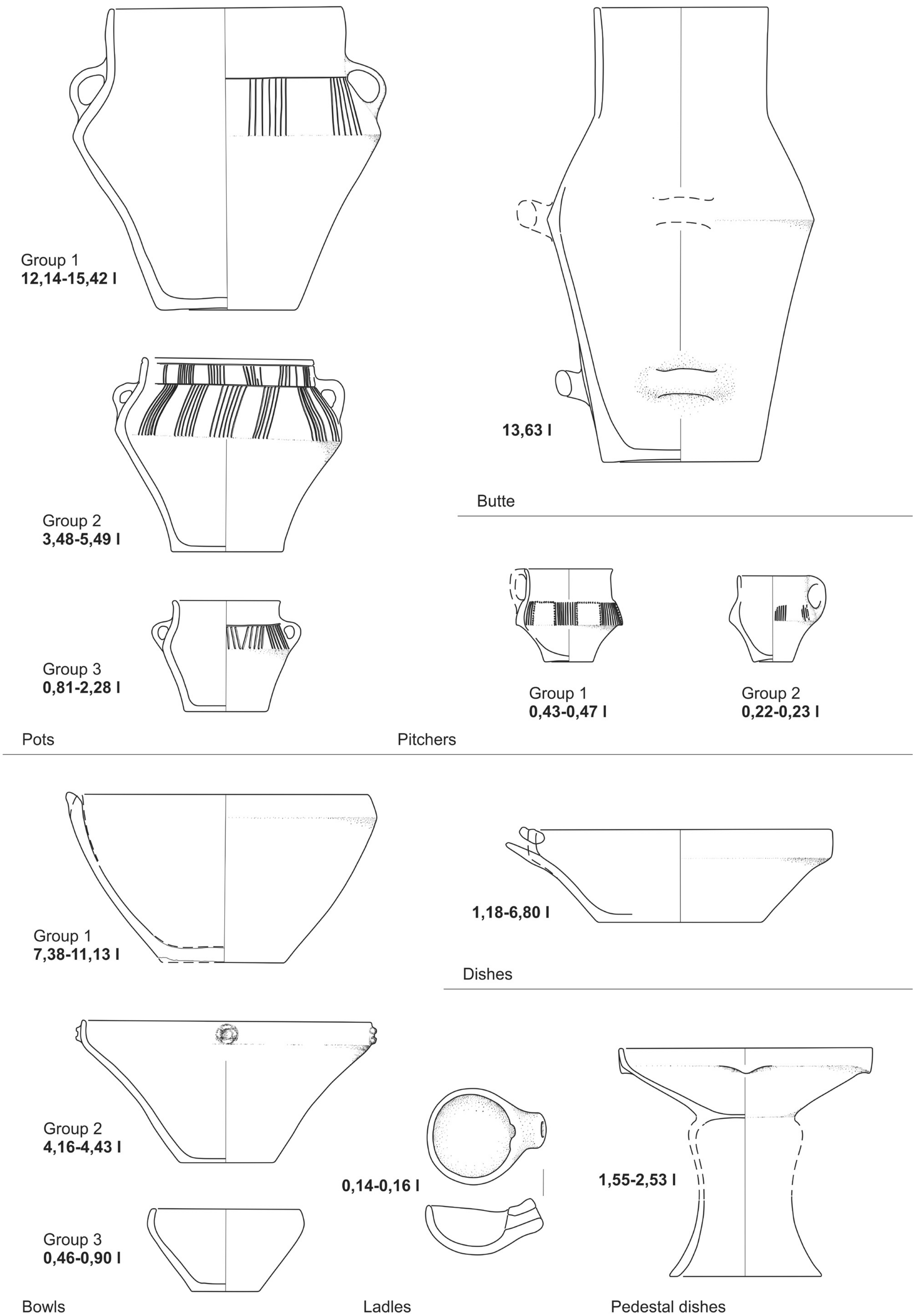
Appendix



App. 1. Pots, a Butte, pitchers, bowls, dishes, pedestal dishes, ladles and their volumes. Scale 1:6.

Vessel type	Context	Drawing Code	Volume in litres	Size of orifice	Reference
pot	Structure 9 (SE 553)	384A	15,42 l	21,9 cm	–
pot	Structure 5 (SE 271)	B 16	15,30 l	23 cm	*Kramberger 2010.Pl. 8.51*
pot	Structure 3 (SE 544)	1123A	12,71 l	23,4 cm	–
pot	Structure 5 (SE 324)	B 165	12,14 l	24 cm	*Kramberger 2010.Pl. 2.12*
pot	Structure 1 (SE 599)	1065A	5,49 l	16,5 cm	*Kramberger 2014.Pl. 9.152*
pot	Structure 11-15 (SE 786)	716A = 719A	5,47 l	17,4 cm	–
pot	Structure 22 (SE 853)	1292A	5,42 l	15,6 cm	*Kramberger 2014.Pl. 7.122*
pot	Structure 5 (SE 324)	B 108	4,97 l	17 cm	*Kramberger 2010.Pl. 4.20*
pot	Structure 4 (SE 1128)	561A	4,82 l	16,5 cm	*Kramberger 2014.Pl. 9.146*
pot	Structure 5 (SE 271)	B 122 = B 107	4,66 l	16,2 cm	*Kramberger 2010.Pl. 7.48*
pot	Structure 5 (SE 324)	B 443	4,21 l	17,4 cm	*Kramberger 2010.Pl. 3.18*
pot	Structure 6 (SE 226)	37A = 45A	3,53 l	15 cm	*Kramberger 2014.Pl. 8.131*
pot	Structure 5 (SE 271)	B 444	3,48 l	16 cm	*Kramberger 2010.Pl. 9.52*
pot	Structure 20 (SE 1420)	1620A	2,28 l	15 cm	–
pot	Structure 5 (SE 271)	B 158 = B 94	0,81 l	11 cm	*Kramberger 2010.Pl. 7.46*
Butte	Structure 20 (SE 1458)	41	13,63 l	18 cm	–
pitcher	Structure 7 (SE 18)	79A = 87A	0,47 l	9 cm	*Kramberger 2014.Pl. 8.135*
pitcher	Structure 22 (SE 820)	1257A	0,44 l	9 cm	*Kramberger 2014.Pl. 7.116*
pitcher	Structure 4 (SE 1128)	558A	0,23 l	6,6 cm	–
pitcher	Structure 5 (SE 271)	B 10 = B 194	0,22 l	6,9 cm	*Kramberger 2010.Pl. 7.42*
bowl (with a spout)	Structure 9 (SE 546)	284A	11,13 l	34,5 cm	–
bowl (with a spout)	Structure 4 (SE 1128)	521A	7,38 l	30 cm	–
bowl (with appliqués)	Structure 5 (SE 271)	B 57 = B 3	4,43 l	30 cm	*Kramberger 2010.Pl. 4.23*
bowl (with appliqués)	Structure 5 (SE 324)	B 174 = B 18	4,38 l	23 cm	*Kramberger 2010.Pl. 1.6*
bowl	Structure 17 (SE 1435)	1840A	4,16 l	26,4 cm	–
bowl	Structure 20 (SE 1458)	1454A	0,90 l	15,3 cm	–
bowl	Structure 5 (SE 271)	B 26	0,82 l	15,3 cm	*Kramberger 2010.Pl. 5.27*
bowl (with handles)	Structure 17 (SE 1435)	1854A	0,79 l	12,6 cm	–
bowl (with small perforated handles)	Structure 9 (SE 546)	391A	0,46 l	13,2 cm	–
dish (with a spout)	Structure 4 (SE 1128)	560A = 556A	6,80 l	33,3 cm	*Kramberger 2014.Pl. 9.143*
dish (with a spout)	Structure 3 (SE 425)	1124A	4,14 l	31,5 cm	–
dish (with a spout)	Structure 4 (SE 1128)	559A	3,17 l	27 cm	*Kramberger 2014.Pl. 9.145*
dish	Structure 17 (SE 1414)	1787A	1,98 l	22,5 cm	–
dish (with a spout)	Structure 20 (SE 1458)	1672A	1,18 l	20,1 cm	–
pedestal dish	Structure 3 (SE 425)	1164A = 1131A = = dš1	2,53 l	28,5 cm	–
pedestal dish	Structure 11-15 (SE 1329)	807A	2,46 l	26 cm	–
pedestal dish	Structure 4 (SE 1128)	522A	2,44 l	28,5 cm	*Kramberger 2014.Pl. 9.142*
pedestal dish	Structure 11-15 (SE 786)	725A	2,03 l	25,5 cm	–
pedestal dish	Structure 9 (SE 553 and SE 546)	373A	1,93 l	26 cm	–
pedestal dish	Structure 9 (SE 553 and SE 468)	352A = 328A	1,66 l	22,2 cm	–
pedestal dish	Structure 5 (SE 271)	B 159	1,55 l	22,5 cm	*Kramberger 2010.Pl. 6.33*
ladle	Structure 5 (SE 271)	B 452	0,16 l	11 cm	*Kramberger 2010.Pl. 9.53*
ladle	Structure 1 (SE 599)	1851A	0,14 l	9,4 cm	*Kramberger 2014.Pl. 9.151*

App. 2. List of fully reconstructed vessels obtained from the settlement structures with volumes measured.

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Neolithic ceramic spoons – indicators of dietary distinctiveness in the eastern Adriatic Neolithic?

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ABSTRACT – *Among the rich and diverse archaeological finds collected at more than fifty known Neolithic sites in the entire area of the eastern Adriatic and its hinterland, ceramic spoons comprise a group of very rare and almost marginalised items. Only eight examples, discovered in the northern and central Dalmatia region (hinterland of Zadar and Šibenik), at open-air Neolithic sites known to date to the Middle and Late Neolithic. Based on current research and in accordance with the available archaeobotanical and zooarchaeological data from Neolithic sites in the eastern Adriatic region, this paper poses a question about the connection of ceramic spoons with the dietary habits of Neolithic communities in the eastern Adriatic.*

IZVLEČEK – *Keramične žlice predstavljajo skupino redkih in celo marginaliziranih predmetov med drugimi bolj bogatimi in raznolikimi arheološkimi najdbami, ki so jih odkrili na več kot petdesetih neolitskih najdiščih na območju vzhodnega Jadrana in v zaledju. Le osem predmetov, ki so jih odkrili na najdiščih na prostem v severni in osrednji Dalmaciji (v zaledju Zadra in Šibenika), lahko datiramo v srednji in pozni neolitik. V članku se sprašujemo o povezavah med keramičnimi žlicami in prehranskimi navadami v neolitskih skupnostih v vzhodnem Jadranu. Te povezave gradimo na podatkih iz nedavnih raziskav in v skladu z dosegljivimi arheobotaničnimi in zooarheološkimi podatki za neolitska najdišča v tej regiji.*

KEY WORDS – *Neolithic; ceramic spoons; dietary habits; eastern Adriatic; Zadar and Šibenik regions*

Introduction

By the mid-20th century, the activities and preoccupations of daily life, as well as different patterns of behaviour conditioned by the objective possibilities and potential of the natural environment were already at the centre of archaeological interest. The life hidden behind rich cultural landscapes and diverse archaeological finds created a need for meaningful and argument-based evaluations of the archaeological record, which hides answers to various questions concerning the social and economic aspects of life of the prehistoric cultures (*Novaković 2008.21–44*). At the same time, Neolithic studies also dealt with archaeological artefacts interpreted as the remains of experience arising from the reality in which a community resided. In this context, the archaeological paradigms developed in the mid-20th and during the second half of the 20th century (processual and experimental archaeology in the1960s, behavioural archaeology in the 1970s and post-processual archaeology in the 1980s) played an important role, along with the general development and intensification of interdisciplinary research, deepening the idea of causal relations between the natural and the cultural, and thus expanding the field of scientific archaeological research work and paving the way for some modern archaeological interests and research concepts. An attempt was made to create a comprehensive archaeological interpretation replaced traditional research approaches and strategies oriented towards stylistic-typological and chronological studies by undertaking research aimed at wider aspects of life, including those related to the eating habits and practices of the Neolithic communities (*Rice 1987; Bakić 2001; Sherratt 2002; Urem-Kot-*

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sou et al. *2002; Richards* et al. *2003; Šoberl* et al. *2008; Bonsall* et al. *2009; Urem-Kotsou 2011.251; Mlekuž* et al. *2012; Budja* et al. *2013; Mlekuž* et al. *2013*).

Life and nutrition in the eastern Adriatic Neolithic

Already in the Early Neolithic, the entire area of the eastern Adriatic, from the Trieste Karst in the north to the Strait of Otranto in the southeast, had become an area of intense interaction with natural resources, which was crucial for the successful development of the Neolithic way of life, as it was based on agriculture and cattle breeding. However, the general acceptance, affirmation and quality of these Neolithic branches, along with hunting, gathering and fishing, were preceded by understanding the naturally heterogeneous environmental conditions in the eastern Adriatic. The alternation of denuded and waterless karst landscapes, sunken karst fields and ridges, limestone plateaus and fertile valleys filled with springs, ravines and underground streams (*Magaš 1998.195*) affected all aspects of life, as well as the character and dynamics of cultural development. At the same time, life defined by natural potential and limitations demanded a rational selection of narrow spatial environmental units and a respectful attitude to local resources, which have very often been the main factors in socio-economic development. The capacity to adapt to objective environmental factors (soil, climate, relief *etc.*) as important existential guidelines reached its full expression in spatial context, starting from the micro-locations of individual settlements to wider spatial patterns of settlement. In this way, settlements became the main centres of interaction between the environment and well-organised Neolithic communities, which attempted to bring all their life preoccupations into the closest contact possible with the available natural resources.

This view is supported by Neolithic sites on the eastern Adriatic divided into three main spatial and settlement clusters based on distribution and density (Fig. 1). In the northern unit, located on the coastal part of Istria and the Kvarner islands, both open-air and cave sites are represented (*Zlatunić 2004.26–38*). In the second cluster, located in the regions of Zadar and Šibenik, open-air sites are predominate (*Batović 1979. 491, 576*), while only cave sites located on the southern Adriatic islands are represented in the third cluster (*Marijanović 2003.111*). Significant differences between these spatial units are evident in terms of economic strategies, which clearly follow the natural and geographic variability of the eastern Adriatic landscape. Conditions for the development of cattle breeding were certainly better for communities located in the dynamic karst relief of the northern and southern part of the eastern Adriatic (*Brusić 2008.63–64*), while the central Zadar and Šibenik regions, still renowned for their large fertile areas, offered the best conditions for agriculture (*Magaš 1998.235; Faričić, Marelić 2014*).

In view of these differences, undoubtedly conditioned by the causal relationship between the Neolithic communities and the natural basis of the eastern Adriatic, the focus of this paper is on the aforementioned central spatial and settlement unit, which includes the Zadar and Šibenik regions. It is a fertile and area in northern and central Dalmatia, which, owing to its natural position and rich economic potential, has remained an important centre of the diverse cultural, historical and economic development of the eastern Adriatic (*Magaš 2013.52–56*).

In a broader geographical context, the wider hinterland of Zadar lies in the Ravni Kotari region, which is characterised by parallel forms of Dinaric spreading. Alternating carbonate peaks and fertile valleys filled with the Eocene flysch deposits form the ba-

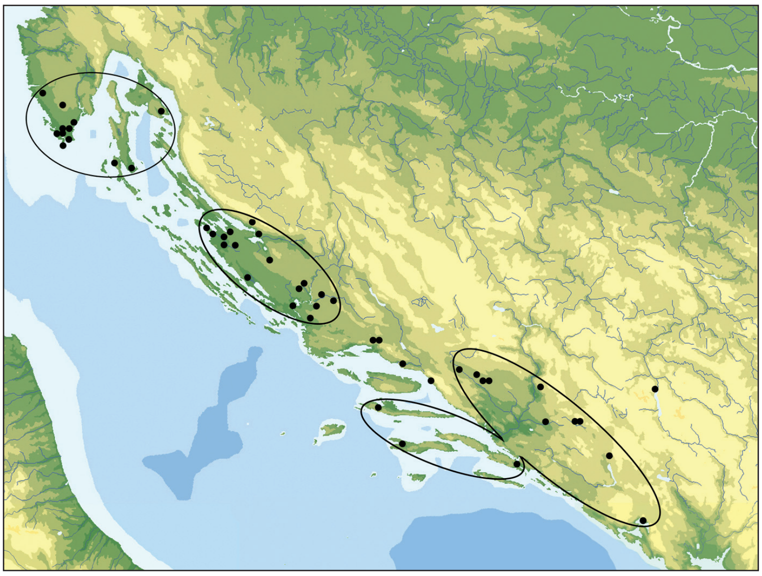

Fig. 1. Spatial-settlement clusters of the Neolithic Eastern Adriatic (after* Marijanović 2009.Karta 1*).

sis of a terrain which has no discernible limitations on internal communication (*Majcen* et al. *1973; Magaš 1998.235*). Due to the agricultural potential and water-retention capacities, flysch deposits played a crucial role in the historical and geographical development of this region (*Surić 2009.28–31*), which is still important in economic terms for the Zadar area. The wider Šibenik region is a transitional area from the northern to the central Dalmatian region. Along with flysch glens, there are basins with deposits of lake sediment from the Neogene, karst hills and karst plateaus, giving this area more dynamic relief features (*Magaš 1998.244*).

Considering the number, distribution or long duration of the Neolithic settlements in the wider Zadar and Šibenik regions (Fig. 1), we come to the conclusion that it was a very favourable spatial and environmental environment. The fact that its natural resources not only attracted, but also permanently satisfied the subsistence and activities of the Neolithic inhabitants is confirmed by the Neolithic settlements which have been found only a few kilometres apart. Alongside high population density, it is important to emphasise that their stratification testifies to long and very often continuous lives through several periods of the Neolithic (*Batović 1979.579–582; Brusić 2008.33–34; Marijanović 2012.7; Čondić 2012/2013*). The constancy of tradition in terms of the retention of the same micro-location for a long period can be considered as a reliable indicator of the balance and stability of life based on various suitable micro-locations, but also evidence of a fairly uniform way of life and economic strategy, which did not require a change from established spatial patterns. From the Early to the Late Neolithic, almost identical micro-locations in the region in northern and central Dalmatia were selected on the periphery of large areas of arable and fertile land close to springs (*Batović 1979.525*). As crucial resource and one of the most important determinants in the development of all forms of productive economy, water had a very important role in northern Dalmatia throughout the Neolithic, as confirmed by previously discovered Neolithic sites, usually located near watercourses (*Batović 1962.32; 1990.32; Korošec 1958.124; Brusić 2008.13; Marijanović 2003a*).

To what extent did the consistency of the way of life adapted to the environmental characteristics affect the nutrition of the Neolithic inhabitants of northern and central Dalmatia? Are there any indications of local particularities associated with strictly regional resources in this context? These are issues which have not received major attention (*Miracle, Pugsley 2006.313–329; Moor* et al. *2007b. 30–32; Marijanović 2009.48–53*). However, the discovery of exceptionally rare ceramic spoons during recent archaeological research conducted at sites at Benkovac, Pokrovnik and Velištak has opened new perspectives on this theme.

The Neolithic site at Barice in Benkovac is definitely among the most important archaeological sites in northern Dalmatia. It is a large settlement complex located along the periphery of the modern town of Benkovac, where Early and Middle Neolithic settlements were identified on the basis of archaeological finds and small-scale trial excavations (*Batović 1990.28; Marijanović 2012*). Judging from the finds, the settlement may also have seen a Late Neolithic phase (Hvar culture).[1] Systematic archaeological excavations were carried out in 2012[2] in the central part of the complex, which can be attributed to the Middle Neolithic, or the Danilo culture. Several successive dwelling horizons with well-defined dwellings were found, as well as rich and diverse archaeological finds, including a ceramic spoon (*Vujević, Horvat 2012.44*).

Fig. 2. Ceramic spoons from Barice (Benkovac) and Pokrovnik (foto D. Vujević, S. Govorčin).

1 The information was found in the documentation of the Regional Museum in Benkovac. I would like to thank colleague Marin Ćurković, director and curator of the museum, for allowing me to see the documentation.

2 The excavations were led by Prof. Branislav Marijanović within the research project *Early prehistoric periods in the eastern Adriatic region*, as part of students' field practice at the Department of Archaeology, University of Zadar.

Fig. 3. Ceramic spoons from Pokrovnik and Velištak (foto E. Podrug).

The spoon was found in the north-western corner of a compact research area of 255m² in the contact layer between the intact Neolithic layers and upper layers destroyed by lengthy agricultural activities (ploughing). This is clayey and loamy soil under which a segment of floor was defined with the remains of a small fireplace. The cylindrical handle is fully preserved, while the ends of the concave part are broken off (Fig. 2.a). The technological characteristics of the spoon correspond to the category of coarse Danilo pottery made of purified clay with inclusions of crystalline limestone and small stones (*Vujević, Horvat 2012.42*).

A similar but finer ceramic spoon was found in 2013 at the Pokrovnik – Copića njive site in the hinterland of Šibenik. It is the Early and Middle Neolithic site (*Brusić 2008; Moore* et al. *2007a; 2007b*) at which the last research campaign was conducted by the Department of Archaeology, University of Zadar.[3] The research in 2013 encompassed the eastern segment of the settlement area (total of 100m²) where only layers of the Danilo culture, *i.e.* Middle Neolithic were found. Immediately under the humus layer, at a depth of 30cm, parent rock with a channel 20–30cm deep filled with small amorphous rocks was found. A ceramic spoon was singled out among the rich ceramic finds with a fully preserved handle and a concave part with broken ends (Fig. 2.b). The walls of the spoon are finely made, while the fabric corresponds to the other ceramic repertory of coarse Danilo pottery made of clay with a small amount of inclusions (*Vujević, Horvat 2016*).

The same site produced another ceramic spoon during the first excavations in 1979 (*Brusić 2008.T. LXXIX, 9*). It was found in the north-eastern part of the excavated area, in a small trial trench (25m²) which contained Early and Middle Neolithic layers in which the bedrock was reached at a depth of as much as 210cm. The spoon was found in the cultural of the Middle Neolithic layer at 30–45cm; this was an intact Neolithic layer with the remains of dwellings (*Brusić 2008.49*). The handle of the spoon is fully preserved, while most of the concave portion is missing (Fig. 3.a). It is made of clay with a high percentage of inclusions.

A ceramic spoon was found (Fig. 3.b) at the Late Neolithic site at Čista Mala – Velištak, located in the hinterland of the city of Vodice (*Podrug 2010*) during the research campaign in 2011[4] in an intact Neolithic cultural layer between humus and bedrock which was not related to some specific archaeological formation. On the basis of radiocarbon dates the layer was ascribed to the first phase of the Hvar culture (4900–4700 BC). Its slightly bent handle was preserved completely, while half of the concave part was missing.

Fragments of three ceramic spoons, hemispherical in shape with thick handles and round section (Fig. 4.b) were found at the Middle Neolithic site of Danilo Bitinj during the first archaeological research projects conducted in the mid-20th century (*Korošec 1959*).[5] It is interesting that the fabric and production technique of these spoons differ from the other ceramics in which the proportion of inclusions is significantly lower, and the walls are much finer (*Korošec 1958.93*).

A ceramic spoon was found among the ceramic finds collected in the 1950s on ploughed fields at the Ba-

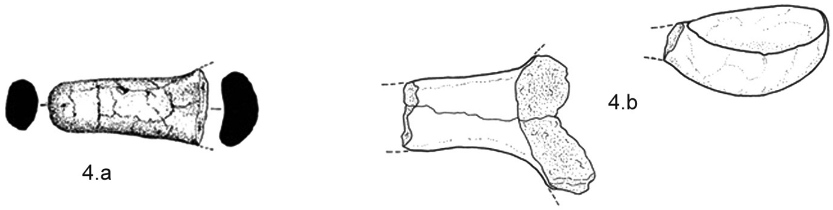

Fig. 4. Ceramic spoons from Smilčić and Danilo Bitinj (after **Batović 1962.Sl. 24.4; Korošec 1959.T. XLVIII, 1–3***).*

3 The research was conducted as part of the research project *Early prehistoric periods in the eastern Adriatic region*, under the guidance of Prof. Marijanović. The research results have not been published yet.

4 I would like to thank Emil Podrug, curator of the prehistoric collection of Šibenik City Museum, for allowing me to publish the find.

5 Precise information about the context of the find is missing.

rice site in Smilčić (*Batović 1962*); later excavations at this site revealed Early, Middle and Late Neolithic settlements. This find was the flattened oval handle of a ceramic spoon, with the concave part completely broken off, and can be recognised by a slight expansion (Fig. 4.a). On the basis of the fabric, the spoon was attributed to the fine Danilo pottery (Middle Neolithic) made of well-purified clay (*Batović 1962.90*).

Discussion

The spatial distribution and scarcity of the ceramic spoons found in the eastern Adriatic region are indeed most intriguing. How is it possible that among all the rich and diverse archaeological finds collected from more than fifty known Neolithic sites in the entire area of the eastern Adriatic and its hinterland, there have not been more such finds? How can we explain their scarcity outside the limited geographical area of northern and central Dalmatia? Is it just a coincidence, or a true reflection of life and cultural development marked by the emergence of local particularities, in this case materialised in the emergence of ceramic spoons? What caused these particularities and how can we interpret them, given what we know about the region in question? Given that the importance of the environment and its potential is attested in almost every aspect of the life of eastern Adriatic Neolithic communities, from distribution and population density, category and type of settlement, economic strategies, spiritual culture and some other material aspects (*Marijanović 2007; Vujević, Horvat 2013*), it seems that answers to these questions should be sought in that direction.

The continuing causal relationship between the natural and the cultural must have assumed a new meaning in the Neolithic period. Natural conditions became an expression of the socio-economic interests of prudent Neolithic communities (*Higgs, Vita-Finzi 1972*) which tried to exploit natural potential as much as possible. In archaeological terms, the relations between the natural and the cultural are reflected in archaeological finds and indicative archaeological appearances, such as the aforementioned micro-location strategies and correspondence of the economic structure in all three Neolithic phases (*Batović 1979*). The study of the direct relationship between economic and settlement aspects with the eating habits of the Neolithic communities discussed in this work on the basis of a few ceramic spoons requires a holistic approach, which implies a consideration of the spatial context in which the spoons were found (geographic-environmental and micro-location) together with the available bioarchaeological information testifying to the survival strategies of Neolithic communities in the eastern Adriatic, *i.e.* the acquisition of food as a form of adjustment to actual natural conditions.

All the previously known Neolithic ceramic spoons were found in the Neolithic settlement in the Zadar and Šibenik regions (Fig. 5). These are open-air sites which date to the Middle and Late Neolithic. Although in these settlements, structures associated with processing and storing foods, such as grain storage pits have been found (*Podrug 2012/2013.205*) along with hearths and fireplaces (*Moore* et al. *2007.17*), their connection with spoons has not been established. Possible connections might be considered only in the case of Barice in Benkovac, where a spoon was found in a cultural layer positioned over a Neolithic house with a small fireplace. However, since shallow pits filled with small rocks and ash were found at the same time and determined as hearth remains outside the excavated dwellings (*Marijanović 2012.12*), this hypothesis on possible connections between the fireplace and spoon remains speculative. A detailed analysis of bio-archaeological data from inside and outside the dwellings would be helpful, especially in interpreting the

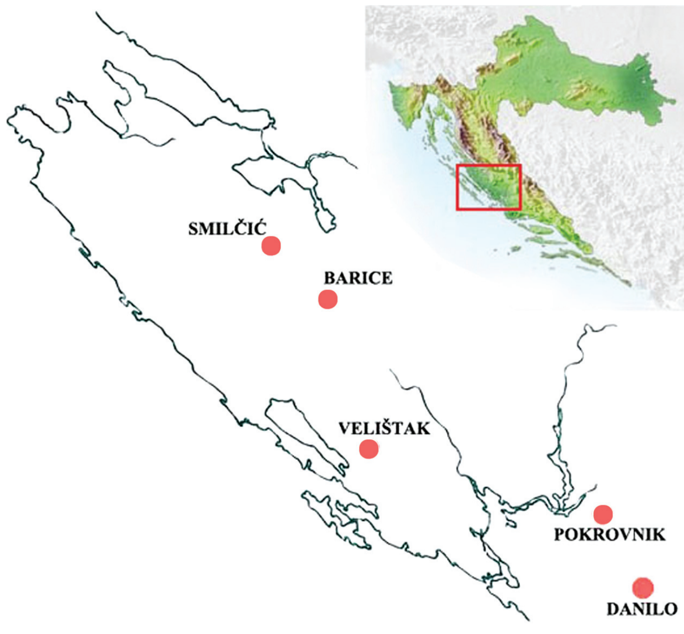

Fig. 5. Position of the Neolithic sites at Barice in Benkovac, Smilčić, Pokrovnik – Copića njive, Danilo Bitinj and Čista Mala – Velištak.

settlement organisation and understanding the principles of preparation, consumption and storage of food. Recently explored Neolithic sites offer more information on this subject, due to interdisciplinary research which is also aimed at completing the image of the economy of Neolithic communities in the eastern Adriatic.

Excavations in Pokrovnik (Copića njive) have shown that the inhabitants of this Neolithic settlement raised domesticated plants and animals, while game and wild plants were barely represented. Ovicaprids are predominate in the domesticated fauna (82.5%), and barley (*Hordeum sativum*), emmer (*Triticum dicoccum*) and einkorn (*Triticum monococcum*) predominate among plant remains from the flotation samples (*Müller, Karg 1990; Moore* et al. *2007b.30*). Only minor differences were attested at the Middle Neolithic site of Danilo Bitinj, which is about 10km from Pokrovnik.[6] Ovicaprids were predominant here as well (79.4%), and flotation yielded remains of many domesticated and wild plants, with einkorn (*Triticum monococcum*), hulled barley (*Hordeum sativum*) and blackberry (*Rubus fruticosus*) as the most common species (*Moore, Menđušić 2004; Moore* et al. *2007.19–20*). Almost identical information was obtained in the recent analyses of animal remains and carbonised plant remains from the nearby Early Neolithic settlements in Tinj and Crno Vrilo (*Huntely 1996; Šoštarić 2009*), while maritime fauna were well represented, which is in accordance with its great importance in the diet of the eastern Adriatic Neolithic communities living close to the coast (*Marguš* et al. *2005; Marijanović 2009.48–49*).

On the other hand, paleobotanical analyses of systematically collected samples from the environment of cave sites situated in the karst hinterlands of Istria and the southern, insular area of Dalmatia which lie within the northern and southern Neolithic spatial and settlement cluster (*Marijanović 2003*) offered different information about the economy of these sites; namely, seeds of domesticated plants have been found only in the layers of the Late Neolithic in Grapčeva cave on the island of Hvar (*Borojević* et al. *2008.286*) and Krčina cave near Klis, where impressions of domesticated wheat grain were found on pottery sherds from the Early Neolithic layers (*Müller 1994.64*). Paleobotanic finds have not been identified at other excavated sites (Pupićina Peć in Istria and Nakovana Cave on Pelješac) although intensive searches have been made (*Forenbaher, Kaiser 2000.13–15; Forenbaher, Miracle 2006.491*).

Considering the karst basis and total lack of arable land near these cave sites, these data are not surprising. Large amounts of animal remains testify to the predominance of cattle breeding in the cave sites from the Neolithic onwards, and domesticated animals were bred primarily for meat (*Miracle, Pugsley 2006.329*). This was confirmed by the results of recent analyses of mammal remains from Vela Spila on Korčula, Zemunica Cave in the foothills of northern Mali Mosor (about 35km from Split) and Vela Peć in the western foothills of Učka (*Radović 2011.52, 85, 132*).

Although we have only a few indirect indicators of the spatial varieties of economic/dietary activities of Neolithic communities on the eastern Adriatic, their causality and compatibility with the objective possibilities of the limited spatial and environmental context in the eastern Adriatic is not disputable. Images obtained from the zooarchaeological and archaeobotanical analyses conducted in the area of the central spatial and settlement unit in which ceramic spoons were found is different from the image offered by the analyses of the remains of flora and fauna recorded in the northern and southern Neolithic spatial and settlement units where ceramic spoons were absent. The main difference is in the palaeobotanical material testifying to the cultivation of the Neolithic founder crops in the Zadar and Šibenik regions, *i.e.* their absence from the cave sites in northern and southern Dalmatia, whose inhabitants engaged exclusively in cattle husbandry. At the present level of exploration, and in accordance with all the aforementioned information, we can assume that the ceramic spoons were related to preparing and consuming cereals, *i.e.* dietary practices related to the cultivation of the primary domesticates in the regions of northern and central Dalmatia. In accordance with this hypothesis, ceramic spoons can be observed as a kind of indicator of dietary distinctiveness in the Neolithic of the eastern Adriatic, where economic and dietary activities were determined primarily by the natural conditions.

Finally, there is the question of the practical use of ceramic spoons. Judging from the small handle, good condition of the walls and lack of traces of burning,

6 The research was carried out within an international cooperation project of Šibenik City Museum, Drniš City Museum and Rochester Institute of Technology (USA).

it seems they were not exposed to fire directly, *i.e.* that they were not used in the cooking process. Some bone *spatulae* (*Bačkalov 1979.24*) shaped in a similar way (Fig. 6.d) which were usually used for stirring (*Vujević 2009.96*) suggest a similar function for the eastern Adriatic ceramic spoons, particularly if we consider the only slight concavity in the upper part of the spoon, which would make scooping up some form of liquid meal almost impossible. In the same context, recent analyses of pottery typology and lipid residues conducted on Neolithic and Eneolithic pottery from Ajdovska jama, Mala Triglavca and Moverna vas in Slovenia are interesting. They show that some vessel types can be linked to specific foodstuffs or food preparation techniques (*Šoberl* et al. *2014*). Among various types of ceramic shapes, the analysis involved ceramic ladles from the Moverna vas settlement (Fig. 6.e); the organic residue analysis suggests they were used with fatty foods (ruminant adipose fat) (*Šoberl* et al. *2014.App. 2: sample 155MV*), so it can be linked to scooping or stirring, *i.e.* actions beyond just storing fatty foodstuffs. To determine the function of ceramic spoons, it is also interesting to emphasise that ceramic spoons found at other Neolithic sites, such as those from continental Croatia (*Homen 1990.61; Minichreiter, Marković 2009.34; Marković 2012.61*), Hungary (Fig. 6.a–b) (*Horváth, Kalicz 2006.60; Regeny 2006.74*), Slovenia (Fig. 6.c) (*Kramberger 2014*) or Slovakia (*Müller-Karpe 1968.Tafel 208.13–17*) usually have larger concavities and holes for attaching a (wooden?) handle. In contrast, all the examples from northern and central Dalmatia have small clay handles, with no evidence to indicate an additional extension handle.

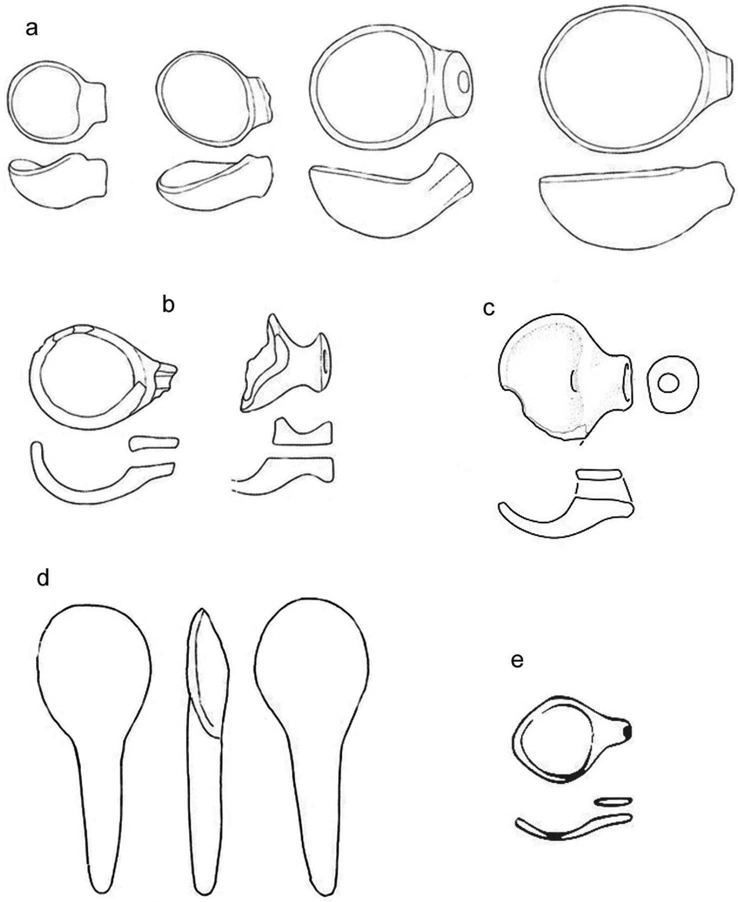

Fig. 6. Ceramic spoons and bone* spatulae*: a: Nagykanizsa (after* Horváth, Kalicz 2006.60*); b: Kaposvár-Gyertyános (after* Regeny 2006.74*); c: Zgodnje Radvanje (after* Kramberger 2014.Pl. 8.141*); e: Moverna vas (after* Šoberl *et al.* 2014.Fig. 3*); d: bone* spatulae *from Starčevo (after* Bačkalov 1979.24*).

Conclusion

Among the diverse range of shapes used for thousands of years in the preparation, serving and eating of different types of food, spoons have proved to be one of the most perfect tools. Their simple design, which has not changed much through history, could be used in a variety of dietary activities, for various food types and ways of preparing food. The function of the ceramic spoons found in the Neolithic settlements in Benkovac, Pokrovnik, Velištak, Danilo and Smilčić cannot be determined with certainty without a precise biochemical analysis and further research, which would help to define the actual function of at least some of the specimens.

Until possible new finds of ceramic spoons are unearthed in some clearly defined settlement contexts unquestionably related to the preparation or consumption of food, and on the basis of examples of ceramic spoons found in a rather small geographic region of the eastern Adriatic inhabited by Neolithic communities engaged in farming 'primary domesticates' (*Batović 1979.553; Šoštarić 2009.51*), we may consider a possible link between the ceramic spoons and nutrition related to cereals. Will the new research in the eastern Adriatic and its hinterland confirm that link or provide some other information on the eating habits of the Neolithic communities of this region? Are ceramic spoons associated exclusively with open-air sites, or can they be expected in the cave sites, as is the case in Slovenia or

Italy, where ceramic spoons were found at open-air sites (*Šavel 2006.90; Kramberger 2010.312*) and at cave sites (*Gilli, Montagnari Kokelj 1996.88*) which had fully developed animal husbandry with agriculture, *i.e.* a mixed economy producing milk and processed milk, meat animal products, freshwater fish and various plants (*Budja* et al. *2013; Šoberl* et al. *2014*)? In future investigations, more attention should be paid to the dietary habits of the Neolithic communities of the eastern Adriatic. In this regard, emphasis should be placed on chemical analyses of organic residues on pottery, which have recently improved our knowledge of the practical use of various vessel forms, food preparation techniques and the diversity of food consumed in the past.

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Identifying Neolithic animal management practices in the Adriatic using stable isotopes

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ABSTRACT – *We synthesise reported stable isotope values for domesticates and wild herbivores from sites spanning the Neolithic in coastal Croatia, Slovenia, and Italy (6000–3500 calBC). Carbon and nitrogen stable isotope values are analyzed as proxies of diet and environment, with differences between species possibly indicating anthropogenic influence. Results are used to characterise diets and address questions of the origin and development of husbandry strategies, especially transhumance, in early farming communities. Changes in pig carbon and nitrogen isotope values through time suggest alterations in practices, whereas values remain relatively constant for cattle and ovicaprids during most of the Neolithic, despite assumptions of seasonal mobility.*

IZVLEČEK – *V prispevku sintetiziramo vrednosti stabilnih izotopov domačih in divjih (rastlinojedih) živali iz neolitskih obmorskih najdišč na Hrvaškem, v Sloveniji in v Italiji (v časovnem obdobju od 6000 do 3500 calBC). Vrednosti stabilnih izotopov ogljika in dušika smo analizirali kot približke za podatke o prehrani in okolju; razlike v teh vrednostih med vrstami živali morda kažejo na antropogene vplive. S pomočjo rezultatov teh analiz smo lahko prepoznali značilnosti prehrane v zgodnje poljedelskih skupnostih na teh območjih in odgovorili na vprašanja o izvoru in razvoju živinorejskih strategij, predvsem transhumance. Spremembe v vrednostih ogljika in dušika pri prašičih v različnih časovnih obdobjih kažejo na spremembe v postopkih prašičereje, medtem ko so te vrednosti za govedo in ovce/koze ostale relativno nespremenjene skozi celoten neolitik, kljub temu da se za te živali predvideva sezonska mobilnost.*

KEY WORDS – *Neolithic; Adriatic; transhumance; domestication; stable isotopes*

Introduction

New stable isotope and lipid residue studies have begun to map and characterise the spread of livestock management practices throughout the Adriatic and Balkans during the Neolithic (*c.* 6000–3500 calBC; *Budja* et al. *2013; Evershed* et al. *2008; Lelli* et al. *2012; Lightfoot* et al. *2011; Šoberl* et al. *2008; Zavodny* et al. *2014*). Scientific advances have also allowed for a more fine-grained view of how Neolithic lifeways varied by site and region, with emphasis placed on secondary product exploitation or the seasonal movement of animals. However, some integral aspects of livestock management (*e.g.*, foddering and grazing) are less visible through traditional archaeological methods. Stable isotope studies offer a systematic approach to mapping these activities both temporally and geographically, and have been applied successfully in a variety of contexts (*e.g., Bocherens* et al. *2000; 2001; Makarewicz, Tuross 2006; Pearson* et al. *2007*).

Stable carbon and nitrogen isotope analyses are especially important for inferring changes in diet and

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environment indicative of anthropogenic influence in the absence of a complete archaeological record. Here we synthesise published stable carbon and nitrogen isotope data from open-air settlements and cave sites in the Adriatic region spanning the Early to Late Neolithic (see Fig. 1; *Lelli* et al. *2012; Lightfoot* et al. *2011; Ogrinc, Budja 2005; Zavodny* et al. *2014*). Comparison of these data can help to identify differences in animal diet between species and through time that may be linked to changes in animal management and exploitation, providing a framework for interpreting management strategies and issues of domestication on a regional scale.

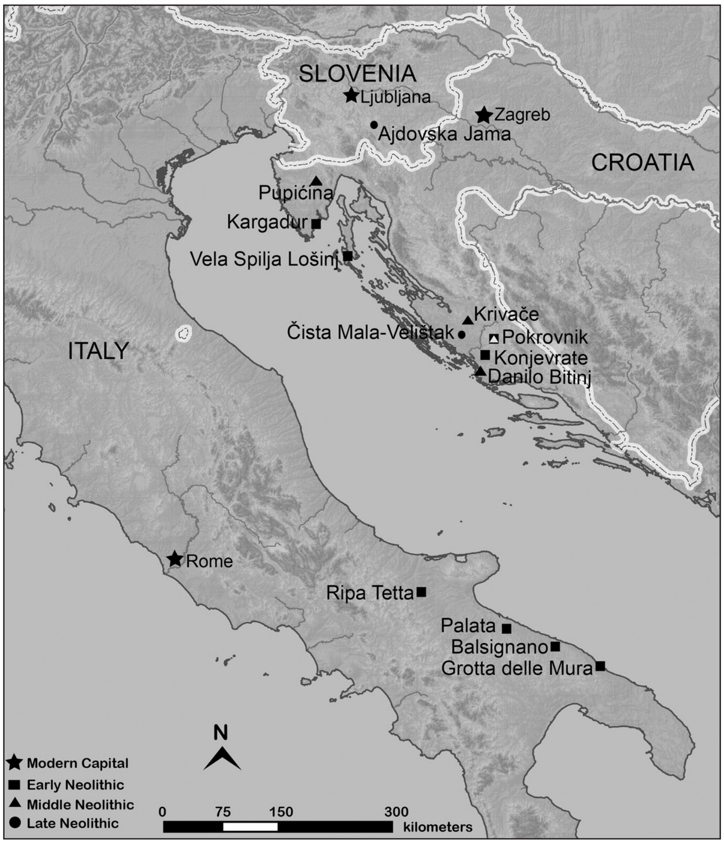

Fig. 1. Map of Neolithic sites mentioned in the text.

Background

Stable isotope studies of domesticated faunal remains have recently advanced our understanding of the origin and spread of agriculture in the Mediterranean world (*Lelli* et al. *2012; Lightfoot* et al. *2011*). Ongoing archaeological studies focus on the introduction, adoption, and adaptation of domesticates by early farming communities and hunter-gatherer groups (*Bass 2008; Lelli* et al. *2012; Lightfoot* et al. *2011; Miracle, Forenbaher 2005; 2006*). However, the precise timing of these transformative events remains poorly defined, in part due to an ephemeral and uneven Mesolithic record in the Adriatic region (*Biagi 2003; Komšo 2006; Lelli* et al. *2012; Miracle, Forenbaher 2005; Moore* et al. *2007a; 2007b*). In most regions, there is also an observable gap between Mesolithic and Neolithic occupational layers that prevents more definitive conclusions about the spread of farming technology and domesticates in the Early Neolithic (*Bonsall* et al. *2013; Biagi* et al. *2008; Forenbaher, Miracle 2006; Malone 2003; McClure 2013; Mlekuž* et al. *2008; Rowley-Conwy* et al. *2013*).

Consequently, the advent of farming in the region has been variously explained with diffusionist, migratory, or native developmental models (*e.g., Bass 2008; Chapman* et al. *1996; Forenbaher, Miracle 2005; Marijanović 2009; Mlekuž 2003; Moore* et al. *2007a; 2007b*). While developed Neolithic lifeways at key sites, such as Pokrovnik in Dalmatia, point to a rapid spread of a complete farming package (*Legge, Moore 2011; McClure* et al. *2014; McClure, Podrug 2015; Moore* et al. *2007a; 2007b*), evidence at other sites along the Mediterranean and Adriatic coasts suggests a much more gradual spread (*Miracle, Forenbaher 2005*). The role of local hunter-gatherer groups in bringing agriculture to the region has also been inconsistently defined, with some arguing for acculturation or adoption (*Bonsall* et al. *2013; Zvelebil, Lillie 2000*) versus displacement by migratory farmers (*Rowley-Conwy* et al. *2013*).

Despite these ambiguities, however, current archaeological survey and excavation along the Adriatic coast is clarifying the temporal and spatial trajectories of the spread of domesticated plants and animals and associated farming technology in the area (Dalmatia: *Marijanović 2009; McClure* et al. *2014; McClure, Podrug 2015; Miracle, Forenbaher 2006; Moore* et al. *2007a; 2007b; Teoh* et al. *2014*; Istria: *Forenbaher, Kaiser 2008; Forenbaher* et al. *2013*; Italy: *Biagi 2003; Biagi* et al. *2008; Malone 2003*; Slovenia: *Bonsall* et al. *2007; Tomaž 2010*). Though there are regional differences in the appearance of the standard Neolithic package, which included domestic wheat, barley, sheep, goats, pigs, and cattle, the Neolithic can generally be divided into Early, Middle, and Late sub-periods, and are often associated with regionally different but characteristic pottery styles.

Impresso ware had arrived in Dalmatia with the first farming groups by the early 6th millennium calBC (for new radiocarbon dates of Dalmatian Neolithic, see *Forenbaher, Kaiser 2008; Forenbaher* et al. *2013; Marijanović 2009; McClure* et al. *2014; Miracle, Forenbaher 2006; Moore* et al. *2007a; 2007b; Podrug 2010*), and reached southern Istria by 5750 calBC (*Forenbaher, Miracle 2006*). The Middle Neolithic period in Dalmatia and southern Istria is marked by the appearance of Danilo pottery (*c.* 5300–4900 calBC), and the Late Neolithic by the use of Hvar style ware that lasts throughout most of the 5th millennium and into the 4th millennium BC (*Forenbaher* et al. *2013; Forenbaher 2014*). The first signs of the Neolithic in northern Istria and the Trieste Karst, however, do not appear until the second half of the 6th millennium BC with the appearance of Danilo-Vlaška pottery style (*Miracle 2006; Forenbaher, Miracle 2006; Forenbaher 2014*). In northeastern Italy, a local iteration of the Danilo and Hvar culture elements, as well as those from the Po valley is reported (*Ferrari* et al. *2014*). In central and southeastern Italy, regional Early Neolithic impressed wares had appeared along the coast by the 6th millennium BC (*Malone 2003*).

Neolithic animal management in the Adriatic

Despite more recent stable isotope studies (*Lelli* et al. *2012; Lightfoot* et al. *2011; Ogrinc, Budja 2005; Zavodny* et al. *2014*) and ceramic residue analyses (*Budja* et al. *2013; Evershed* et al. *2008; Šoberl* et al. *2008*), zooarchaeology remains the primary method for identifying Neolithic economies and animal exploitation strategies in the Adriatic since domesticated species dominate most faunal assemblages at both village and cave sites (*Legge, Moore 2011; McClure 2013; Miracle, Forenbaher 2005; Miracle, Pugsley 2006; Moore* et al. *2007a; 2007b; Radović* et al. *2008; Rowley-Conwy* et al. *2013*). Population profiles and mortality curves act as proxies for herd management, and are used to estimate birthing and culling seasons for different species. Additionally, age-at-death profiles built from tooth eruption and wear patterns can be used to compare observed slaughter patterns with idealised curves for milk, wool, and meat exploitation (*Payne 1973*). According to Payne, when a species is managed primarily for milk production, very young individuals are slaughtered at a higher rate than adults. This contrasts with a strategy concentrated on meat production, where larger numbers of animals survive to be older juveniles or adults (*e.g., Legge, Moore 2011; Payne 1973; Vigne, Helmer 2007*), or a wool-driven economy, where as many animals are allowed to reach adulthood as possible.

Recent work at the cave sites of Pupićina (*Miracle, Forenbaher 2006; Miracle, Pugsley 2006*) and Vela Spila (*Radović* et al. *2008*) in Istria have used mortality profiles to identify changes in herd composition and exploitation from the Middle Neolithic onwards. Radović and colleagues (*2008*) argue that ovicaprid remains at Vela Spila most closely resemble Payne's milk-curve, with juveniles likely being culled between early spring and late fall. Mortality curves of faunal remains at nearby Pupićina, however, have been interpreted as indicative of both meat and milk exploitation according to the season of site use (*Miracle, Pugsley 2006; Rowley-Conwy* et al. *2013*). In Dalmatia, sheep age data from Pokrovnik suggest that early farmers practiced a mixed or meat-focused strategy (*Legge, Moore 2011.187–188*), while in Italy, Rowley-Conwy *et al.* (*2013*) argue that southern Italian farmers exploited ovicaprids for milk and cows for meat.

However, kill-off models provide only an approximation of animal management, and other factors such as accidental mortality, disease (*e.g., Legge, Moore 2011.187*), mixed management strategies, and statistical similarities between some practices may complicate interpretations of the archaeological record (*e.g., Bréhard* et al. *2010; Brochier 2013; Greenfield 2005; Vigne, Helmer 2007*). Stable isotope and lipid residue analyses can provide complimentary evidence of animal exploitation practices. For instance, analyses of lipid residues at sites in the Near East and southeastern Europe suggest that the processing of dairy products was present in some regions before the 7th millennium BC (*Evershed* et al. *2008*). In the Adriatic, dairy lipids have been identified on the inside of ceramics from the Middle Neolithic site Mala Triglavca, indicating the use of milk products by Vlaška groups (*Budja 2014; Budja* et al. *2013; Šoberl* et al. *2008*).

The question of transhumance

Seasonal transhumance, or annual rounds of herds between different grazing grounds, is a historically well-documented pastoral adaptation in the Mediterranean and Adriatic (*Moore* et al. *2007b; Porčić 2008; Šašel 1980*). In the case of central Dalmatia, the seasonal movement of livestock to temporary pastures played a fundamental role in local farming adaptations well into the 20th century (*Moore* et al. *2007b*). Recent ethnographic work at the modern village of Pokrovnik, in Dalmatia, demonstrates the existence of a transhumant management strategy as recently as the past century, with herders pasturing sheep in the nearby Dinaric Alps during the summer months and wintering in the coastal valley alongside the village (*Moore* et al. *2007b*). In this system, animals are able to graze on fresh grass, while allowing the land surrounding each village to regenerate from winter pasturing. Elsewhere in southeastern Europe, sedentary pastoralists have been identified in Neolithic Romania (*Greenfield, Jongsma 2008*), but transhumance as a pastoral strategy is not documented until the Bronze Age in the region (*Arnold, Greenfield 2006*).

The role of transhumance in the Neolithic is less clear. The distribution of archaeological sites suggests that higher elevation and/or rockier terrain in the Adriatic region were primarily used by pastoralists during the Neolithic (*e.g.*, Istria, Slovenia; see *Miracle 2006; Mlekuž 2003, 2005*; see also *Dennell 1978; Halstead 2006*). Known cave sites like Pupićina and Vela Spila may have acted as seasonal outposts for shepherds and their flocks (*Rowley-Conwy* et al. *2013*), and there is some evidence that ovicaprids and cows were stabled in caves at different points in prehistory (*Bonsall* et al. *2013; Boschian, Montagnari Kokelj 2000; Mlekuž 2005; Mlekuž* et al. *2008*). The predominance of ovicaprids at these and other cave sites (*Rowley-Conwy* et al. *2013*) also implies a transhumant strategy, as cows and pigs were less likely to make seasonal rounds.

In one regional study of the northern Balkans, Arnold and Greenfield (*2006*) tested the hypothesis that a transhumant economy would cull more juveniles during springtime in the highlands, and more adults would die during the winter while pasturing near lowland villages. Similarly, analyses of the Pupičina assemblage have identified the majority of ovicaprid remains as belonging to neonates and juveniles (60–81%; *Miracle, Pugsley 2006*). Assuming a single birthing season in the early spring, researchers suggest that Neolithic shepherds brought their flocks to the cave sites in the spring and summer to graze, before moving back into the lowlands during the colder months.

Stable isotopes, diet, and animal management

Stable carbon and nitrogen isotopes in bone collagen can be used as proxies of diet, and reflect the average dietary protein during the last several years of an animal's life (*DeNiro, Epstein 1978; 1981*). Animal diet is inferred based on the isotopic composition of food at the trophic level of foods consumed. Anticipated differences in stable isotope values between species and over time can be attributed to changing patterns of mobility, residence, and, by extension, management strategies during the Neolithic as communities invested more time and energy in agricultural lifeways (see Fig. 2). Local environmental variation in basal productivity and water availability, as well as metabolic factors, can alter the stable isotope composition of bone and collagen (*DeNiro, Epstein 1978; 1981; Towers* et al. *2011*).

We expect that animal management strategies and their corresponding isotopic signatures will remain similar throughout the circum-Adriatic during this time period, but that there will be clear differences between species due to different exploitation goals and practices. We hypothesise that ovicaprids participated in a seasonal pattern of transhumance between the coast and mountains, while cattle and pigs remained in coastal valleys near permanent settlements throughout the year (*Marković 1987; Nimac 1940; Perišić 1940*). Carbon and nitrogen stable isotope values should reflect this difference if the practice was indeed implemented during the Neolithic in the Adriatic (see Fig. 2). We also suggest that if caves were used as seasonal sites for penning and culling practices, we should also see differences between values from cave and open-air settlement sites.

Finally, we expect wild local herbivores (deer and hare) to have isotopic signatures noticeably different from domestic animals, as their diet should reflect the local environment with limited anthropogenic influence. Deer (*Capreolus capreolus* and *Cervus elaphus*) isotope values are reported from Pupićina, Karagadur, and Vela Spila Lošinj, while hare (*Lepus* sp.) isotope values are from Vela Spilja Lošinj and Ajdovska Jama. These samples represent the Early to Late Neolithic and most of the geographic region under consideration, but for this paper we present them as one group, with the assumption that all environments are similar (terrestrial C_3) and do not change over time (*Bailey 2000.139*).

Neolithic sites in the Adriatic region

The similar ecological and environmental landscapes across the Adriatic region allow us to contextualise results from multiple studies reporting values for domesticated animals at Neolithic sites in Dalmatia (Croatia), Istria (Croatia), Italy, and Slovenia. The background of each site sampled in this study is given below.

Dalmatia

Five Neolithic sites in central Dalmatia have archaeological evidence of intensive use of domestic animals and crops, suggesting that human populations were dependent on agriculture and livestock throughout the Neolithic. Isotope values are from Zavodny and colleagues' (*2014*) study on Neolithic transhumance in this coastal region.

Konjevrate is an Early Neolithic village located less than 10km from Pokrovnik. The site is currently under a modern churchyard (Fig. 1). Test excavations from the 1990s remain unpublished (for a short description see *Menđušić 1998*), though recovered pottery, stone tools, and animal bones are curated by the Šibenik City Museum. The presence of Impresso style pottery places the site in the Early Neolithic and AMS radiocarbon dates attest to Early and Middle Neolithic occupations (*McClure* et al. *2014; McClure, Podrug 2015*).

Pokrovnik, a village roughly three hectares in size, was occupied continuously throughout the Early and Middle Neolithic, and is located only a few kilometers from the Middle Neolithic site of Danilo Bitinj (Fig. 1; *Moore* et al. *2007b*). Excavations were undertaken in 1979 (*Brusić 2008*), and more recently in 2006 (*Moore* et al. *2007b*) and in 2010–2013 (*unpublished*). Reported radiocarbon dates suggest the site was occupied circa 6000–5100 calBC (*Legge, Moore 2011; McClure* et al. *2014*), making it one of the earliest dated open-air Neolithic villages in Dalmatia. Recent studies have identified over 90% of the faunal assemblage (n = 2400) as domesticated species (*Legge, Moore 2011; Moore* et al. *2007b*).

The Middle Neolithic settlement of Danilo Bitinj is located in a valley several kilometres from the Adriatic coast, and is thought to have been one of the most extensive sites of its type in southern Europe (Fig. 1; *Moore* et al. *2007a*). Past excavations in 1953, 1955 (*Korošec 1958; 1964*), and 1992 (*Menđušić 1998*) provided a wealth of material, although more recent excavations have focused especially on the recovery and identification of over 1600 animal bones, most belonging to domesticates (*Legge, Moore 2011; Moore* et al. *2007a*).

Krivače is another Middle Neolithic village located in the Bribir Valley (Fig. 1) and was first excavated in 1963 (*Korošec, Korošec 1974*), again during the early 2000s (*unpublished*), and most recently in 2013 (*Podrug* et al. *2013;* see also *McClure* et al. *2014; McClure, Podrug 2015*).

Čista Mala-Velištak is currently the only excavated Late Neolithic village in the region (Fig. 1; *Podrug 2010*). The available radiocarbon dates (4900–4700 calBC) place occupation at this site firmly in the early phase of the Hvar culture (*McClure* et al. *2014; McClure, Podrug 2015; Podrug 2010*).

Istria

Carbon and nitrogen values are reported for domesticates from Neolithic sites located north of central Dalmatia in the coastal region of Istria (Fig. 1; *Lightfoot* et al. *2011*). Lightfoot *et al.* (*2011*) focused on human dietary changes during the Mesolithic-Neolithic transition, finding a higher degree of dietary overlap between these periods than originally thought. Three sites have comparable isotopic data for domesticated animals: Kargadur, Vela Spilja-Lošinj, and Pupićina.

Kargadur is a coastal open-air village site that is one of the most recently excavated of its kind in Istria (*Komšo 2006b*). Vela Spilja-Lošinj is a prehistoric cave site, located on the island of Lošinj off the coast of Istria. Excavations during

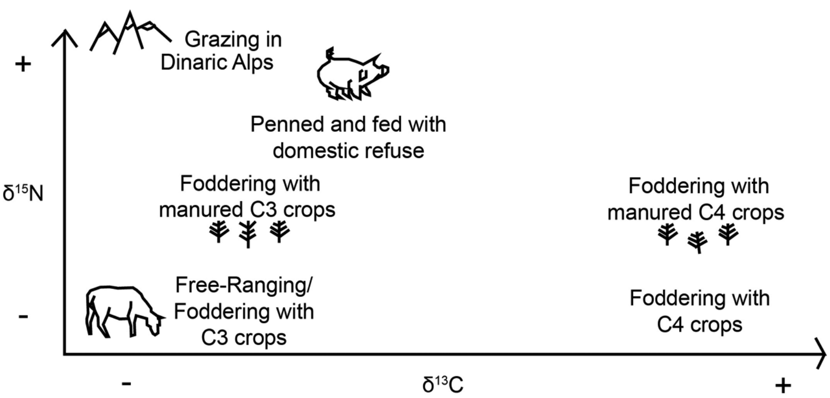

Fig. 2. Expected stable isotopic shifts according to different management strategies. Assuming free-ranging grazing or foddering with C_3 plants as a baseline, a switch to foddering with C_4 plants will enrich $\delta^{13}C$ by roughly 10–15‰ (**DeNiro, Epstein 1978*****). Foddering with manured crops, either C_3 or C_4, will enrich $\delta^{15}N$ by 1–3‰ (*****Bogaard** *et al.* **2013*****). Animals fed with domestic refuse will shift to a higher trophic level, enriching $\delta^{13}C$ by 1–3‰ and $\delta^{15}N$ by 3–5‰ (*****Schoeninger, DeNiro 1984*****). Grazing exclusively at higher arid elevations, such as in the Dinaric Alps, will enrich $\delta^{15}N$ in relation to lowland grazing individuals (*****Ambrose 1991*****).***

the 1950s uncovered a Mesolithic occupation (*Mirosavljević 1962; 1968; 1974*), and more recent studies have also focused on Neolithic components of the site, including the identification of Early Impresso wares (*Komšo* et al. *2004*).

Pupićina Cave, in inland Istria, was occupied numerous times throughout prehistory, and excavations have uncovered a significant Neolithic presence (*Miracle, Forenbaher 2006*). Zooarchaeological analysis of Neolithic animal remains have determined that domesticates comprised over 80% of identified taxa throughout the Neolithic (*Miracle, Pugsley 2006*). Ovicaprids comprise the majority of these domesticated faunal remains, although the presence of cattle and pigs increased in the Late Neolithic.

Slovenia

Located in southeastern Slovenia, Ajdovska Jama is an inland cave site that was infrequently occupied from the Paleolithic until the Middle Ages, though a series of archaeological excavations undertaken from 1884 onwards have uncovered a substantial Neolithic component (*Bonsall* et al. *2007; Horvat 1989*). Early radiocarbon testing dated approximately 31 human burials to two periods within the Late Neolithic (*Ogrinc, Budja 2005*), although more recently published radiocarbon values for these same human remains cluster between 3485–3340 calBC (*Bonsall* et al. *2007.732*). Domesticated sheep, goat, and cattle bones, many with clear cut marks, were found in burial contexts alongside hearths containing carbonised grain. A recent paleodietary study determined that Ajdovska Jama humans ate a 'terrestrial diet' of mostly domestic animals and C_3 plants (*Ogrinc, Budja 2005*), a conclusion echoed by Clive Bonsall *et al.* (*2007*).

Italy

Recent research suggests that farming practices first spread along the eastern Adriatic coast and then crossed the sea to Italy by the start of the 6th millennium BC (*Lelli* et al. *2012; Miracle, Forenbaher 2005; Skeates 2000; Starnini 2002*). Similar to central Dalmatia, southeastern Italy also exhibits little evidence of a strong Mesolithic tradition (*Biagi 2003; Lelli* et al. *2012*), making it an ideal point of comparison for mapping possible introductions and changes in animal husbandry among first farmers along the Adriatic coast.

Here we include stable carbon and nitrogen isotope values reported for domestic animals from four early Neolithic sites by Roberta Lelli *et al.* (*2012*; see Fig. 1) as part of a human paleodietary study. Radiocarbon dates indicate a Neolithic date for village sites: Ripa Tetta (5860–5600 calBC), Palata (5620–5470 calBC), and Balsignano (5570–5480 calBC). All of these sites are open-air settlements that were surrounded by ditch structures and whose inhabitants participated in an early agricultural economy. Palata and Balsignano are situated on the Adriatic coast, whereas Ripa Tetta is located farther inland. The fourth site, Grotta delle Mura, is a coastal cave dated

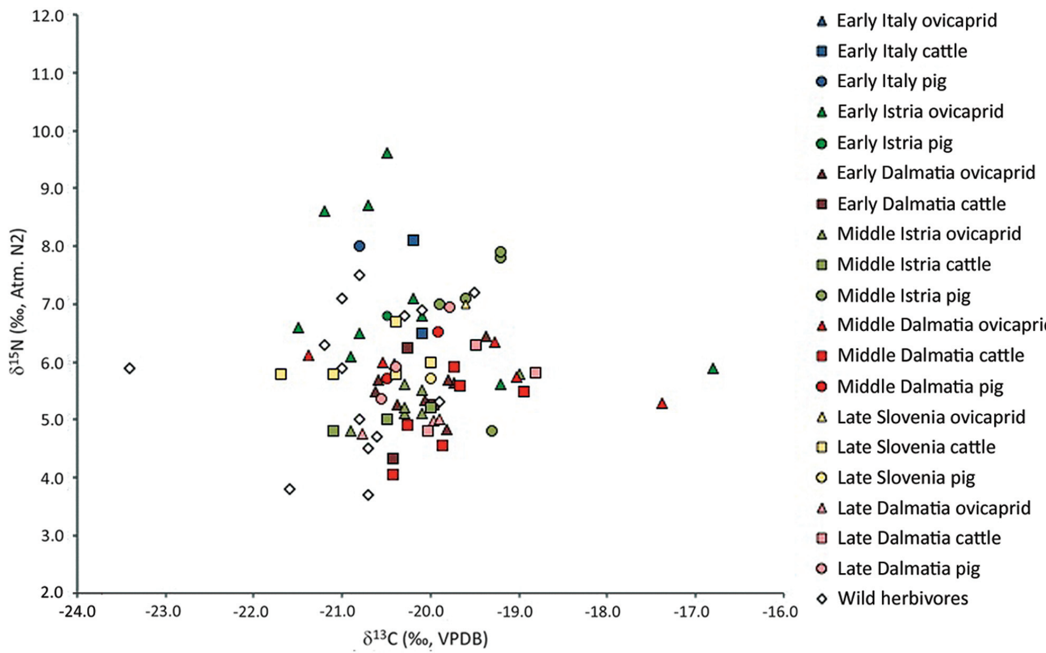

Fig. 3. Stable carbon and nitrogen values for all Neolithic samples discussed in this paper (**Lelli *et al.* 2012; Lightfoot *et al.* 2011; Ogrinc, Budja 2005; Zavodny *et al.* 2014*).***

to the Early Neolithic on the basis of Impressed Ware pottery associated with domesticated fauna. Collectively, these assemblages offer an opportunity to detect possible management differences on each side of the Adriatic.

Discussion

Here we compare the stable carbon and nitrogen isotope values for cows, ovicaprids, and pigs across the Neolithic Adriatic, as well as reported isotope values for local indigenous herbivores (hare and deer) as a control for non-human influenced diet in the environment. Values are reported in Table 1 and Figure 3.

Despite our initial predictions of temporal and species-specific changes in stable isotope signatures throughout the Neolithic period, Figure 3 demonstrates that such differences are not actually present over time or by region. We see a tight cluster of points, suggesting that cattle, ovicaprids, and pigs had largely similar diets throughout the Neolithic period regardless of region (Slovenia, Istria, Italy or Dalmatia). Reported isotope values for contemporary wild deer and hare in Istria and Slovenia also appear to overlap with domesticated values, suggesting that there may not have been much difference between human-managed and wild diets during this period. However, a uniform diet space does not necessarily mean that animal management remained the same through time or was the same for all species. Very little is known about the degree of uniformity in vegetation in the region, though indigenous plants were overwhelmingly C_3 and evidence from Neolithic sites indicates that early agricultural staples – wheat, primarily einkorn and emmer, barley, and legumes – were also all C_3 pathway plants as well (*Bailey 2000. 139*). C_4 plants, such as millet, were presumably not in wide use by Neolithic communities in this region (*Hunt* et al. *2008*), despite their presence in very small quantities at some sites (*Legge, Moore 2011; Moore* et al. *2007b*).

Given zooarchaeological evidence consistent with seasonal rounds of ovicaprids between upland caves and lowland settlements (*Miracle, Pugsley 2006; Radović* et al. *2008*), we might also expect isotopic differences according to archaeological context. If ovicaprids were lambed on their way to higher pastures and then culled there (*Arnold, Greenfield 2006; Miracle, Pugsley 2006*), ovicaprids from cave assemblages should have higher nitrogen values because of the majority of life spent at higher elevations (*Ambrose 1991*) and/or continued nursing until death (*Nehlich* et al. *2009; Richards* et al. *2001*). As seen in Figure 4, however, ovicaprid stable carbon and nitrogen values are clustered regardless of archaeological context and through time. Two-tailed t-tests (assuming unequal variances, *Ruxton 2006*) show no significant differences in carbon or nitrogen values between caves and settlements when compared ($p = 0.436$ and $p = 0.472$, respectively). When caves and settlements are grouped according to period, however, there is a significant difference in reported stable nitrogen values for the Middle Neolithic Pupićina cave and contemporary settlements of Danilo-Bitinj, Krivače, and Pokrovnik ($p = 0.042$). However, when a more conservative non-parametric Mann-Whitney U test is applied because of the small sample size (*Fagerland 2012*), this significance disappears ($U = 8.5$, $n_1 = 5$, $n_2 = 5$, $p > 0.05$, two-tailed). Given these findings, we cannot confidently conclude whether the seasonal movement of ovicaprids was a mainstay of Neolithic economies in the circum-Adriatic region.

In addition, comparison of ovicaprids with wild herbivores generally, and between Middle Neolithic ovicaprids and all wild herbivores specifically, show

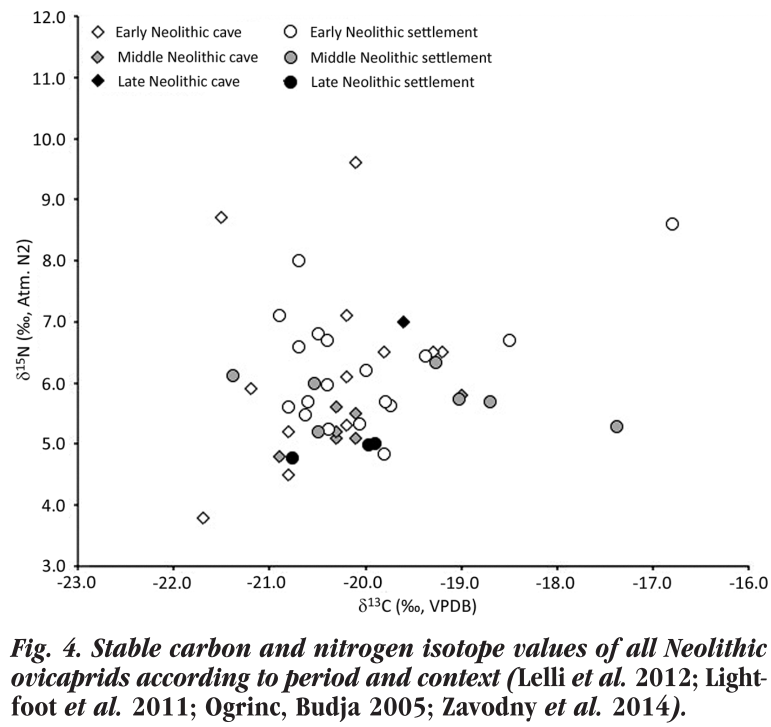

Fig. 4. Stable carbon and nitrogen isotope values of all Neolithic ovicaprids according to period and context (**Lelli *et al.* 2012; Lightfoot *et al.* 2011; Ogrinc, Budja 2005; Zavodny *et al.* 2014*).***

statistically significant differences in carbon values (t-test, unequal variances, p = 0.012 and 0.014, respectively), but not nitrogen. A Mann-Whitney U test comparing all wild herbivores, Middle Neolithic cave ovicaprids, and Middle Neolithic settlement ovicaprids similarly shows a significant difference in carbon (p = 0.045) but not nitrogen values (p = 0.320). We suggest the differences in carbon isotope values may be a result of different feeding strategies between species (*e.g.*, browsing versus grazing or forest versus pasture; *Bocherens* et al. *2015; Lohse* et al. *2014*), although it is unclear whether these differences have anything to do with human intervention in animal diets.

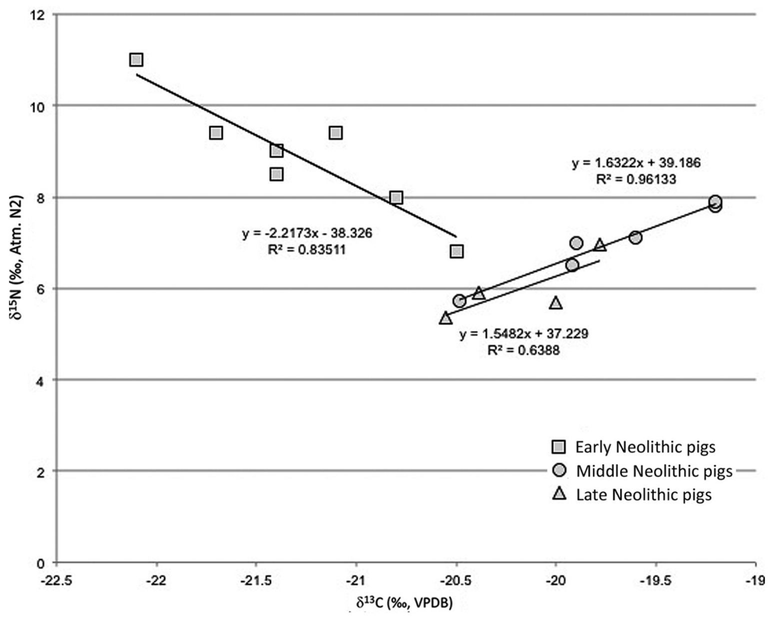

Fig. 5. Stable carbon and nitrogen isotope values of all Neolithic pigs (**Lelli *et al.* 2012; Lightfoot *et al.* 2011; Ogrinc, Budja 2005; Zavodny *et al.* 2014*****).***

One explanation for a similar diet space between cave and village animals is foddering. In this case, farmers provide animals with much of their subsistence, creating a very different kind of animal management system that may well have a similar isotopic signature regardless of the position of the herd in the seasonal round. Furthermore, the extent to which coastal valleys may have been preferred transhumance routes as opposed to transhumance to inland areas during the Neolithic is unknown, as current theories rely heavily on historical models in the region.

In short, current stable isotope data fall short in assessing the degree of transhumance during this period for ovicaprids.

A closer look at isotope values reported for pigs, however, reveals some differences in the species across time and space. Pigs are present in all regions during all periods (Figs. 3 and 5), and there appears to be a signal of changing management strategies between the Early and Middle-Late Neolithic. Statistical analyses highlight a significant difference in stable carbon values between Early and Middle Neolithic pigs (t-test assuming unequal variances, *Ruxton 2006*; p = 0.0002) and Early and Late Neolithic pigs (p = 0.003), although carbon and nitrogen values are not significantly different between Middle and Late Neolithic pigs (p = 0.122 and p = 0.068, respectively). We suggest that these differences in stable carbon and nitrogen signatures may reflect a shift in the foddering or management strategy of pigs between Early and Middle-Late Neolithic times throughout the Adriatic.

Elevated nitrogen in pigs may reflect increased manuring practices in fields (*Bogaard* et al. *2013; Madgwick* et al. *2012*), penning (*Bogaard* et al. *2013*), or different climatic and environmental settings (*Madgwick* et al. *2012*). Statistically different carbon values for pigs between time periods may signal a change in foddering practices, such as the inclusion of small amounts of C_4 species. *Panicum miliaceum* (broomcorn millet) is the most likely C_4 candidate, having been recovered from archaeological contexts in Europe prior to 5000 calBC (*Hunt* et al. *2008*), including Middle Neolithic contexts at Pokrovnik (*Legge, Moore 2011; Moore* et al. *2007b*) and at sites in neighbouring Serbia (Gomolava, *c.* 3700–3600 calBC). However, just across the Adriatic, varieties of millet were not known in northern Italy until the early Bronze Age (*c.* 1700–1500 calBC; *Tafuri* et al. *2009; Zohary, Hopf 2000*) or in southern Italy until Classical times (*Tafuri* et al. *2009*). While it is possible that Middle and Late Neolithic sites in Dalmatia and Istria obtained and utilized domestic millet, either for feeding animals or as part of the human diet, the spread and adoption of this millet species in southeastern Europe remains unclear and the results presented here can neither support nor refute the clear presence of millet in the Adriatic Neolithic.

Conclusion

Stable carbon and nitrogen isotope analyses provide a valuable tool for inferring changes in diet and environment. We find that the carbon and nitrogen isotope values reported in this paper remained largely stable for ovicaprids and cattle over the majority of the Neolithic, suggesting that livestock husbandry for these species remained fundamentally the same throughout the period in much of the Adriatic. Stable isotope data for domesticated pigs, on the other hand, may indicate different foddering or management practices as the Neolithic period progressed. Despite faunal data and other types of archaeological evidence, we also cannot definitively argue for or against ovicaprid transhumance on the basis of current stable isotope results. Future studies should focus on expanding sample sizes for domesticated animals at sites reported here and other Neolithic occupations throughout the circum-Adriatic region. Additionally, there is a need for background isotopic information on vegetation, either wild or domesticated, that may have been used for foddering or grazing by early farmers. Our results demonstrate the utility of isotope studies for addressing important questions regarding the Neolithic in the Adriatic, and highlight the need to continue quantitative scientific studies in the region.

ACKNOWLEDGEMENTS

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Tab. 1. Summary of stable isotope results for samples included in this study, organised by region.

Region	Site	Period	Sample #	Species	Δ13C	Δ15N	C:N	Reference
Dalmatia, Croatia	Konjevrate	Early	KON-2	*Ovis aries*	–19.8	4.8	3.24	*Zavodny* et al. 2014
		Early	KON-4	*Ovis aries*	–19.4	6.4	3.20	
		Early	KON-5	*Bos taurus*	–20.3	6.2	3.26	
	Pokrovnik	Early	PK-3	*Ovis aries*	–20.6	5.7	3.19	
		Early	PK-4	*Ovis aries*	–19.8	5.7	3.16	
		Early	PK-5	*Ovis aries*	–20.4	6.0	3.18	
		Early	PK-7	*Bos taurus*	–20.4	4.3	3.16	
		Early	PK-15	*Ovis aries*	–20.1	5.3	3.17	
		Early	PK-19	*Ovis aries*	–19.7	5.6	3.17	
		Early	PK-21	*Ovis aries*	–20.4	5.2	3.18	
		Early	PK-22	*Ovis aries*	–20.6	5.5	3.17	
		Early	PK-37	*Bos taurus*	–20.0	5.3	3.17	
		Middle	PK-14	*Bos taurus*	–19.7	5.6	3.2	
		Middle	PK-27	*Sus scrofa*	–19.9	6.5	3.3	
		Middle	PK-31	*Ovis aries*	–20.5	6.0	3.3	
		Middle	PK-36	*Bos taurus*	–18.9	5.5	3.0	
		Middle	PK-39	*Bos taurus*	–19.7	5.9	3.2	
	Danilo	Middle	DA-6	*Ovis aries*	–19.0	5.7	3.21	*Zavodny* et al. 2014
		Middle	DA-13	*Ovis aries*	–17.4	5.3	3.21	
	Krivače	Middle	KRI-1	*Ovicaprid*	–19.3	6.3	3.2	*Zavodny* et al. 2014
		Middle	KRI-2	*Sus scrofa*	–20.5	5.7	3.3	
		Middle	KRI-3	*Bos taurus*	–20.4	4.0	3.1	
		Middle	KRI-9	*Ovis aries*	–21.4	6.1	3.2	
		Middle	KRI-10	*Bos taurus*	–19.9	4.6	3.2	
		Middle	KRI-11	*Bos taurus*	–20.3	4.9	3.2	
	Čista Mala-Velištak	Late	CMV-1	*Sus scrofa*	–20.6	5.4	3.2	*Zavodny* et al. 2014
		Late	CMV-2	*Bos taurus*	–19.5	6.3	3.2	
		Late	CMV-3A	*Bos taurus*	–18.8	5.8	3.1	
		Late	CMV-4	*Sus scrofa*	–20.4	5.9	3.2	
		Late	CMV-5	*Ovis aries*	–20.8	4.8	3.2	
		Late	CMV-6	*Sus scrofa*	–19.8	7.0	3.2	
		Late	CMV-7	*Bos taurus*	–20.0	4.8	3.2	
		Late	CMV-28	*Capra hircus*	–20.0	5.0	3.2	
		Late	CMV-38	*Capra hircus*	–19.9	5.0	3.2	
Istria, Croatia	Kargadur	Early	BB13	*Ovicaprid*	–20.9	7.1	3.2	*Lightfoot* et al. 2011
		Early	BB14	*Ovis aries*	–16.8	8.6	3.1	
		Early	BB16	*Ovis aries*	–20.8	5.6	3.2	

Region	Site	Period	Sample #	Species	Δ13C	Δ15N	C:N	Reference
		Early	BB17	*Ovicaprid*	–20.7	6.6	3.1	
		Early	BB18	*Ovicaprid*	–20.5	6.8	3.1	
		Early	BB12	*Cervus elaphus*	–20.6	4.7		
		Early	BB20	*Cervus elaphus*	–21.2	6.3		
	Vela Spilja Lošinj	Early	BB26	*Sus scrofa*	–20.5	6.8	3.1	*Lightfoot* et al. *2011*
		Early	BB29	*Ovicaprid*	–19.2	6.5	3.1	
		Early	BB30	*Ovicaprid*	–21.2	5.9	3.1	
		Early	BB34	*Ovicaprid*	–20.2	6.1	3.1	
		Early	BB36	*Ovicaprid*	–21.5	8.7	3.1	
		Early	BB39	*Ovicaprid*	–20.1	9.6	3.1	
		Early	BB27	*Lepus* sp.	–21.0	5.9	3.0	
		Early	BB28	*Lepus* sp.	–21.0	7.1	3.0	
		Early	BB37	*Lepus* sp.	–20.3	6.8	3.1	
		Early	BB41	*Lepus* sp.	–20.8	5.0	3.1	
		Early	BB32	*Capreolus capreolus*	–20.8	7.5	3.1	
		Early	BB33	*Capreolus capreolus*	–19.5	7.2	3.1	
		Early	BB38	*Capreolus capreolus*	–19.9	5.3	3.1	
		Early	BB40	*Capreolus capreolus*	–20.1	6.9	3.1	
	Pupićina	Middle	BB50	*Ovis aries*	–20.3	5.1	3.0	*Lightfoot* et al. *2011*
		Middle	BB51	*Ovis aries*	–20.1	5.1	3.1	
		Middle	BB52	*Ovis aries*	–20.3	5.2	3.0	
		Middle	BB53	*Ovis aries*	–20.3	5.6	3.0	
		Middle	BB54	*Ovis aries*	–20.1	5.5	3.0	
		Middle	BB55	*Capra hircus*	–19.0	5.8	3.0	
		Middle	BB56	*Capra hircus*	–20.9	4.8	3.1	
		Middle	BB57	*Bos taurus*	–21.2	4.8	3.2	
		Middle	BB58	*Bos taurus*	–20.0	5.2	3.1	
		Middle	BB59	*Bos taurus*	–20.5	5.0	3.1	
		Middle	BB62	*Sus scrofa*	–19.6	7.1	3.1	
		Middle	BB63	*Sus scrofa*	–19.9	7.0	3.1	
		Middle	BB64	*Sus scrofa*	–19.2	7.8	3.0	
		Middle	BB65	*Sus scrofa*	–19.3	4.8	3.2	
		Middle	BB66	*Sus scrofa*	–19.2	7.9	3.1	
		Middle	BB60	*Cervus elaphus*	–20.7	4.5	3.1	
		Middle	BB61	*Cervus elaphus*	–20.7	3.7	3.2	
Italy	Basignano	Early	Bal III	*Ovis aries*	–20.0	6.2	3.4	*Lelli* et al. *2012*
	Grotta delle Mura	Early	GM 1	*Ovicaprid*	–19.5	6.5	3.4	Lelli et al. 2012
		Early	GM 2	*Ovicaprid*	–20.2	5.3	3.3	
		Early	GM 3	*Ovicaprid*	–20.2	5.3	3.3	
		Early	GM 4	*Ovicaprid*	–20.2	7.1	3.4	
		Early	GM 5	*Ovicaprid*	–20.8	5.2	3.4	
		Early	GM 6	*Ovicaprid*	–21.7	3.8	3.5	
		Early	GM 7	*Ovicaprid*	–20.8	4.5	3.5	
		Early	GM 8	*Ovicaprid*	–19.8	6.5	3.4	
	Palata	Early	Pal B5	*Bos taurus*	–20.1	8.1	3.4	*Lelli* et al. *2012*
		Early	Pal II fauna	*Ovicaprid*	–18.5	6.7	3.4	
		Early	Pal US7	*Ovicaprid*	–20.4	6.7	3.4	
	Ripa Tetta	Early	Rp 5	*Sus scrofa*	–20.8	8.0	3.4	*Lelli* et al. *2012*
		Early	Rp 6	*Bos taurus*	–20.2	6.5	3.5	
		Early	Rp 7	*Ovicaprid*	–20.7	8.0	3.3	
Slovenia	Ajdovska jama	Late		*Bos taurus*	–21.1	5.8	3.4	*Ogrinc, Budja 2005*
		Late		*Bos taurus*	–20.4	6.7	3.4	
		Late		*Bos taurus*	–21.7	5.8	3.4	
		Late		*Bos taurus*	–20.4	5.8	3.2	
		Late		*Bos taurus*	–20.0	6.0	3.2	
		Late		*Ovis aries*	–19.6	7.0	3.2	
		Late		*Sus scrofa*	–20.0	5.7	3.3	
		Late		Deer*	–23.4	5.9	3.7–3.9	
		Late		*Lepus* sp.	–21.6	3.8	3.3	

* Ogrinc and Budja (2005) average stable isotope values for three deer.

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Archaeological culture, please meet yoghurt culture: towards a relational archaeology of milk

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ABSTRACT – *Taking milk as a point of departure, we set out on a journey to explore the 'mutual becomings' of different bodies, species, and things. We argue that milk should be understood as a component in an assemblage that connects animals, humans, hormones, enzymes, bacteria, food, genes, technologies and material culture. These complex entanglements produced new, unexpected results and effects. Since they form part of this assemblage, all its components are profoundly changed. Focusing on this diversity of relations between humans, other creatures, things and substances is a key to an archaeology that does not radically separate humans and nonhumans.*

IZVLEČEK – *Mleko je izhodišče za pot raziskovanja 'medsebojnih vzpostavljanj' različnih teles, vrst in stvari. Mleko moramo razumeti kot komponento v zbiru, ki povezuje ljudi, živali, hormone, encime, bakterije, hrano, gene, tehnologije in materialno kulturo. Iz teh zapletenih prepletov vznikajo novi, presenetljivi učinki, ki spreminjajo vse vpletene komponente. Prav osredotočanje na bogastvo odnosov med ljudmi, drugimi bitji, stvarmi in snovmi je ključ za drugačno arheologijo, ki ne ločuje več ostro med ljudmi in neljudmi.*

KEY WORDS – *archaeology; milk; gut bacteria; companion species; assemblages; relations; practices*

Introduction

Archaeology is about long-term patterns of human entanglements in the material world. We are what have become by being entangled in webs of dependencies, with humans and nonhumans. And a key to an archaeology that does not radically separate humans and nonhumans is to approach the diversity of relations between humans and the material world inhabited by other creatures, things and stuff.

I argue for a different sensibility that allows us to experience relations between human persons and other materialities as less hegemonic. I argue for the dissolution of ontological boundaries, more symmetry and democracy between humans, animals and things. In this ways, the entities we study can be seen as assemblages of heterogeneous materialities, which exchange properties, stuff, and produce surprising and interesting effects. We can focus on the 'mutual becoming' of different assemblages that include humans and other companions.

This paper is about milk, not as an inert substance that can be studied in isolation, but as a messy encounter, a knot, an element in an assemblage that connects animals, humans, hormones, enzymes, bacteria, food, genes, technologies and material culture. These complex entanglements have produced new, unexpected results and effects that we can see in archaeological record.

Archaeology of milk

Impressive developments in archaeological science have provided new ways to study material traces of humans' consumption of animal milk. Organic residues preserved in pottery vessels provide direct evidence that people drank milk in the Neolithic, from the Near East and south-eastern Europe, North Africa, to Denmark and the British Isles (*Dudd, Evershed 1998; Evershed* et al. *2008; Craig* et al. *2005; Dunne* et al. *2012; Copley* et al. *2003; Šoberl* et al. *2008; Budja* et al. *2013*).

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This new evidence pushed the beginning of the consumption of animal milk back to the seventh millennium BC and links it with the domestication of animals and introduction of pottery technology. Some researchers argue that once animals were domesticated, the potential benefits of these products would have been exploited rapidly (*Rollefson, Kohler-Rollefson 1992*). Other even suggest that the domestication of sheep, goats and cattle in the Near East could have been at least partly motivated by a desire for milk (*Helmert, Vigne 2007*).

As raw milk lipids absorbed in pottery are rapidly destroyed by burial, the high frequency of ruminant milk lipids in vessels could indicate that they were used to process (heat) milk in operational sequences of dairy production. The presence of mid-chain ketones, which are lipid pyrolysis products, suggests that dairy products were heated in these pots (*Craig* et al. *2005*). The detection of milk lipids in specialised vessels similar in form to modern cheese strainers provides compelling evidence that the vessels were used to separate milk curds from whey (*Salque* et al. *2013*). This new evidence emphasises the importance of pottery vessels in processing dairy products lactose-intolerant prehistoric farming communities, particularly in the manufacture of reduced-lactose milk products. Analyses of stable isotope ratios in the tooth enamel of cattle has provided evidence of seasonal herd management and weaning of calves that indicate cattle management for dairying (*Balasse 2003; Balasse* et al. *2012*).

On the other hand, palaeogentic analyses have clearly demonstrated that the first farmers to have consumed dairy products were clearly not able to consume milk as adults (*Burger* et al. *2007; Burger, Thomas 2011; Leonardi* et al. *2012*).

Milk lipids in pots are found more frequently in areas where cattle are abundant in archaeological record (*Evershed* et al. *2008*). Studies have shown a significant geographic correlation between high diversity in cattle milk genes, the locations of the European Neolithic cattle farming sites, and present-day lactose tolerance in Europeans, suggesting a complex gene-culture co-evolution between cattle and humans (*Beja-Pereira* et al. *2003*). The trait of lactase persistence emerged at *c.* 5500 somewhere in the Carpathian basin or central Europe (*Itan* et al. *2009*). The fact that human bodies adapted to digesting lactose so late means that there was not been strong selective pressure on drinking milk. Obviously, there were other ways of obtaining the benefit of milk than adapting body, *i.e.* by harnessing the material culture and work of microbes.

It appears that the consumption of milk cannot be clearly separated into 'cultural' and 'natural' domains. The biological aspects of human milk consumption and its evolutionary history are clearly enmeshed with cultural practices and preferences.

Flat ontology: relations, networks and assemblages

One of the most significant developments in modern science has been in the formation of two separate domains. On the one hand, we have 'nature', the realm of natural sciences, exploring causal interactions between material things, and on the other, 'culture', the domain of social sciences, studying the socially constructed reality of institutions, ideas and interpretations. Sciences have been busy keeping the domains separated by carefully sorting phenomena into each of them; but this process of 'cleaning' is also its greatest drawback (*cf. Latour 2002*).

However, in recent decades there has been a resurgence of studies that challenge this rigid division and focus on the messy borders between the two domains, studies that tackle the dirty and messy way in which both domains are entangled in a web of mutual relations. We have the 'multi species' or animal turn (*Choy* et al. *2009; Mullin, Cassidy 2007; Kirksey, Helemreich 2010*), studies of the 'human/animal interface' (*Birke 2009*), 'inter-species' (*Livingstone, Puar 2011*), 'post-human' (*Haraway 1991*) or 'non-human' (*Wolfe 2009; Callon 1986*), 'other than human' (*Hallowell 1960*) and 'more than human' (*Whatmore 2002*) approaches which question the hegemonic and rigid divisions between domains.

It turns out that things and phenomena that are taken to be either natural or social are usually some messy mix of both, enacted through webs of associations and relations of different kinds. This is the main concern of science and technology studies (*Latour, Woolgar 1979; Latour 1993*), for example, which effectively demonstrated that the modern way of separating nature from the social world is historically contingent.

The main idea is that there is no separate nature and culture, but what Donna Haraway (*2003*) calls 'naturecultures' or what Bruno Latour refers to as 'collectives' (*2005*). This attentiveness to associations now tends to circulate under the shorthand of Actor-Network Theory (ANT) (*Latour 2005*).

Things come into being and exist by participating in an emergent web of materially heterogeneous relations. Gilles Deleuze and Félix Guattari (*1987.88*) talk of '*agencement*' (inadequately translated into English as 'assemblage'), ANT talks of the 'actor-network' (*Latour 2005*).

In this perspective, agency is not something possessed (solely) by humans, or nonhumans, for that matter. Agency is about the ability to respond, to change things, about the "*possibilities of worldly re-configurings*" (*Doplhijn, Tuin 2012.55*), and it enlists nonhumans as well as humans. Agency is distributed rather than situated in a hegemonic subject-object relationships; it is a result of complex heterogeneous entanglements, networks, imbroglios, assemblages.

This is a flat ontology, in which all entities – animate and inanimate, human and nonhuman – are accorded equal treatment and ontological status (*Byrant 2001*).

These approaches are part of a wider turn towards matter itself. Matter is interesting again; materiality is no longer passive, inert matter, shaped by determinist, causal schemes, but rather something vital and imbued with its own agency (*cf. Bennett 2010*).

How can one study milk, then? Milk does not fit simple divisions between human/animal, cul-ture/nature. The human consumption of animal milk emerged through new, historically contingent relations between humans and animals that were enacted at the beginning of the Neolithic. These relations produced new things, effects, and associations. To study this complex of entanglements, assemblages, we have "*to follow the imbroglios wherever they take us*" (*Latour 1993.3*).

Assemblages

In archaeology, an assemblage is conventionally understood as a "*group of artefacts recurring together at a particular time and place, and representing the sum of human activities*" (*Renfrew, Bahn 2008. 578*), a passive reflection of either ethnic/cultural groups or functional toolkits. In art, an assemblage is a work produced by the incorporation of everyday objects into the composition. Although each non-art object acquires aesthetic or symbolic meanings within the context of the whole work, it may retain something of its original identity. This is closer to the modern understanding of assemblage in archaeology, where an assemblage is understood as a more or less deliberate association of objects brought together in the context of some, possibly ritual, activity. This notion of assemblage in archaeology is implicit, for example, in discussions of structured depositions (*cf. Pollard 2001; Bradley 2005*).

However, such understandings of assemblages imply a divide between human agents – those who arrange or assemble – and the passive things that have been arranged and assembled together. This idea of human agency imposes a vertical, hierarchical ontology based on subject/object relationships, with humans at the top and animals, plants, and things at the bottom.

More recently, however, assemblage has gained traction as a translation and appropriation of the concept designated by the French word '*agencement*' in the work of Gilles Deleuze and Félix Guattari (*1987*). In this form, assemblage has been increasingly used to designate not a static configuration, arrangement or a state of affairs, but rather a process of the arranging, becoming, organising, emerging of heterogeneous bodies and things that come "*in connection with*" one another (*Kennedy* et al. *2013.45*).

Organisms are not assemblages; they are organically connected into wholes in which each organ is vital for the coherence of the organism. But assemblages are not seamless wholes. While they appear to function as a whole, their components can be taken out of a system and 'plugged' into another, where they play a different role, and still work (*DeLanda 2006. 10–11*). This makes assemblages more resilient and open to change. Assemblage works on various spatial and temporal scales and can hence be viewed more as an 'ecologies' rather than organisms (*DeLanda 2006.10*): "*allowing the possibility of complex interactions between component parts is crucial to define the mechanisms of emergence, but this possibility disappears if the parts are fused together into a seamless web*".

Emergent properties are signs that an assemblage is real. The effects, the agency, of the assemblage are emergent properties. The relationship between an assemblage and its components is complex and nonlinear: assemblages are formed and affected by heterogeneous components which may be assemblages themselves, but may also act back upon these components, imposing restraints or adaptations in them.

One of the main features of assemblage is that it is able to retroactively affect its parts.

Jane Bennett's (*2010.20–22*) sees assemblages as a form of distributive agency and focuses on how materialities emerge and circulate within an assemblage. The resulting actions, are distinct from the power of each materiality considered alone. They are multiply organised into a relational whole, one in which the collective is defined by its internal relations.

In addition to their openness to new connections, there are spaces of potential, spaces of non-realised becomings, or virtuality, which limit what an assemblage can do. An assemblage is never a solid block, but an open-ended collective, a "*non totalizable sum*". An assemblage does not only have a distinctive history of formation, but a finite life span (*Bennett 2010.13*). An assemblage is always already a becoming.

Donna Haraway emphasises that "*history matters in naturecultures*" (*Haraway 2003.3*), but this history is not a (biological) evolution for some entities and (social) history for others, deepening the gap between nature and culture. As Bruno Latour (*1993.82*) says, "*history is no longer simply the history of people; it becomes the history of natural things as well*". Histories of assemblages acknowledge the intimacies, entanglements, mixtures and violence which inform and limit us (*Haraway 2003.20*).

Companion species

'Domestication' is an idea born with the Enlightenment that presupposes a clear distinction between the natural 'wilderness' of animals and their cultural 'domestication' (*Cassidy 2007.1*). Domestication is thus seen as a specific animal state or form, the result of a oneway relationship, whereby humans actively domesticate passive, biological, wild animals by forcing them into a new domesticated, cultural state (*Mlekuž 2013*).

However, in order to be more than an empty word, domestication has to be explained by focusing on historically specific material practices and relations between humans, animals and material culture. When speaking of the processes of domestication, we also need an alien phenomenology that is able to shift from the perspective of humans to cows (for example, "*History According to Cattle*", an exhibition which "*exhibits bovine culture and the relationship between cattle and their companion species*" (*Gustafsson, Haapoja 2015.7*)).

However not only cows domesticate people; many different creatures, stuff, material culture and other things are involved in, and contribute to, the process of domestication. Thus, rather than a clearly defined state of animals, domestication could be understood as an assemblage containing many components, including humans and animals, in the process of becoming arranged or fixed together. Domestication is a fragile ecology of humans, animals, material culture and stuff that emerged through practices and material relations and which retroactively affects all sides. Sheep, cows, but also humans are the effect of webs of genetic, nutritional, agricultural, economic, environmental and technical relations that unfolded over millennia. They emerged through webs of relations and practices, from herding, caring for, fighting back, milking and eating. The result is an increasingly complex assemblage that has produced surprising effects.

So, to dumb down this thesis, it is not enough to say that humans domesticate cows and sheep, we must also say that cows domesticate humans (*cf. Budiansky 1992*). However, if humans belong to an assemblage involving cows, we must also account for other components of the assemblage, such as other animals, plants, bacteria, material culture and substances. Living with animals is a material practice. Material culture such as corrals and pens emerged to shelter animals, but also to concentrate people, animals, things, and substances together, and mix or separate into distinct categories, such as bulls, heifers, cows, calves and weaners. They made for close contact between animals and humans, the exchange of substances and bacteria, and structured face-to-face interactions, and reduced the possible outcomes of such interactions (*cf. Mlekuž 2013*). Domestic animals, cows, sheep, goats as well as humans, are enacted through these material practices (*Law, Lien 2013*). What we have here are not merely domesticated animals, but different companion species (*Haraway 2008*), species that accompany each other for millennia, entwining their histories. Dogs, sheep, cows, and goats are companion species to us, and cereals, legumes, mushrooms and the bacteria living in our gut are too. Companion species do not merely live next to each other, but are in an interrelation of co-constitution. Influences are not simple: what is at stake here are lives and survival (*Haraway 2003; 2008; Tsing 2012*).

From the evolutionary standpoint, the aim of biological organisms is to reproduce. To do this, cows need to escape predators – such as wolves, keep open grasslands to grow and being able to produce offspring. Through domestication, cows recruited humans to protect them, to fight predators and to clear woodland, by seducing humans with their taste, fat and milk. As humans became more entangled in the bovine life, selective pressures were exercised on human beings, such that our social relations changed, as we adapted culture to raise and herd animals. Furthermore, as diets, and ultimately lives, became more dependent on meat and milk, human bodies also changed (*cf. Bryant 2011.18*).

So what we are studying here are messy contact zones where the boundaries separating nature from culture have broken down, and where encounters between humans and other beings generate mutual ecologies and co-produced niches (*Kirksey, Helmreich 2010.546*). Donna Haraway claims that beings do not exist as independent entities, but only in relations; we continue into each other, without clear boundaries limiting/defining entities previous to the relation (*Haraway 2003; 2008*).

Relations and practices

Understanding domestication as an assemblage requires attention to the relations between components of assemblage. Everything – subjects, objects, species, things – is produced and enacted through relations. Thus, as Donna Haraway (*2003.24*) says, "*The relation is the smallest unit of analysis, and the relation is about significant otherness at every scale*".

What defines animals and humans is what they actually do to each other and not some a priori essence or status. Therefore, domestic cows are being done through the specific actions done to them. However, they are not passive things being shaped into a specific cow form. They present a series of resistances and their own agencies. Most people who work closely with them know that, with animals "*you aren't going to get to do it the way you want*" (*Cote 2004.9*). Domestication often invokes subordination and domination (*cf. Ingold 2000.61–76*). However, all practices of human animal interactions require both sides to be available and attuned to each other. Both, humans and cows, transform the practices that articulate them into what Viviane Despret (*2004.133*) calls an 'anthropozoogenetic practice', a practice that constructs animal and human through situations in which both humans and their cow domesticate each other. These activities establish relations that have complex and often unpredictable and surprising effects on both sides. The most interesting characteristic of practices that may be defined as practices of domestication are articulation of new relations, new ways of being human with non-human, human with cow, cow with human (*Despret 2004.125*).

Animals can be reduced to raw materials, as food and also antlers, horns and bones and hides. Some animals are more suitable than others for this. Sheep and goats, for example, reproduce ten times faster than cattle. But even these practices require specific relations to emerge. A sheep is not only an individual animal with an economic value; it is first of all part of a herd. A herd requires long-lasting relations of care, and this is inseparable from geography, from topography and from meteorology (*Law, Mol 2008.64*). The shepherd cares for individual sheep, of course, but first of all for the herd as a whole, which is more than sum of individual sheep. Individual sheep can be transformed into raw material, whereas the herd must not be lost; it must increase, which means that pastoralists try to avoid any unnecessary slaughtering of animals. This leads to a "*very careful life*", whereby households try to avoid sharing meat with other households, resulting in self-sufficient, solitary isolated communities, lacking social interaction and political institutions: "*the successful pastoralist hoards rather than hosts*" (*Paine 1971.167; Ingold 1980*).

On the other hand, when usually large, slow-growing ungulates like cattle are reared for milk, they become food producers, workers, rather than food itself. They contribute their work, converting cellulose into milk. Milking is an essential part of their everyday care. The focus of care is on the individual animal, with her own identity, skills, biography. Daily care requires the development of skills and knowledge on both sides. A milk cow is not just born; it is produced along with the milker through the daily practice of milking. This also means a greater involvement of humans, and therefore increased demand for labour. The dairy pastoralist's wealth in large stock is therefore equal to the abundance of the labour force, usually women and children (*Ingold 1980*). Wealthy owners whose herds exceed the maximum manageable size, loan or give some animals to other households. Conversely, if someone is short of animals, they may seek gifts or loans from the betteroff (*Dahl, Hjort 1976.136–37*).

Animals produce milk for the household where they live, irrespective of who owns a particular animal; however, the owner retains control over the slaughter of an animal and over its offspring. This establishes a network of social relations between households, which are reflected in herds. Animals become a medium and symbols of social cohesion (*Evans-Pritchard 1940*).

This means that it is hard to predict the outcome of individual practices and relations. Assemblages are full of surprises; they are creative. They have unpredicted effects and make new things. However, to say that they make new things tells us nothing about the desirability of new things (*Law, Mol 2008*).

Milk as stuff

Milk is a foodstuff, food; but first of all, stuff, matter. As Annemarie Moll (*2002.42*) says "*matter isn't as solid and durable as it sometimes appears*". There are numerous forms of resistance in the process of obtaining milk from animals. Milk cannot be simply extracted from animals, perhaps by force; it requires co-dependency. Obtaining milk from animals enacts practices, bodily routines, material culture and knowledge. And this knowledge is enacted through practical material events.

Milking is a specific physical encounter, with its own temporality in the daily and seasonal cycle. The daily interaction of milking establishes relations of closeness between animals and people, structures the pattern of interactions and practices, and defines, maintains and contests the social roles of both animals and humans. It involves close, physical contact between animal and human, relations of mutual trust (*Bock* et al. *2007.112*).

But milk is food for infants. To be able to produce milk, a cow must first calve. Milk is first of all food for calves, lambs and kids. Different animals produce different quantities and qualities of milk, in a specific rhythm and composition tailored to nurture their own species. Thus for cows, the lactation period normally lasts 305 days; however, among 'primitive' animals that have not been 'upgraded', the period can be much shorter, up to 6 months. During the lactation period, milk production decreases, and after approximately 300 days, it may drop to some 15–25% of its peak volume. After this period, the cow is usually 'dried off', *i.e.* not milked, so that the udder can regenerate before the next calf is born. The whole cycle then starts all over again, normally for five to seven years.

A calf needs about 1000 litres of milk for growth, which is exactly the quantity which the wild cow produces for each calf. As milk is food for calves, no milk is produced without them. Thus humans compete with calves for milk.

Cows can be milked only after the activation of a neuroendocrinal mechanism that releases oxytocin into the blood stream; this forces the expulsion of the milk from udder. This is the so-called milk let-down reflex, a complex ecology within the cow's body, part of the cow's rich and complex materiality (*Costa, Reinemann 2004.1*).

However, this embodied ecology is not isolated; it is coupled with other bodies and the environment. Neuro-endocrine mechanism of milk ejection is activated by the presence of a stimuli evoked by sight, smell, and sound from the nursing calf (*Costa, Reinemann 2004.1*). Oxytocin is a substance that dissolves boundaries, breaking down the border between cow and calf.

The effect of the let-down reflex gradually diminishes as the oxytocin is diluted and decomposed in the bloodstream, disappearing after 5–8 minutes. If the milking procedure is prolonged in an attempt to 'strip' the cow, an unnecessary strain is put upon the udder; the cow becomes irritated and may become difficult to milk.

Mammals have different ways of producing milk. Dairy cows store less than 30 percent of the total milk yield volume in the cistern; the remainder is stored in the alveoli and must be extracted by invoking oxytocin. In goats and sheep, cisternal milk, which can be extracted without activating the milk let-down reflect accounts for up to 75% in goats and up to 50% in sheep. However, even in small ruminants, oxytocin-mediated milk ejection produces milk with higher fat content (*Costa, Reinemann 2004. 1–2*).

In order to obtain milk, the milker must enter into a relationship with a cow as a calf. This is done by hijacking the cows's milk-let-down reflex either by using body techniques or material culture. Usually the calf is shown to the cow to stimulate milk flow. If the calf is slaughtered, since it is a competitor for milk, material culture can also be harnessed to break the boundaries between bodies and stimulate cows to produce milk. Among the Nuer in East Africa, it is customary to use calf dolls; when a calf dies or is slaughtered, it is stuffed with straw and placed in front of the cow to stimulate milk flow. There is also a technique, ethnographically well documented in Africa, which consists of blowing into the cow's vagina, either directly from the mouth or by means of a tube, in order to stimulate milk flow (*Le Quellec 2011*). We have abundant pictographic evidence for this technique in Saharan rock art.

Milking is a physical skill, knowledge and material practice that establishes a relationship of care between cow and human and must be both. The milker and animal respond and engage with one another in a multitude of subtle ways. Relations between bodies that allow milking can be described as affects. Affects are forces of encounter, visceral intensities, modes of the body's interactions with its surroundings and other bodies, the resonance of bodies in continuity and movement. Affect belongs to the realm of potential, as tendencies or incipient acts, indeterminate and emergent. In many cases, affect is never actualised in action and remains virtual. An affect is independent of conscious perception and language, as well as emotion; it is a purely autonomic, non-discursive, non-representational reaction to other bodies (*Massumi 2002.28*). Affects help us to see beyond the body as an individualised entry and grasp the interconnected nature of bodies of various kinds. Affect is the capacity of bodies to enter into relations. As Bruno Latour says (*2004.225*), "*to have a body is to learn to be affected, meaning 'effectuated', moved, put into motion by other entities, humans or nonhumans. If you are not engaged in this learning, you become insensitive, dumb; you drop dead*."

In this way, we can see bodies not as actualised objects, but carriers of potentials, forces of individuation, expressions, realised through an interface with the world. Instincts such as milk let-down do not have to be taken as reflex actions, but as accumulated affects, condensations of habits that became innate through evolution (*Parikka 2010.24*). In this way, cows can learn to let down milk just by hearing the familiar sounds of milking preparations.

What I am saying is that a cow, an historically specific cow (along with the person who milks it) is a result of affects sedimented through bodily relations, through practices of milking. Practices are a somewhat patterned weave of relations, and milking is the creation of a cow (together with the milker) in particular ways. We may think of this as an intricate choreography; but if this is a choreography, then it takes effort, work, continual reworking, and is more or less precarious (*Law, Lien 2013*).

Milk as food

Milk is a foodstuff, stuff that nurtures the consumer. The substances in milk provide both energy and the building materials necessary for the growth of infants. Milk is "*vibrant materiality*"; it affects the bodies that consume it. It "*increases human flesh*" (*Bennett 2010.137*) by making tissues grow, bodies fat and bones strong.

All mammals produce milk. It is something we humans share with other mammals. This common mammalian heritage allows us to establish specific relations with other mammals through relations of consuming milk. All mammals are totally dependent on their parents or other caretakers for the provision of many of the necessities of life. The developing mammal moves from complete dependence on mother's blood when in the uterus, to total dependence on mother's milk, a mixed diet of mother's milk and solid food, then independent feeding.

Milk is a complex fluid containing around 100 000 types of organic molecules, such as lipids, proteins, carbohydrates in the form of milk sugar (lactose), gases and minerals. Milk is an emulsion of fat globules, a fine dispersion of casein micelles, a colloidal solution of globular proteins and a colloidal dispersion of lipoprotein particles (*Atkins 2009.115*). Cow's milk is about 88% water and about 3% protein. The two main proteins are casein and whey proteins, which include lactalbumin and lactoglobulin. Casein comprises about 82% of the total protein. It has high nutritional value and contains all the essential amino acids, such as lysine (*Amanatidis 1999.395*).

Milk provides its own material resistances to consumption by adult humans or other mammals. This unruly behaviour of milk is at the root of the difficulties with drinking and adopting milk for human consumption (*Atkins 2009*).

Lactose is the principal sugar in milk, and milk is the only source of lactose in nature. It enhances the absorption of calcium and phosphorus from the intestine. In order to be digested the lactase enzyme is needed to break down lactose in the gut.

After weaning, most mammals normally cease to produce the lactase needed to digest milk, which results in lactase deficiency, hypolactasia, or the adult type of lactose maldigestion (*De Vrese* et al. *2001.421*) which is the inability to digest lactose, a sugar found in milk and to a lesser extent milk-derived dairy products. Hypolactasia is accompanied by clinical symptoms such as bloating, flatulence, nausea, diarrhoea and abdominal pain. This effect of milk on the body is called lactose intolerance. The symptoms are caused by undigested lactose in the large intestine, where the lactose is fermented by gut flora (*de Vrese* et al. *2001.422*).

What, and how strong, the effects of undigested lactose are on a body depends first on the amount of lactose ingested, but also on the body itself, individual sensitivity, the rate of gastric emptying, gastrointestinal transit time, and the pattern of flora in the large intestine, which is why diarrhoea rarely occurs after the application of antibiotics. Lactose-intolerant people can ingest a certain amount of lactose without feeling symptoms; most people can tolerate around 9–12g (or 1 glass of milk) (*de Vrese* et al. *2001.422*). However, for a lactose intolerant adult, *i.e.* most of the people that came into the contact with milk during the domestication of animals, the consumption of more than a cup of milk can have effects quite different from 'increasing the flesh'.

Thus, in order to be digestible, new materialities have to enter the assemblage. Milk has to be subjected to a process in which a starter culture of bacteria ferments/digests milk sugar to produce lactic acid. The agency of microbes makes milk digestible for humans.

Gut bacteria

Fresh milk is largely a 20th-century phenomenon, made possible by the advent and spread of refrigeration technology. People who milk cows, goats, and other ruminants have always been able to enjoy fresh milk, but as a practical matter, most have had access to milk primarily in fermented forms. Generally, fermentation stabilises milk, transforming it from a highly perishable substance into much more stable forms.

Yoghurt is made by warming milk and introducing a special culture of bacteria. The usual starter culture employed to produce yoghurt is a mixture of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp *bulgaricus* (*Fernandes 2009.77–84*). Bacteria provide work, by breaking down lactose, releasing lactic acid, which acts to coagulate the milk into a curd consistency. Yoghurt offers all the nutrients in milk, but has much less lactose (*Amanatidis 1999.396*).

Cheese has been made for centuries and is one of the most effective ways of preserving milk. Cheese is a stabilised curd of milk solids produced by casein coagulation and the entrapment of milk fat in the coagulum (*Fernandes 2009.61–73*). Basically, cheese is made by using specific bacteria or rennin (*chymosin*), an enzyme produced in the stomach lining of newborn ruminants and extracted from the inner mucosa of the fourth stomach chamber of unweaned calves, to coagulate the casein so that it separates into a thick curd and watery whey. The whey is removed and the curd is further processed to produce different cheeses (*Amanatidis 1999.396–397*). The water content is greatly reduced, in comparison with milk, by the separation and removal of whey from the curd. Most cheese is now produced with a carefully selected starter, which produces predictable and desirable results. *Lactococcus lactis*, *Streptococcus thermophilus*, *Lactobacillus helveticus* and *Lactobacillus delbrueckii* are the primary species used in cheese making (*Fernandes 2009.61–73*).

There are many different cheeses. They vary because of differences in the treatment of the starting bacterial culture or rennet and the way the curd is treated subsequently and matured (*Amanatidis 1999.396–397*). These starter cultures and subsequent treatment of cheese are regionally specific, thus the connection between food, animals, place and identity is woven through the use of microbial cultures.

However, to recruit microbial cultures, we need specific technology and material culture: containers which mix and store substances and keep an assemblage together, while strainers separate the assemblage into solids (curd) and liquids (whey) that contain lactose; pots where yoghurt is fermented, strainers that separate whey from curd, bacterial culture that ferment milk are external organs, external stomachs and guts. In the words of Don Ihde (*2002.137*), "*We are bodies in technologies*". Technologies are not mediators, interfaces between us and the world; technologies are organs, full partners, in our assemblages with the world (*Haraway 2008.249*).

Microbes not only contribute a kind of labour to the production of yoghurt or cheese, but also confer a certain vitality on them. Thus raw-milk cheese, yoghurt, kefir can be seen as an assemblage, an ecology, that matures and ages, and can then be spoiled and die (*Paxson 2008.38*). This ecology is then digested in the human digestive system, a series of mutual transformations in which the border between the inside and outside becomes blurry. As Jane Bennett describes the relation enacted through eating (*2010.49*), what I eat "*both is and is not mine, you both are and are not what you eat*". And: "*If what is eaten is to become 'food', it must be digestible to a formerly foreign body. Likewise, if the eater is to be nourished, it must accommodate itself to a formerly foreign body. Both, then, have to have been mutable, to have always been a materiality that is hustle and flow as well as sedimentation and substance*" (*Bennett 2010.134–135*). In the relation established through the act of eating, then, all bodies are merely temporary congealments, a becoming of materiality.

Life is enmeshed in elaborate food webs through which stuff circulates. Eating establishes relations between organisms and between organisms and the environment; in this way ecologies emerge. As Timothy Morton (*2009*) has argued, 'ecology' does not refer to 'nature' but rather to the manner in which an organism, human or otherwise, is imbricated with another. Ecology is thus the manner in which entities are entangled with one another in assemblages everywhere. However, relations in food webs are unstable; balances may easily shift, and their overall coherence is frail (*Bertoni 2013.61–62*).

Eating helps us attend to the situatedness, the materiality and the multiplicity of relations. Eating is a material practice where ecologies are created, where relations are established, where assemblages are created and maintained. Attending to the process of eating can improve our understanding not only of eating but also of relating (*Bertoni 2013.64*). Eating is thus a formation of an assemblage, of humans and non-human, all of which bear some agentic capacity. By ingesting milk and dairy products, by intertwining flows of materiality, our history crosses with the histories of bacteria.

Gut-brain axis

The human intestines contain approx. 100 trillion micro-organisms, ten times the number of human cells in the body. This gut flora has around a hundred times as many genes in aggregate as there are in the human genome. As a species, we are a composite of many species, with a genetic landscape that encompasses not only the human genome, but also those of our bacterial symbionts.

The intestinal habitat of an individual contains 300–500 different species of bacteria. The large intestine contains a complex and dynamic microbial ecosystem with high densities of living bacteria that achieve concentrations similar to those found in colonies growing under optimum conditions (*Guarner, Malagelada 2003*).

The relationship between gut flora and host is interdependent: gut flora contribute energy from the fermentation of undigested carbohydrates and the subsequent absorption of short chain fatty acids to the host. Mammalian genomes do not encode most of the enzymes needed to degrade the structural polysaccharides present in plant material. Herbivorous mammals rely on intestinal microorganism to metabolise energy from plant food. Ruminants benefit from microbial protein and the absorption of energy released by anaerobic microorganisms in the form of fermentation acids in the foregut. Other herbivores and omnivores acquire additional energy from microbial fermentation in the hindgut of carbohydrates that were not digested in the upper gut. Animal species with similar digestive anatomies and nutrition also share similar gut microbiota (*Flint* et al. *2012.289*).

Colonisation of the gastrointestinal tract of newborn infants starts immediately after birth. During human evolution, changes in dietary preferences, food production and preparation such as cooking, agriculture and cooking have also influenced the intestinal microbiota. We have evolved eating both plants and animals, while also co-evolved with them – our coevolutionary histories encompass not only the plants and animals themselves but also their microbial associates. Gut flora are our companion species.

Though the history of unfolding relation with other species, animals and plants established through eating, we have incorporated a variety of bacteria-rich living foods. Bacteria break down nutrients we would not otherwise be able to digest, and play an important role in regulating the balance between energy use and storage. Intestinal bacteria synthesize some essential nutrients, including B and K vitamins. They provide defence against invading pathogens. Even more, intestinal bacteria are able to modulate the expression of certain genes related to diverse and fundamental physiological functions, including the immune response.

External bodies, cultures ingested in our bodies, help to absorb nutrients. The *lactobacillus* and other starter cultures are probiotics, microorganism which contribute to the well-being of the host organism. Probiotic bacteria in fermented and unfermented dairy products improve lactose digestion and eliminate the effects of lactose intolerance. These beneficial effects are due to microbial lactase in bacteria, which is released in the small intestine, but also to the positive effects on gut flora, and suppression of symptoms (*de Vrese* et al. *2001.425; Perez Chaia, Oliver 2003.90*).

A growing body of evidence shows connections between the brain and the condition of the bacteria living in the gut. Changes in the composition of microbiota thus affect human behaviour (*Tillisch* et al. *2013*). A diet rich in *Bifidobacterium animalis* subsp *Lactis*, *Streptococcus thermophiles*, *Lactobacillus bulgaricus*, and *Lactococcus lactis* subsp *Lactis* produces changes in mid-brain connectivity associated with emotion and sensation. Gut microbiota play a role in modulating pain sensitivity, stress responsiveness, mood, or anxiety, and can alter mental processes and reduce stress responses. This so-called gut-brain axis connects the health of gut microbiota to the unconscious system regulating human behaviour (*Dinan* et al. *2015*).

The gut contains microorganisms that share a structural similarity with the neuropeptides involved in regulating behaviour, mood, and emotion, a phenomenon known as molecular mimicry. We are fundamentally dependent on a myriad of essential neurochemicals produced by microbes. For example, the brain's serotonergic system, which plays a key role in emotional activity, does not develop appropriately in the absence of microbes (*Clarke* et al. *2012*). Around 90 per cent of the serotonin, a brain neurotransmitter in the body, is made in the digestive tract (*Yano* et al. *2015*).

Even more, gut flora influence human eating behaviour and dietary choices (*Alcock* et al. *2014*). They induce cravings for foods in which they specialise, or foods that suppress their competitors, rather than simply passively living off whatever nutrients we choose to send their way. They control reward and satiety pathways in the host's body, the production of toxins that alter mood, changes to receptors, including taste receptors, and hijacking of the vagus nerve, the neural axis between the gut and the brain (*Alcock* et al. *2014*). Bacterial species have different dietary preferences; they not only compete with each other for food and niches within our digestive tracts, but their aims often conflict with ours when it comes to our own actions.

We can say, after Jane Bennett (*2010.137*), that dairy products "*have the power not just to increase human flesh but also to induce human moods, modes of sociality and states of mind*". They affect our brain. Someone who drinks fermented milk thinks and act in a different way from a non-milk drinker and craves different foods. The productive power or agency of the milk drinker is an emergent property of confederacy, an assemblage of stuff, microbes, animals and other foreign materialities.

Conclusions

Who ate whom? Who made whom act? Who changed whom? Who is an agent here? We can say that humans mobilised bacteria to drink cow's milk, but this is not the whole story. Cows seduced humans with their milk so that humans would protect them from predators; but we should also imagine the converse situation: bacteria have influenced humans without their knowledge to make them domesticate cattle and drink milk.

The fact that human behaviour can be attributed to multiplicities of mindless organisms poses a huge problem for the Cartesian division between the mind and body and the divide between humans (subjects) and cows, milk, bacteria, material culture and other stuff (objects). This complex assemblage of different materialities strikes a deadly blow to a liberal, Western model of an agent as a free, rational, individual subject; and to agency equated with unique human cognitive structures, rational action, the capacity for skilful social practice, conscious practice, subjective experience, intentionality, inter-subjectivity and free will.

Who influences whom and who is influenced by whom are questions that can no longer receive a clear answer. All – humans, cows, bacteria, milk, material culture – are cause and effect of each other's movements. All induce and are induced, affect and are affected (*Haraway 2008.230; Despret 2004.125*).

Today, cows are machines for turning grass into milk. The average yield of modern cows is about 6000 litres per year, with particularly efficient animals actually producing up to 20 000 litres. There are around 264 million dairy cows worldwide, producing nearly 600 million tonnes of milk every year. And today, more than 35% of humans worldwide can digest milk, while this percentage is much higher in Europe and the Near East.

But these modern cows and modern humans are the result of a long and complex history of interactions and interventions that resulted in the realisation of some potential in cows, humans and other creatures, while denying others. This intense becoming results in what Bruno Latour calls "*internalised ecologies*", intense socialisation, a reconfiguration of animals, plants and humans, which results in different bodies, such as those which can digest lactose or that have a much lower milk let-down threshold (*Latour 1999.208*).

As Anna Tsing (*2012.144*) says, "*Species interdependence is a well-known fact – except when it comes to humans. Human exceptionalism blinds us*". To talk of companion species means to accept that who and what we are is always something relational, emergent, process-like, historical, mutable, specific, contingent, finite, complex, impure (*Haraway 2004; Pali Monguilod 2006.252*).

Following the flow of the milk, we come to a realisation that nothing exists in and of itself. Instead, things exist and take the form that they do by participating in an emergent web of materially heterogeneous relations. Things exists only in assemblages. Acknowledging this, we can shift from the assumption that we know what milk, cow, humans, bacteria, pot *etc.* are to an attention to what and how this milk, cow, human, bacterium, pot were produced through specific material practices (*Law, Mol 2008*).

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Vessel guardians: sculpture and graphics related to the ceramics of North-Eastern European hunter-gatherers

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ABSTRACT – *North-Eastern European hunter-gatherer ceramic sculptures, relief sculptures and graphic images on vessels are discussed. Five groups of finds are distinguished according to their chronology (4000–2500 calBC) and the subject that is represented (birds, human heads, human figures, mammal heads* etc.*). We believe that the production of these items was a female craft; they were made for ritual purposes and their emergence was independent of any influence from pastoral/agricultural societies.*

IZVLEČEK – *V članku predstavljamo skulpture, reliefe in grafične upodobitve na keramičnih posodah lovcev in nabiralcev v severnovzhodni Evropi. Glede na kronologijo (4000–2500 calBC) in upodobitve (ptice, človeške glave, človeške figure, glave sesalcev itd.) ločimo pet skupin najdb. Posode so izdelovale ženske; namenjene so bile ritualni uporabi in niso povezane z vplivi živinorejsko-poljedelskih skupnosti.*

KEY WORDS – *hunter-gatherers; forest zone; Eastern Europe; ceramics; clay sculpture*

Introduction

It is well known today that north Eurasian Holocene hunter-gatherer-fishing peoples used ceramic vessels, but it is less known that they also made small clay sculptures, depicting human, zoomorphic and probably mixed/fantastic images. Moreover, there existed clay sculptures merged with vessels have been found, which parallel numerous and well-known finds from south-east European and Near Eastern agricultural societies. Graphic images of birds and humans on ceramics are also known among north-east European foragers. The making of clay sculpture survived among forest zone foragers for an extremely long time, until the Early Iron Age, the first centuries AD, when agriculture finally became a constant (and sometimes considerable) element of subsistence.

This paper focuses on artefacts from the period from 4000 to 2500 calBC (in Russian archaeological literature, traditionally defined as the Middle/Late Neolithic – Eneolithic/Early Metal Period).[1] A number of cultures of presumably sedentary groups engaged in hunting, gathering and fishing were dispersed over a huge area of the north-east European forest zone, including modern Russia (to the west of the Urals), the eastern Baltic countries and partly Finland (see Fig. 1).

Most of the settlements in these regions are as multilayer sites, where mixed artefacts from different epochs, usually from the Late Mesolithic to the Neolithic, Bronze, sometimes even the Iron Age, can be identified. The landscape of the Russian Plain is full

1 The Early Metal Period is the term applied to the period of transition from the Neolithic to the Bronze and Early Iron Age in the north-eastern European forest zone (*e.g.*, in Finland, North Karelia and the Arkhangelsk districts of Russia), where the presence of metal items occured extremely late in comparison with other parts of the forest zone; therefore, the terms 'Eneolithic' and 'Bronze Age' are not used there.

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Fig.1. Zone of distribution of portable ceramic art in north-eastern Europe (map: E. Kashina).

of rivers; the main basins are formed by huge rivers, such as the Volga, Western Dvina, Northern Dvina and their numerous tributaries, large and small, and lakes, which together form a wide network of waterways. Most of this area could have been used all year round, by boat in warmer seasons and on ice in winter. Fishing played a considerable (if not the leading) part in subsistence, which is argued in numerous studies on technology and paleo-dietary matters (see *e.g., Piezonka* et al. *2013*). The most common type of dwelling at that time was semi-subterranean and rectangular, with fireplace(s) inside, narrow inclined exit(s), wooden plank walls, and measuring 40–120m^2. Ceramics appeared around 5500–5000 calBC (that is, the beginning of the Neolithic for Eurasian forest zone foragers) and its development during the next 2500 years, stated briefly, go through several great phases: 'Early Neolithic' (plain surface, poor decoration, 5500–4000 calBC), 'Middle Neolithic' (mineral temper, comb and pit decoration, 4000–3000 calBC), 'Late Neolithic' and 'Early Bronze' or 'Early Metal Period' (different organic temper – so-called Porous Ware – comb and pit decoration of numerous types, 3000–2500 calBC and later) (*Oshibkina 1996; Bahder* et al. *1987*). Obviously, the process of adopting ceramic technology was faster in southern parts of the north European forest zone, while the northern part seems to have been rather 'conservative' and even 'slow' in the uptake of ceramic technology.

The making of Stone Age hunter-gatherer ceramics is believed to have been a female domain. The considerably fast spread of ceramic technologies to the north appears to have been connected with kinship alliances (*Tsetlin 1998; Zhulnikov 2006*). Due to climate conditions, pots could only be made in the summer. Vessels of simple oval – or egg-shaped forms with a diameter of 20 to 40cm were probably used for storage as well; organic cooking residue occurs considerably rarely; some sherds have holes indicating attempts to repair broken vessels; some vessels were buried.

Clay sculpture in the Eastern European forest zone appear in the form of sets, which are widespread among cultures with Comb-Pitted Ware of the Eastern Baltic basin, and located beside the hearth in dwellings. They comprise several human figures (schematic, embryo-like) (*Kashina 2009*), birds, snakes and mammals – elk, beaver, or otter. Some were painted with red ochre; others could have been placed on a flat surface, because have flat bases or holes in the bottom for a thin handle to be attached (*Kashina 2007*). Most of the items were found in fragments, but there is no evidence that clay sculptures were deliberately destroyed, although some researchers have expressed this opinion (*Nuñez 1986; Loze 2005*). The most probable reason for the fragmentation is the multi-layered character of the sites and the occasional nature of the particular domestic rituals during which these sets of items were used (*Zhulnikov 2009*). However, they cannot be regarded as disposable, because some pieces have polished surfaces here and there. Thus they were kept safe for some time and a number of unknown actions were performed with them until the moment they were discarded.

Fragments of vessels with sculptures of human head on the rim and vessels decorated with a belt of waterfowl images around the rim (on both of which this paper focuses), are sometimes found at the same sites and in similar contexts with clay sculptures, and also come from Comb-Pitted Ware cultures. The best example is the set from Peski IV-a site, Karelia (Fig. 2), which was found in an area of 25m^2 inside a dwelling (*Kashina 2007; Zhulnikov, Kashina 2010*).

It is necessary to mention that the same clay paste was used for ordinary vessels, special ones and sculp-

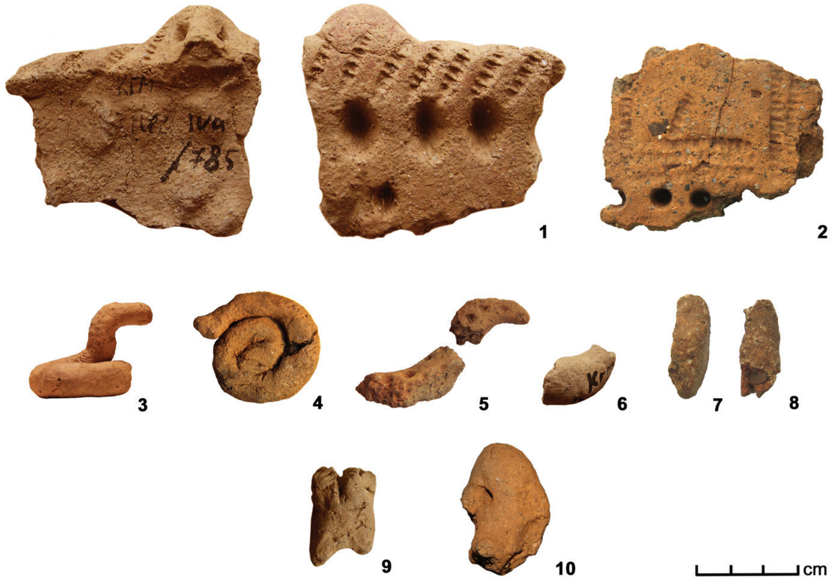

Fig. 2. Set of ceramic objects, Peski IV-a site, Republic of Karelia, Russia (photo: E. Kashina, A. Zhulnikov). 1 vessel fragment with human head; 2 vessel fragment with birds; 3–4 snake sculptures; 5–6 bird sculptures; 7–8 unknown sculpture fragments; 9–10 human sculpture fragments.

tures, so it can be supposed that sculptures and special vessels were made simultaneously with ordinary ones. Thus, there existed certain symbolic connections between sculptures and special vessels in rituals. The sets in question could represent a model of the universe and the presence of anthropomorphic ancestors in this context. They are believed to have played an important part in female spirituality and were probably needed to protect a particular dwelling, family members and especially children (*Kashina 2009*).

Images and vessels: morphological groups

The ceramic art connected with vessels can be divided into five groups:

❶ fragments of vessels decorated with a belt of waterfowl images around the rim;
❷ fragments of vessels decorated with images of humans and humans with birds;
❸ fragments of vessels with human head sculptures on the rim;
❹ fragments of vessels with full-figure sculpture/relief sculpture;
❺ fragments of vessels with a zoomorphic head on the rim.

Group 1 consists of nearly 40 pieces (single sherds or partly preserved vessels), most of which are connected with the Baltic Comb and Finnish Comb-Pitted Ware (*Pesonen 1996*). Several finds have also been made in the centre and north of European Russia. Before firing, images of swans or geese were made with comb stamps below the vessel rim, usually about 4 x 6cm, and definitely representing birds swimming in a row to the left (more rarely) or to the right (Fig. 3).

Most vessels were reconstructed as large examples, 30–40cm in diameter and height, with 15–24 birds depicted on them (*Zhulnikov, Kashina 2010*), but some could have been smaller (about 20cm in diameter) (*Schulz 2006*). Several partly preserved vessels were found in dwellings; two have holes and even resin pieces, clear evidence of restoration. So far, no organic residue has been detected on the inner surfaces of any sherds, except one vessel fragment from the Joroinen Kanava site in Finland (*ibid.*).

Group 2 consists of seven images of humans below the vessel rim and another two vessels where a human is placed in a row of birds. All finds are single sherds or partly preserved vessels. Two pieces, so-called Porous Ware, found in Latvia and the Vologda district, date to the terminal phase of the Neolithic or the Early Bronze Age. Three pieces (Finland, Velikiy Novgorod district) are Late Comb Ware, four pieces (Lithuania, Republic of Belarus) are Corded Ware. Linear stamped or sometimes carved human figures measuring 6–10cm are depicted en face with legs apart or bent at the knees, apparently dancing;

Fig. 3. Vessel fragment with bird images, Chornaya Guba IX, Republic of Karelia, Russia (photo: E. Kashina).

sometimes the belt zone is marked with a horizontal line, and sometimes horns or a phallus appear (*Kashina 2006*). A vessel from Kolomtsy (Velikiy Novgorod district) (Fig. 4) was found buried (*Peredolski 1905*), so perhaps this bird/human/bird-human ornamentation was 'hidden' when the vessel was in use.

Group 3 consists of nine sherd finds from different sites distributed rather compactly to the east, from the Gulf of Finland of the Baltic Sea, depicting a human head attached to the rim, facing into the vessel. These heads fully correspond to the anthropomorphic sculptures, and are contemporaneous, but dispersed more locally. Their head decoration, when present, consists of two types, both made with a comb stamp: an inverted trident and a row of oblique imprints continued on the vessel rim. The rim head from the Peski IV-a site (see Fig. 2, 1, reverse side) was painted with red ochre. According to the reconstruction based on another find from Karelia – a large vessel from Chornaya Guba IX site (Fig. 5) – four heads were placed crosswise on one vessel.

Fig. 5. Vessel fragment with a human head on the rim, Chornaya Guba IX, Republic of Karelia, Russia (photo: E. Kashina).

It is also necessary to mention that this large example (diameter 50cm, height 60cm) was restored with resin and stringing (*Vitenkova 2002*). According to Alexandr Zhulnikov, simple protrusions on vessel rims occurred in different regions of north eastern Europe from the Final Stone Age until the Early Iron Age and do not correspond directly to the abovementioned Group 3, which is distributed rather locally. Nevertheless, he argues that both Early and Late hunter-gatherers of the north eastern European forest zone shared quite similar worldview and beliefs, which is why rim protrusions, being obviously non-utilitarian details, appeared here and there during several epochs (*Zhulnikov 2012*).

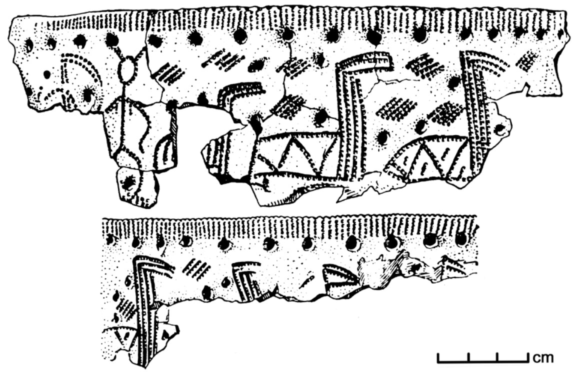

Fig. 4. Vessel fragment with human and bird images, Kolomtsy, Velikiy Novgorod district, Russia (after* Peredolsky 1905*).

Group 4 includes six pieces. Two sculptures attached to the vessel rim are Asbestos Ware (Karelia) and one to Late Pitted-Comb Ware (Central Russia). Two relief sculptures of full human figures (Lithuania and Central Russia) and one relief sculpture of a human head (Latvia) probably date to the Late Neolithic/Early Bronze Age (Porous Ware). All images are situated immediately below the vessel rim. According to the reconstruction by Zhulnikov, two human figures found in a dwelling were placed opposite each other on one vessel, as if 'looking' inside the vessel, and some feathers were perhaps attached to their heads, because several pinholes were made in them (Fig. 6).

Fig. 6. Reconstruction (plaster) of a vessel with figurative sculptures found at Voinavolok XXV site, Republic of Karelia, Russia (photo: E. Kashina).

The comparison of the human figures coloured with red ochre reveals a certain difference in details: 'blind'/pin-holed eyes, three/four pin-holes on the top of the head. Three relief sculptures of a human figure/head differ greatly from each other and were separated by long distances (Lithuania, Latvia and Nizhny Novgorod district), so they probably reflect convergent traditions. Two full-figure reliefs 'hug' the vessel with long outspread arms, their legs slightly apart. Both examples (Nizhny Novgorod district and Lithuania) date to approx. 3000 calBC or even later (Fig. 7).

Fig. 7. Vessel fragment with a human figure in relief, Volosovo, Nizhniy Novgorod district, Russia (photo: E. Kashina).

Group 5 consists of four quite similarly modelled pieces: the head of an unknown mammal on a rim with a protruding muzzle and raised ears, facing away from the vessel. All finds are from the centre of European Russia and situated comparatively close to the forest-steppe border (the Volga and Oka River basin). All of them are from Eneolithic-Early Bronze Age ceramic traditions, probably dating to 3000–2500 calBC or even later. One vessel (Galankina Gora, Republic of Marij-El) was found in the fireplace area of a dwelling (*Solov'iev 1987*). Another fragment (Vladychinskaya-Beregovaya I site, Ryazan district) (Fig. 8) (*Studzitskaya 1980*) has a pinhole in the top of the head, probably for fastening a feather or something else. This unique type of vessel sculpture was probably influenced by some cultural impulse from the forest-steppe zone, but direct analogues remain unknown.

Conclusions

Ceramic sculpture and graphics on vessels provide abundant data for studying hunter-gatherers' ritual life, domestic beliefs, mythology, pottery making and pottery decoration. Several common traits unite these materials. Firstly, these are rare finds, made in settlement contexts, supposedly in a dwelling, or near a fireplace. They were obviously not connected with funeral rites, but only with hearth and home. Secondly, the position of the image on the vessel is always very similar, regardless of the region, ceramic traditions or period, *i.e.* close to the vessel edge. The sculpture is on the rim top; reliefs and graphics are on the upper surface adjoining the rim. Thirdly, these sets of sculptures and special vessels were handled with care for extended periods and definitely were not disposable items. Taking into consideration the fact that such ceramics were probably made by women, it can be inferred that the general symbolic meaning of all these special vessels could have been connected with female spirituality, rites performed inside the house, probably of an occasional character, and with the storage of some unknown content in such vessels, which unfortunately in most cases have left no residues on their inner surfaces.

The idea of the vessel edge as a 'liminal' zone which needs special protection against evil seems to be a universal, ecumenical notion, connected not only with ceramic vessels, but also with caves, female bosom, plaited hair, wounds, costume cuffs and belts *etc.*, and widely discussed in the literature (see *e.g., Moshinskaya 1976; Antonova 1984*).

The special meaning of waterfowl images (which are also among the sculptural and graphic images on vessels) for north Eurasian prehistoric hunting societies has already been mentioned in a number

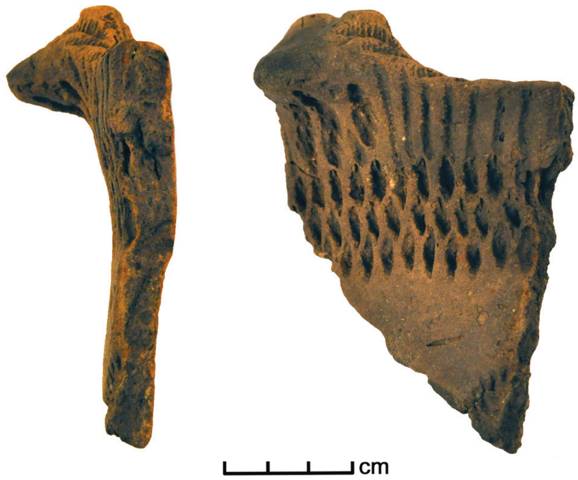

Fig. 8. Vessel fragment with zoomorphic relief, Vladychinskaya Beregovaya I, Ryazan district, Russia (photo: E. Kashina).

of semantic/semiotic studies. Waterfowl played a notable role in cosmology and the cycle of life and death, and were strongly connected with such notions as the 'human soul' and 'childhood' (see *e.g., Napol'skikh 1990; Zhulnikov 2009*). A decorative belt of swimming swans or geese surrounding the vessel and probably also protecting its contents appears on some finds. The idea of a vessel as a symbol of the universe is also well known from archaeological and ethnological studies (see *e.g., Antonova 1984; Kosarev 2008*).

The volume of vessels in the eastern European forest zone Final Stone Age, is recognised generally as 20–50 litres. This fact, no matter whether it was for cooking or for storage, could mean the collective use of contents: big meals, big stocks of edible (or non-edible) stuff consumed or kept, obviously, by one family or kin group. Even moving a large vessel filled with something could require concerted action by, for example, two people.

Returning to chronology, the earliest images in our study, the so-called sets of sculpture, the interpretation of figurative sculptures as ancestors, accompanied by animals of three universal levels – birds (sky), mammals (ground) and snakes (underworld) – have already been discussed (*Kashina 2007*). Evidently, the same ancestors were depicted as vessel guardians in the form of human figures or heads on the rims. Graphic and relief representations of human figures seem to be the latest, but could also be interpreted as vessel guardians. Depicted individually, not accompanied by birds, they probably reflect some changes in beliefs, perhaps influenced by heterogeneous groups which also settled the forest zone (Globular Amphorae, Corded Ware, Battle Axes, Fatyanovo), traces of which are sometimes visible in local material culture (*Girininkas 2002*).

The 'Neolithic decline' and the formation process of Bronze Age forest hunter-gatherer cultures are not clear enough. Seemingly, some traditions survived; for example, some rare finds of vessels decorated with birds in central and north-eastern European Russia are slightly reminiscent of Neolithic ones (*Zhulnikov, Kashina 2010*). Also, some vessel fragments with simple protrusions on the rims are known from the eastern European forest zone, probably an echo of Late Neolithic/Early Metal Period rim sculptures (*Zhulnikov 2012*). The appearance of the 'vessel-guardian' idea and also of clay sculpture production in the Eastern European forest zone definitely was a process that occurred independently of southern pastoral/agricultural traditions. It seems to have originated in south-eastern Finland, southern Karelia and northern European Russia between 5000 and 4000 calBC (*Ivanischeva, Kashina 2015*).

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Analysis of late mid-Neolithic pottery illuminates the presence of a Corded Ware Culture on the Baltic Island of Gotland

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ABSTRACT – *In this paper, we discuss variations seen in the ornamentation and modes of manufacturing pottery from the end of the mid-Neolithic 4600–4300 BP on the Island of Gotland in the Baltic Sea. The Pitted Ware cultural groups have been discussed as a western influence from the Swedish mainland, but the aDNA on skeletal remains point to eastern influences. We analyse and discuss pottery from the well-investigated Ajvide Pitted Ware site and what these variations mean in term of intra- and inter-island relationships, ethnicity and change, and we suggest the development of what could be described as a hybrid culture.*

IZVLEČEK – *V članku predstavljamo razlike v ornamentih in izdelavi lončenine s konca srednjega neolitika, 4600–4300 BP na otoku Gotland na Baltskem morju. Kulturne skupine jamičaste keramike so bile tu interpretirane kot zahodni vpliv s celinske Švedske, vendar stara DNK v neolitskih človeških kostnih ostankih kaže na vzhodne vplive. Analiziramo lončenino z dobro raziskanega najdišča jamičaste keramike Ajvide in pojasnjujemo, kaj te razlike pomenijo na otoku in med otoki, kako so povezane s populacijskimi premenami in kulture opišemo kot hibridne.*

KEY WORDS – *Pitted Ware Culture; Corded Ware Culture; Battle Axe Culture; hybrid culture; pottery; identity; Gotland; Baltic Sea; mid-Neolithic*

Introduction

The focus of this article is an analysis of decorative designs on pot-sherds from the well-documented Pitted Ware Culture (PWC) site of Ajvide on South West Gotland Island in the Baltic Sea, which is dated to the mid-Neolithic (5300–4300 BP). We use this case study to address the following questions: is the pottery with cord imprints found at Gotland PWC sites a feature that is an influence from the Funnel Beaker Culture (FBC) or the Battle Axe Culture BAC, which is a Scandinavian variety of the Corded Ware Culture (CWC). Secondly, why is pottery with cord imprints found at Gotland PWC sites and not at the Swedish mainland PWC sites?

To arrive at better models of interpretation of human colonisation and migration *vs.* the transmission of ideas and trading of prestige goods and commodities during Neolithic in Scandinavia, we suggest that it is increasingly important to make detailed analyses of the genetic, material cultural and environmental evidence alike and their temporal variations. Here we mainly focus on pottery, but we discuss other types of material culture, radiocarbon dates and isotope and genetic studies.

The typical pottery style of ornamental design of PWC pots include pits, incisions and stamps made with bones and combs tools, whereas PWC pottery made by groups on the also includes sherds with cord imprints. The cord imprints are patterns that are generally typical of the FBC groups that were contemporaneous with PWC in the earliest phase

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of the mid-Neolithic (MN A *c.* 5300–4800 BP) and the BAC, which was contemporaneous with the PWC on the Swedish mainland during the late mid-Neolithic (MN B *c.* 4800–4300 BP).

The earliest human traces on Gotland were found at the Stora Förvar cave site on the islet of Stora Karlsö and date to the Scandinavian mid-Mesolithic phase, (*c.* 8000 BP) (Fig. 1 and Tab. 1). This small raised limestone islet lies approx. 10km south-west of the Gotland mainland. During the following phase, the Late Mesolithic (*c.* 7500–6000 BP), there are finds of human activities also on mainland Gotland, especially in the north. The Scandinavian Early Neolithic (*c.* 6000–5500 BP), human occupation of Gotland was located close to an inshore lake system in the centre of the island (*Österholm 1989.74*), where the first evidence of pottery on Gotland was found. The pottery has cord imprints and is from the FBC tradition, while other finds at these sites indicate flint tool manufacturing in conjunction with hearths with burnt bone fragments and nut shells (*Thorsberg 1997; Österholm 1989; Lidman 2014*). The FBC groups have been interpreted as farming communities that utilised domesticate animals and had megalith burial customs (*Martinsson-Wallin, Wallin 2010*).

The FBC pottery tradition and Neolithic lifestyle ended in the Scandinavian mid-Neolithic (*c.* 5500–4300 BP) and human settlement on Gotland has been described as part of the PWC, sub-Neolithic tradition. According to radiocarbon dating, the FBC and the PWC co-existed during the earliest part of this time frame (mid-Neolithic A *c.* 5500–4800 BP) and the discussion has focused on whether the FBC groups were the ancestors of the PWC or the PWC ancestors were from an earlier Mesolithic group on the island. Another version is that the PWC groups migrated to Gotland Island in the mid-Neolithic and had no previous ancestors on the island. Current research data support the latter hypothesis.

The PWC tradition dominated Gotland for some 500 years during the mid-Neolithic. At the end of the mid-Neolithic (MN B *c.* 4800–4300 BP) traces have been found of material culture typical of the BAC, such as corded ware and typical battle axes. The former are found at coastal PWC settlements, but the latter are found all over Gotland, especially towards the hinterland close to the lakes and wetlands (*Palmgren 2014a*). Here, the discussions have focused on whether a new group of people from the corded ware BAC tradition migrated to Gotland Island and mixed with PWC groups or whether only BAC material culture, a few marriage partners and ideas that found its way to Gotland Island.

Scandinavian Stone Age phase on Gotland	BP	BC
Mid-Mesolithic	*c.* 8000–7500 BP	*c.* 6000–5500 BC
Late Mesolithic	*c.* 7500–6000 BP	*c.* 5500–4000 BC
Early Neolithic	*c.* 6000–5500 BP	*c.* 4000–3500 BC
Mid-Neolithic A	*c.* 5500–4800 BP	*c.* 3500–2800 BC
Mid-Neolithic B	*c.* 4800–4300 BP	*c.* 2800–2300 BC

Tab. 1. Scandinavian Stone Age phases and their approximate BP and BC dates.

Pitted Ware Culture

The term Pitted Ware Culture was coined by researchers in the early 1900s, when Stone Age sites with pottery decorated with distinct pits were found in east mainland Sweden (*Malmer 2002*). These sites

Fig. 1. Map of the distribution of PWC tradition. The green colour indicates the approximate distribution of PWC culture. M stands for 'Mälar Valley', G for 'Gotland' (after* Palmgren 2015*).

were found inland, but due to shoreline displacement it was calculated that they were coastal bound during the Neolithic. The PWC groups have been discussed as belonging to a homogeneous culture, and these groups were distributed over large parts of Northern Europe, but with regional variations among the pottery assemblages (Fig. 1). The regional traits can be detected in variations in the ornamentation and durability of the ware. The archaeological remains of PWC groups have been found on the east and south coasts of Sweden, and on the Baltic islands of Åland, Gotland and Öland, but also on the west coast of Sweden, north-eastern Denmark and south-eastern Norway (*Malmer 2002.120–122*). This tradition is dated to the mid-Neolithic (*c.* 5300–4300 BP), the earliest sites being found in areas in the Lake Mälaren Valley (*Hallgren 2011.32*) (Fig. 1).

The east coast mainland Sweden pottery from the PWC groups has been divided into various types based on pottery from the Fagervik site (Fagervik II–IV) and with regard to the different stratigraphic levels in which they were found (*Bagge 1951*). Fagervik I belongs to the FBC tradition and Fagervik V belongs to the BAC tradition, so Fagervik II–IV has been interpreted as stemming from the PWC tradition. However, the south and west Swedish pottery from the PWC tradition does not conform to the template of the Fagervik pottery style. Given that PWC pottery ornamentation actually varies from place to place, it has been suggested by Welinder (*1973.56*) that the PWC tradition should be divided into East Swedish, South Swedish and Gotlandic and a North Sea group.

A marked difference between the East and West Swedish PWC ware is that the latter is dense, while the former is both dense and porous (*Strinnholm 2001*). This was because they were tempered in different ways. For example, some ware found in eastern Sweden and on Gotland was tempered with material that has been degraded due to taphonomic processes. This process is common in pottery tempered with crushed limestone, which is the typical temper of the PWC pottery found on Gotland. The choice of this type of temper is not surprising, since most of the bedrock on Gotland is limestone, but sources of quartz and granite are limited. However, the latter two are among the most common materials for temper on the east coast of Sweden during the late mid-Neolithic (*Ytterberg 2007.392*).

Archaeological research has shown that these groups had a sub-Neolithic life style, including marine hunting and foraging. The animal bone residues found at these sites show that their subsistence was based mainly on seal hunting and fishing. They also utilised domesticate animals such as pig, dog and cattle to a minor extent, but no traces of crops have been found.

The PWC sites on Gotland are located on the coast and the activities are interpreted as settlement/hunting sites in the early phase and burial sites during the later stages (*Martinsson-Wallin 2008; Wallin 2015; Wallin, Martinsson-Wallin in press*). The early Ajvide pottery shows various traits that are similar to the PWC pottery found at sites on the Swedish east coast. Since the Ajvide site is located in the south-western part of Gotland and close to the Stora Karlsö site (which was in continuous use during the mid-Neolithic), and sites on the northernmost point of Öland Island, it is likely that they had close contacts between east Sweden and Ajvide/Stora Karlsö sites during this time (*Papmehl-Dufay 2003*).

The PWC Ajvide-site – graves and pottery

The earliest excavations at Ajvide were carried out in 1923. Excavations were not resumed until 1983, when large-scale work began, continuing with some minor breaks until 2008 (*Österholm 1989; 2008; Burenhult 1997; 2002; Ajvide Database 2009*). The field work of over 20 years was carried out in the form of field training by Stockholm and Gotland universities. The very rich cultural layers, which can be over half a metre thick, are typical at most sites with PWC graves on Gotland, but are less common along the Swedish coasts. The Ajvide site has never been subjected to modern ploughing, and below the topsoil of approx. 20cm of mixed material, the cultural layers were intact. A large quantity of archaeological finds was recovered, consisting of around 2300kg of bone fragments, 3300kg of ceramic sherds and 200kg of flint (*Ajvide Database 2009*). The total size of the excavated area is approximately 3000m^2, although this is only a small part of the estimated 200 000m^2 size of this site (*Wallin 2015*).

The Ajvide site is situated on a cape close to the shore, and phosphate analysis (*Österholm 1989*) has shown that the area of utilisation follows the shoreline displacement and topography of the cape in a north-south direction (Fig. 2).

Several areas with dark 'fatty' soil have been found on the site, which have been interpreted as areas for ritual activities such as ritual butchering. To date, four (possible five) 'dark areas' have been found. These areas yielded a larger amount of pottery than other areas, and the radiocarbon dates indicate that these areas were utilised only in the latter part of the mid-Neolithic (MN B) (*Wall, Martinsson-Wallin in press*).

The graves

Over 200 PWC graves have been found on Gotland, and with their high frequency and rich grave goods (*Stenberger* et al. *1943; Janzon 1974; Wallin, Martinsson-Wallin 1992; Österholm 1989; 2008; Burenhult 2002; Wallin in press*) they differ significantly in comparison with PWC graves found along the Swedish mid-Neolithic coasts (*Papmehl-Dufay 2003. 186*). To date, 85 graves have been excavated at the Ajvide site, the largest PWC grave site in northern Europe. Among these graves, eight features have been interpreted as graves with grave goods, but without human remains (cenotaphs). In total, 89 individuals have been found in the excavated graves (*Burenhult 2002; Österholm 2008; Wallin, Martinsson-Wallin in press; Wallin in press*).

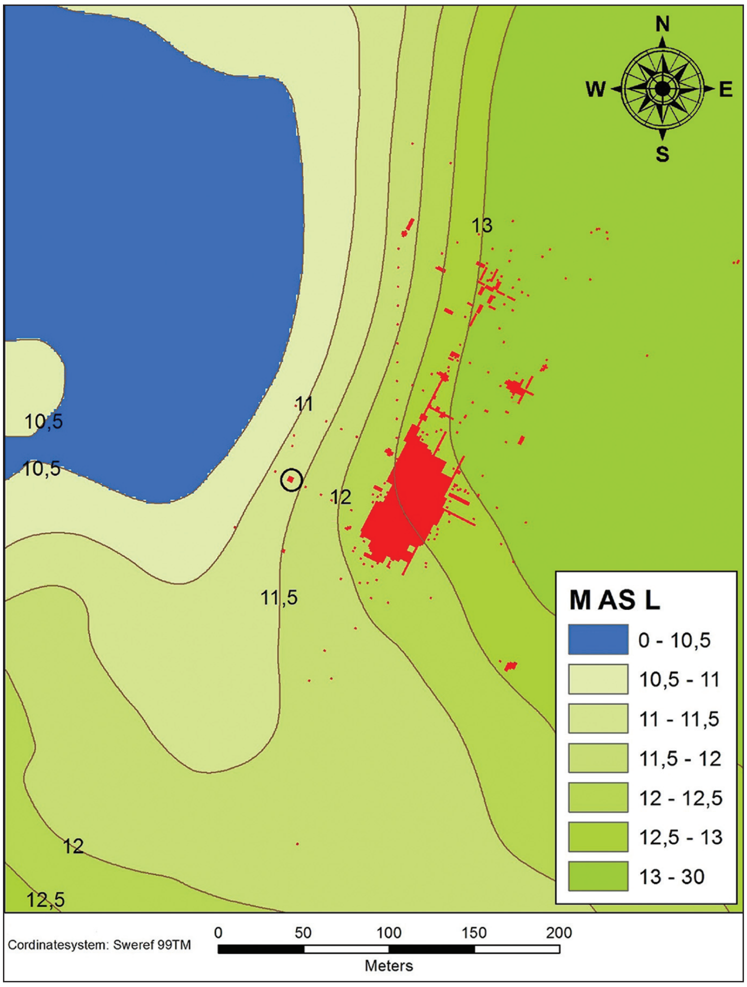

Fig. 2. Mas L values at the Ajvide site. The red colour represent excavated areas; cast study trench is marked with a black circle. The site was above 10.5m level during the late MN B (after* Gustavsson, Palmgren 2015*).

The most of the human skeletal remains were in a supine position, although in at least five of the graves the deceased was buried on the side in a crouching position (hocker position) (*Burenhult 2002; Österholm 2008*). In the latter part of the mid-Neolithic, the PWC groups on the Swedish mainland lived side by side with BAC groups. The latter typically placed their dead in a crouching position, facing east. In comparison with the five Ajvide burials in a crouching position (two men, two women and one juvenile), they are facing north (*Burenhult 2002; Palmgren 2014a.69, 114; Wallin 2015*).

Four of these graves were found on the margins of the burial area, which may indicate that they were late burials. Radiocarbon dating was carried out on three of the graves: no. 28, (*Burenhult 2002.100, Figs. 62b, 128*), no. 36 (*Burenhult 2002.103, 134, Figs. 70a, b*) and no. 73 (*Wallin, Martinsson-Wallin in press*). The individual in grave 28 is dated to *c.* 5200–4500 BP (*i.e.* the early-mid phase of MN) and the ^{13}C isotope analysis shows that this individual had a terrestrial diet. Grave 36 is dated to *c.* 4800–4400 BP (*i.e.* early-mid MN B) and ^{13}C isotope analysis shows that this individual had a marine diet. This is the only grave at the Ajvide grave site that was associated with a ceramic sherd with ornamentation resembling corded ware imprints. The date of the human bone remains from the third (grave 73) is *c.* 4500–4300 BP (*i.e.* late MN B) and ^{13}C isotope analysis shows that this individual had a terrestrial diet. Both individuals in grave 28 and grave 73 show a tendency to a terrestrial diet, but the former is earlier and the latter came from one of the later graves. Thus the evidence is inconclusive, but see the further discussion below on the find material in grave 36.

The grave goods

The grave goods found at Ajvide are varied and numerous. Considering that the PWC was a hunter- gatherer culture, artefacts such as flint fish hooks, arrow heads and axes *etc.* are among the grave goods. The ^{14}C-dates on the graves show that a trend in the custom of providing the deceased with numerous durable grave goods declined during the latter part of the MN B (*Wallin in press*). Gotland is rich in Ordovician flint, but the quality is poorer and it cracks more easily compared with south Scandinavian flint. All the axes found in the graves are of south Scandinavia flint, which is a durable material and it is probable that these axes were considered exotic status objects.

Some grave goods recovered from Ajvide most likely originated from the BAC and perhaps from the Single Grave Culture (SGC) in Denmark. Although the burial area yielded artefacts from the Danish and Swedish variants of the Corded Ware Culture (CWC) alike, the burial area at Ajvide actually have fewer artefacts that resemble the Danish and Swedish CWC in comparison with other PWC sites with graves on Gotland (*Palmgren 2014a.57–62*). In fact, there seems to be a major difference between the southern and northern parts of Gotland concerning typical BAC artefacts (*Palmgren 2014a*) (Fig. 3). Artefacts found at the Ajvide site that can be described as characteristic of BAC are described below.

A faceted grindstone was found in grave 19 (*Burenhult 2002.96, 119–120, Figs. 50–5*) of a type characteristic of the BAC on the Swedish mainland. It is one of four faceted grindstones found on Gotland. Two of these, which are of an early model (four sides), were found at the burial area at Ajvide and at the Visby PWC site. In both cases, the grindstone was placed on the deceased man's right shoulder with their hand placed on it (*Janzon 1974; Burenhult 2002.119, Fig. 50*). The remaining two grindstones are of late models (*i.e.* have more than four sides), but were only stray finds (*Palmgren 2014a*).

Ten excavated graves at Ajvide contained amber beads in various forms (*Ajvide Database 2009*). Amber is not a natural resource on Gotland, and probably originated from southern Sweden and/or Denmark, from where other imported exotic artefacts originated, although it cannot be ruled out that some of the amber artefacts originated from the Baltic and/or Poland (*Axelsson, Strinnholm 2013.149*).

Six excavated graves on Ajvide contained flint axes (*Ajvide Database 2009*). All of them are thick-butted, a common characteristic of late FBC or BAC traditions. Several flint axes found on Gotland probably originated in Denmark, such as at the Västerbjers PWC site. Several artefacts, including flint axes which have been linked with the Danish SGC due to their shape and ^{14}C-dating of the human skeletal remains with which they were found (*Stenberger* et al. *1943; Ebbesen 2006; Palmgren 2014a*). However, none of the axes at Ajvide had straight edges, which probably means that these did not originate in Denmark.

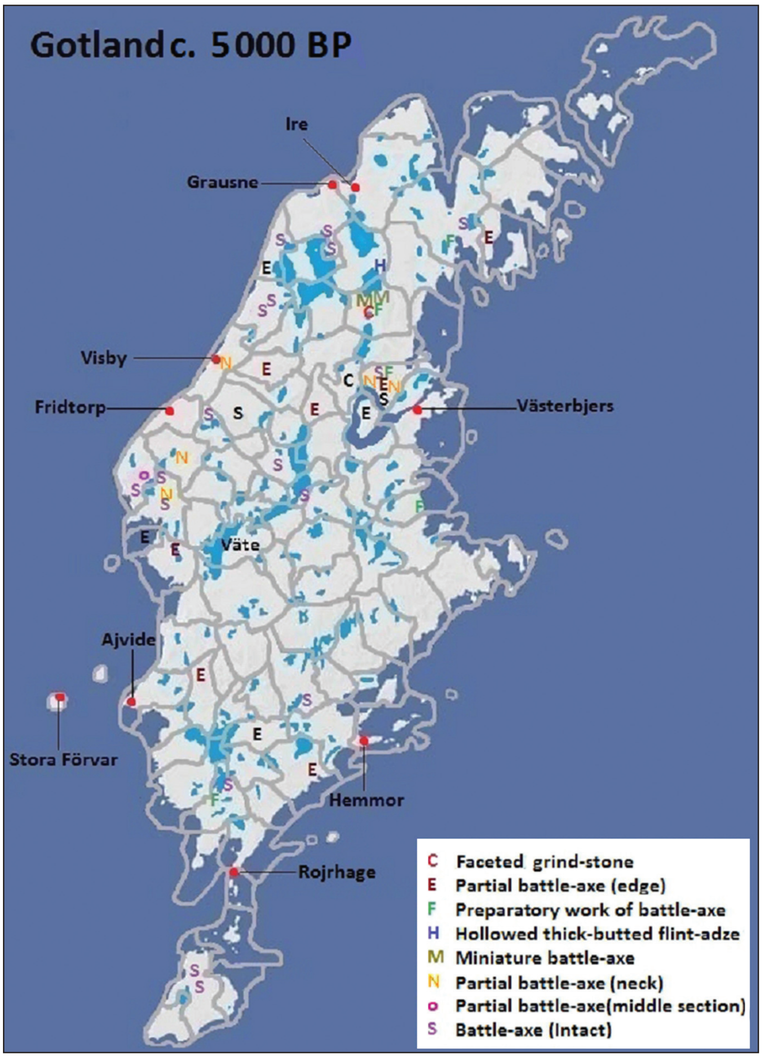

Fig. 3. BAC artefacts on Gotland. Grey lines represent parish borders. The letters in black colour represent only parish finds and not the exact location (from* Palmgren 2014b*).

As mentioned earlier, grave 36 contained a ceramic sherd decorated with imprints which resemble corded ware. There are several aspects that are interesting regarding this item. Firstly, it was tempered with crushed limestone, which is the most common temper in the PWC ceramics, but not FBC or BAC pottery. Secondly, it was found by the legs of a deceased woman (marked with a red circle, see Fig. 4) who had been placed in a crouching position, which is common in BAC. Thirdly, the sherd is decorated with what appears to be a right-twisted corded imprint, but the imprint was made by another tool to make it resemble corded ware. It is possible that the deceased originated from the BAC although 'real' cord imprints were not used in the PWC in this early contact phase, hence the crouching position, but the imprints that resemble to corded ware were used to show the woman's origin. The date could fit into the earliest Corded Ware Cultural tradition from continental Europe (*c.* 4800 BP) but the ^{13}C isotope value indicated that she had a marine diet, which is typical of the PWC. Perhaps future genetic studies can provide further information on the origin of this individual.

The case study pottery analysis

Pottery from the Ajvide site has previously been subjected to formal analysis regarding the pottery ornamentation design and some technical analysis of the clay (*Sharp 1985; Österholm 1989.97–117; Lidman 2013*). An ornamentation design scheme was worked out by Österholm (*1989.110*). The obvious ornamentation on the PWC pottery (which also provided the name for the culture) are pits, generally *c.* 0.3–1cm in size (Fig. 7), decorating the rim, neck and shoulder of the vessels. Besides the pits, various incisions and stamps were created with bones and combs *etc.* (*Österholm 1989.103–110*).

The MN B pottery used in our analyses was from a test pit 50m the west of the area that has been interpreted as the core area of the site (Fig. 2). A test pit, 1m^2 in size, was excavated by Österholm in 2000 with the aim of finding the western limits of the site. The test pit revealed large quantities of pot sherds, but numerous bone remains were also found. Of particular interest was that several sherds bore designs that were not previously described. In the light of the new finds, the test pit was extended by an additional eight m^2 in the following year. The intention of the excavator, Österholm, was to carry out a further analysis of the interesting sherds, but this was not done until 2014 (*Palmgren 2014b*).

The sherds recovered from the test pit weighed 16kg, which can be compared with the 250kg of pot sherds from Ajvide previously analysed (*Österholm 1989*). The material used for the analysis comprises 487 decorated sherds found between 11.14–10.89m above sea level (m.a.s.l.) (second and third levels of the cultural layer) (*Palmgren 2014b*). The same criteria and ornamentation design scheme as worked out by Österholm (*1989.110*) was used in our analysis. The analysis of the sherds from the test pit showed that cord imprints were the most common ornamentation; of 487 analysed decorated sherds, 102 have cord imprints (approx. 20%). Sherds with cord imprints appear only as a single pattern or combined with pits. It was estimated that the 102 sherds derived from between 20–30 vessels, but only one out of five imprints could be defined as right-twisted (*Palmgren 2014b*).

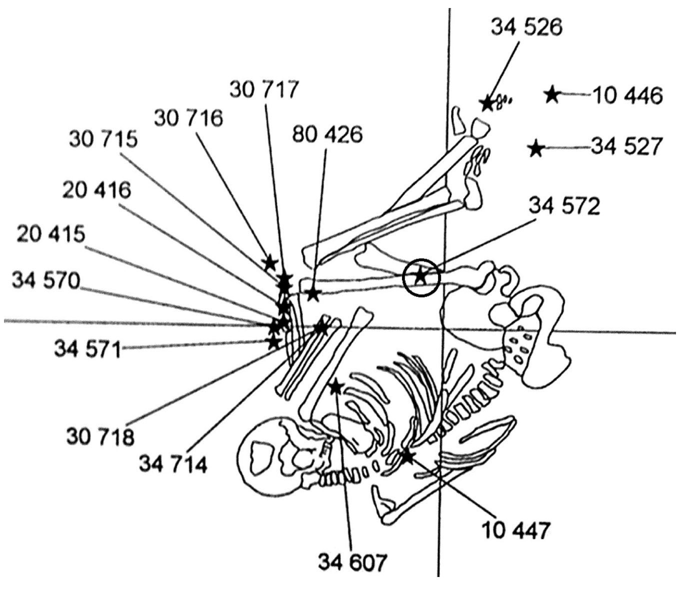

Fig. 4. Grave 36 on the Ajvide site. Circle shows where the sherd with imprints resembling corded ware was found (from* Burenhult 2002.134*).

A few, but not the majority, of the sherds have been affected by wave action. It is likely that the sherds were deposited close to the contemporary shoreline and since there were more sherds affected by wave actions in the western quadrants, which held fewer sherds and were closer to the sea than the others. The shoreline at the Ajvide site has been estimated to around 10.5m a.s.l. at 2400–2300 BC (*Palmgren 2014b.40*) and the bottom of the cultural layer in this test pit was at 10.89m. a.s.l. Two ^{14}C-datings of bone remains from the cultural layer, one pig tusk and one tooth from a pig mandibular found at a slightly different depths in the centre of the excavated squares, were used as samples for dating. Pig bones were preferred, since previous isotope analyses of pig bones from similar contexts on Gotland have shown that the pigs did not eat a marine diet and we wanted to avoid the reservoir effect (*Eriksson 2004; Wallin, Martinsson Wallinin in press*). The results of the ^{14}C analysis showed that both layers dated to between *c.* 4630–4460 BP (see Tab. 2).

Fifty-seven different designs were defined on the sherds from the test pits, of which 18 were new (*Palmgren 2014b.27–30*). This analysis increased the number of pottery ornamentation designs to around a hundred different patterns found so far at the site. However, some designs are quite similar in shape and form, which might reflect creativity and change in the decorative scheme over time that may possibly be related to various pot-making traditions within Gotlandic PWC.

The sherds used in this analysis were found close to the sea, and given them a.s.l. value and ^{14}C-datings, the trench was most likely under water during the earliest phase of the site. The pottery found at this location thus reflects a late phase (*i.e.* late MN B). Earlier analysis by Österholm (*1989.108, 110*) showed that a few pot-sherds with cord imprints were found at Ajvide (ornament type 63–65) at the larger excavated areas called areas D and C (see Figure 2 the larger red areas). A few sherds of the types 64–65 (vertical cord imprints) have been found in the early MN A level and the younger MN B level, but type 66 (horizontal cord imprint) is mainly linked to the younger MN B level. Type 66 is more common than 63–65, but cord imprints are rare compared to other designs (*Österholm 1989. 112–114*).

New techniques

Österholm was of the opinion that the earliest pots at Ajvide had funnel-like necks (*1989*) but this was not shown on the rim sherds found in the test trench. This, together with the location close to the late MN B sea shore, the radiocarbon dates and the ornamentation designs on the pots which among others show cord imprints, indicate that the pottery in the test pit relates to the late phase of the PWC site. The pottery from the trench also revealed four new techniques.

❶ The surface of some sherds can be labelled as degenerative and 'sloppy' since the patterns are blurred and are crudely finishished.

❷ A number of sherds also have a cruder surface in general, even if the patters are more distinct than the sherds referred to above. The potter did not take so much care to polish the surface as before. It is likely that this was due to the fact that the potters stopped using polishing stones and instead used other tools of organic material when they finished the pot surfaces (*Palmgren 2014b; 2015*).

❸ Four sherds have an additional coarse slip of clay (barbotine) on the outer surface which has been taken to mean that the pot was ready made with decorations and dried, whereupon an extra layer of clay was applied on the pot (Fig. 10). This type of pottery was common during the Bronze Age (3700–2500 BP) and perhaps at the end of the late Neolithic (4300–3700 BP), but not found on pots dated to earlier time frames. It should be noted that a coarse slipped outer surface makes the pot easier to handle and keeps the contents cool (*Hulthén 2011. 32*), so this might be a utilitarian aspect.

❹ A number of sherds also have quartz temper, which is very uncommon in Gotlandic PWC pot manufacturing. On the other hand, this type of temper is very common in FBC, while some PWC pots from the Stora Karlsö cave site were also tempered with this material (*Palmgren 2015*). Grog is a common temper in BAC pots, but mainland BAC pots also have tempers with crushed quartz.

Aside from the 'sloppily' made or 'degenerative' pottery, the sherds from these vessels were also poorly fired and the proportion of temper is large. It can also be added that, when analysing sherds from Stora Karlsö, a corded imprint pattern was found underneath an extra clay slip layer which had been added to the outside of the vessel (*Palmgren 2015.9*).

Layers	Lab nr.	BP	BC	Probab.
Layer 2 (11,11–11,02 MASL)	Ua-48709	4002 ± 38 BP	2630–2450 BC	95.40%
Layer 3 (10,96 MASL)	Ua-48708	4020 ± 43 BP	2670–2460 BC	92.80%

Tab. 2. Radiocarbon dates from the test trench.

Twelve sherds from the Ajvide site and four from the PWC site at Hemmor on the eastern side of Gotland were subjected to XRF-analysis (Fig.

5). Several of the Ajvide sherds were from the case study area. This analysis measures the levels of various elements in the core of the sherds. Three sets of analyses were made and a mean value calculated. The analysis of the sherds from Ajvide suggests that the clay might have been derived from different clay sources. Thin-section analyses of pot-sherds from Ajvide site are underway which might support or refute this interpretation. TCT tests (Thermal Color Tests) by Österholm (*1989.99, 116–117*) indicate that the pottery at Ajvide was made with clay from three different sources and that the earlier pots (MN A) were more durable ware than the younger examples. The clay in the four Hemmor sherds seems to be more homogeneous and could have come from one clay source, but further analyses are needed to confirm this. Thin-section and inductively coupled plasma mass spectrometry (ICP-measures the levels of various elements in the core of the sherds) analyses on seven sherds with cord imprints from the Stora Förvar cave site indicate that the analysed raw material came from four different clay sources on Gotland (*Palmgren 2015.11*). In addition to this, one sherd displayed clay that is unknown in Gotland. Due to the imprints and low calcium value of this sherd, it has been interpreted as deriving from a BAC context on the Swedish mainland (Fig. 6). Stora Förvar cave site is probably a place where several groups from around the island and from the Swedish mainland met and brought their locally made pottery. The Ajvide site is probably connected to Stora Förvar, since it is the closest PWC site to this islet site. Further petrochemical analysis and thin sections are needed to confirm the above suggestions.

The FBC and the PWC culture on Gotland

The largest known FBC on Gotland site is Mölner/Gullarve, located in Väte parish (Fig. 3). This site has been dated to the Early Neolithic (*c.* 7000–5500 BP) (*Österholm 1989.82*); the dates are not conclusive and have large ranges, and according to Lidman's study some of the pottery on the site could derive from the early MN A phase (*Lidman 2014*). One megalithic site with around 30 interred individuals has been located on Gotland; it has been excavated and dated to *c.* 5300–5200 BP (*Wallin, Martinsson-Wallin 1997; Martinsson-Wallin, Wallin 2010*). Isotope analyses (^{13}C values) of the human skeletal remains from this site show that these people had a terrestrial diet. This contrasts with contemporaneous individuals buried in PWC contexts who had a marine diet. The isotope studies in conjunction with genetic analysis and an extensive dating programme of the human skeletal remains from the Neolithic sites on Gotland comprise an ongoing project that will provide further data on this dynamic phase (*Paul Wallin, 2014, pers. comm.*) (*Wallin 2015; Wallin in press; Wallin, Martinsson-Wallin in press*).

Some of the PWC skeletal remains at the Ajvide site have been subjected to DNA analyses, and in comparisons with FBC groups on the Swedish mainland, the Ajvide people show a closer genetic similarity to people now living in the Baltic area (*Malmström* et al. *2009; Skoglund* et al. *2012*). The result of the genetic studies of PWC mid-Neolithic individuals from Ajvide also show that nine out of ten (six from Ajvide) lack the T-allele, which has been associated with the ability of adults to consume unprocessed milk (*Malmström* et al. *2010*). This indicates the presence of adult lactose intolerance among the PWC population. The extremely low presence of cattle bones on the sites probably suggests that these animals were mainly kept for meat production for feasting, and/or as status objects and does not indicate milk-production in the first place. According to this study, the PWC groups seem to have originated from a Eurasian hunter-gather population. The prevailing view is that the PWC groups and/or their cultural traits spread from the east coast of the mid-Sweden area southwards and also to Gotland Island.

FBC groups that preceded and were partly contemporary with the PWC, as well as subsequent BAC

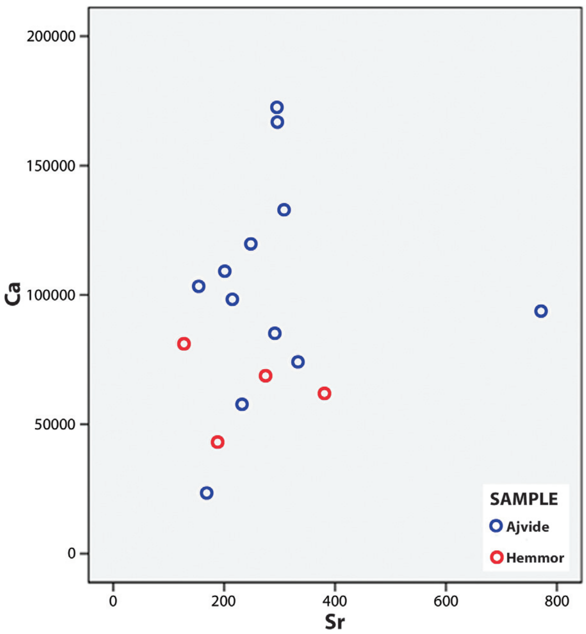

Fig. 5. XRF-analysis on pottery from the Hemmor and Ajvide sites.

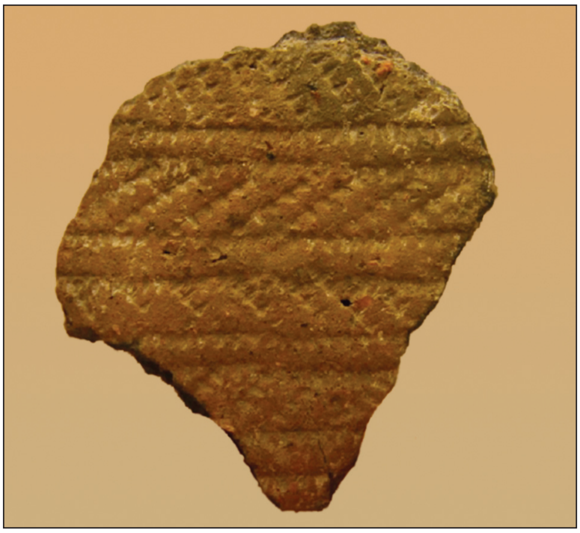

Fig. 6. Sherd from Stora Förvar cave site, most likely manufactured by the BAC on the Swedish mainland (photo: Erik Palmgren).

groups, used pottery with cord imprints. However, the cord imprints of the FBC differed from the BAC (*Larsson 2009*) and, for example, the latter is always left-twisted (*Larsson 2009.242–247*). The PWC groups, especially on the mainland, seem to have avoided using cord imprints and also differed from the FBC and BAC traditions in that their ware had convex bases.

There are also traces of crop grain imprints in corded ware from the early Neolithic on Gotland (*Österholm 1989.84*). This, together with the evidence of the megalith grave and the isotope analysis, indicate that people moved in from the south and introduced a farming lifestyle on Gotland in the Early Scandinavian Neolithic. However, as discussed above, they are not the ancestors of the mid-Neolithic PWC groups, and these farming communities did not seem to succeed very well in the long run. Current research suggests that the FBC and PWC were two distinct groups with different lifestyles on Gotland at the beginning of mid-Neolithic and that the PWC groups eventually spread all over Gotland, probably at the expense of the farming communities. So far, there is no material or genetic evidence that FBC and PWC groups mixed. The PWC groups spread over the island and became the dominant and only culture during the next 500 years.

Evidence of BAC influences during the MN B phase on Gotland

The late mid-Neolithic (MN B *c.* 4800–4300 BP) has been discussed as a time when major changes in the material culture occurred on Gotland after around 500 year of PWC tradition. At the end of the MN B, the PWC and the Battle-Axe Culture (BAC) co-existed on the Swedish mainland. The latter show influences from Corded Ware/Single Grave culture (SGC) groups in south Scandinavia, but in an east Scandinavian setting, this culture has been called the Battle-Axe tradition, also with influences from the east (*Malmer 2002*).

As mentioned above, a few artefacts found at Ajvide and at other Gotland PWC sites are typical of the BAC. Comparisons with artefacts found in the southern Swedish mainland and Denmark show that it is likely that contacts between Gotland and these areas were of equal importance during the early MN B phase. These contacts are, for example, shown in early types of four battle-axes and the two faceted grindstones that were found in graves at what have been interpreted as PWC sites. In the late MN B, phase it seems that contacts with the southern Swedish mainland increased, while contacts with Denmark ceased (*Palmgren 2014a*).

Fig. 7. Typical PWC pottery from the test trench (photo: Erik Palmgren).

A total of 60 battle-axes have been found on Gotland, of which 56 are stray finds, and around 50% are complete (*Palmgren 2014.69*). Only one example can be tied to an origin from the Danish SGC; the remainder are of a type tied to the Swedish BAC. Four axes found in graves are shaped like early models, but the stray finds are of the middle or late models (*Palmgren 2014a*). The same pattern is seen with grindstones (see above) (*Palmgren 2014a*). An interesting detail is that the faceted grindstones are not made of quartzite, which is the most common material for these types of grindstones at mainland Swedish sites (*Lindström, Boije 2000*). The grooves on the grindstones also are unique to the Gotlandic specimens. Taking these two facts into account, it is very likely that these grindstones were manufactured on Gotland and used in other ways than the mainland ones.

Fig. 8. Pottery with zig-zag patterns from the test trench (photo: Erik Palmgren).

Besides battle-axes and faceted grindstones, finds of five unfinished battle-axes and four reused axes (*i.e.* with additional shaft holes) (*Palmgren 2014a*), four-sided bone plates with unique designs, *Cerastoderma edule* and *Dentalium* shells (*Janzon 1974*) and pottery with grog temper (*Hulthén 1997*) and cord imprints have been found in various PWC contexts on Gotland. So far no evidence that grog temper and cord imprints were used by mainland PWC- groups has been found, but these traits are common among the early mainland BAC-groups (*Hulthén 1997*). That these features occur on the Gotland PWC sites is probably due to contacts with BAC groups on mainland Sweden (*Palmgren 2014a*). Another BAC trait is that the deceased were buried in a crouching position (hocker), which occurs on PWC burial areas on Gotland towards the end of the MN B phase (see above) (*Palmgren 2014a*).

Gotlandic PWC identity

The PWC culture seems to have had a strong identity, which was expressed in their pottery, especially the pit design, and a sub-Neolithic lifestyle. Empirical research on artefact assemblages found at PWC sites on Gotland show that with time they became quite different from PWC mainland assemblages (*Papmehl-Dufay 2003*). The stone axes, grindstones and pottery patterns made by Gotlandic PWC groups in the MN B phase diverge from those made by PWC groups on the mainland (*Palmgren 2014; Petrén 1992.35*). An explanation could be that Gotland became isolated due to a decline in seafaring, and that interactions with the Swedish mainland thereby ceased. This view is probably not correct, since external interactions are indicated by exotic goods like flint and amber, which are found at PWC sites on Gotland throughout the Neolithic period.

Since an increasing number of sites have been found on Gotland dating to the mid-Neolithic, it has been suggested that the population on Gotland increased during this time. With a growing island population, it might have been of less importance to engage in external contacts with distant family groups on the mainland. Increasing interactivity among the PWC groups on the island could have created a stronger island group identity. Martinsson-Wallin's (*2008*) study of bone remains from various PWC sites indicated that there could have been three spheres of intra-site interaction, one including sites on the west side, one on the east side and a third towards the north.

Based on the results of analysed material and the discussion above, we suggest that on the one hand it became increasingly important to show an island identity, but at the same time contacts intensified with southern mainland Sweden towards the end of MN B, which are indicated though influenced from the BAC in that area.

In the last phase of PWC, there was a decline in pot decorations in PWC groups on mainland Sweden, (*i.e.* fewer designs were used). This has been interpreted as the intention of the PWC groups to show group cohesion and homogeneity (*Olsson 1997.450*) to distinguish them from groups with other cultural affiliations, such as the BAC groups. The cord imprints actually do occur on the Gotland pots from the latter part of the mid-Neolithic (MN B) and the ornamentation on the pots became more varied than at east mainland Sweden PWC sites.

Favouring certain material culture and certain designs are ways to express identity (*Hylland Eriksen 2010.*

Fig. 9. Pitted pottery with left-twisted cord imprints from the test trench (photo: Erik Palmgren).

345). Based on the analyses and discussion above, we argue that PWC groups on Gotland made conscious choices to decorate their pots in certain ways to strengthen their island identity and that a hybrid culture appeared in the MN B phase on Gotland. Hybridisation is an interesting phenomenon wherein traits or elements meet and form something new. These changes occur in the flow of time when there are interactions between peoples and/or groups of people, but the term has close ties to a post-colonial research strategy (*Van Dommelen 2006; Bhahba 2004*). We have no evidence that PWC groups were colonised by BAC groups, but rather it seems like a conscious choice by the PWC groups to include BAC material culture. These traits might have come with a few BAC people as marriage partners and/or through new interactions directed to south Scandinavia. We argue that the BAC expressions were 'rephrased' within the frames of the PWC culture to arrive at a localised cultural expression. Hybridisation at the cognitive level and the material expressions attached to this are especially interesting as they create meaning which is both a part of the local production/consumption system, but also reaches beyond this system (*Martinsson-Wallin 2011.102*). The hybridisation seen during the MN B phase on Gotland had a strong PWC signature, but the pottery designs became more diverse with time and finally also included BAC cultural traits. This differs from the PWC mainland group strategies, where BAC traits seem to have been avoided. In mainland PWC groups in coastal east Sweden no sherds with corded imprints have been found so far (*Larsson 2009*). Perhaps this is a sign that Gotland PWC groups wanted to distance themselves from earlier allies and kin.

The analysis of late MN B PWC pot sherds at Ajvide show an increasing quantity of corded ware and some new techniques that could be associated with the BAC culture. The difference shown between the Ajvide corded ware and the mainland BAC corded ware tradition is that the former used both right-twisted and left twisted cord imprints, but mainland BAC corded ware bears only left twisted imprints (*Larsson 2009*). The hybridisation of pottery ornamentation designs found at Ajvide in the last part of MN B combines pits and cord imprints that are both right- and left-twisted, and also in some cases a clay slip and rougher surface occur only on Gotland and not on the Swedish mainland PWC sites. In comparison with the PWC tradition, it is considered that the BAC tradition hadstricter rules regarding material and social culture (*Malmer 2002*). The current research does not support the notion that the mainland PWC groups changed into the BAC, although at the end of the MN B, BAC pottery sherds have been found at a few mainland sites with PWC influences, termed a 'third group pottery' (*Larsson, Graner 2010*). So far, no PWC pottery with BAC influences has been found on the mainland, and comparisons with 'third group pottery' sherds on mainland sites have been found only in small numbers. The 'third group pottery' also seems to have been in use over a short period.

Conclusion

Even if FBC groups with corded ware were contemporaneous with PWC groups on Gotland in the early MN A phase, there are really no indications that the PWC groups were influenced by, or mixed with, FBC groups. The analyses of pottery ornamentation designs from the PWC site at Ajvide show that the sherds with corded imprints were in fact influenced

Fig. 10. Three sherds with an extra coarse slip of clay (barbotine) from the test trench (photo: Erik Palmgren).

by the BAC tradition, since they are found in contexts that date to late MN B. The analysis of other types of material remains, such as battle axes, facetted grindstones and grave positions (crouching position) of the dead supports the hypothesis that there are BAC influences and traits in the late phase of PWC on Gotland. Since the corded imprints are both right- and left-twisted and found in combination with pit imprints in the Ajvide sample, this suggests the emergence of a hybrid culture where the PWC groups incorporated elements of the BAC cord imprint traditions. The BAC cored ware tradition on the other hand was always left-twisted, but PWC groups on Gotland made conscious choices to include these traits to arrive at new symbolic expressions. The argument that a hybrid culture emerged on Gotland in the MN B is also supported both by the finds of a few burials in the crouching position, which is a BAC trait, but they were facing north rather than east, as well as the use of local material and variations in the shape of the groves of the facetted grindstones. The hybrid culture that emerged on Gotland in the MN B diverge from the pattern of PWC and BAC groups on mainland Sweden, and we suggest that this was a way for the PWC groups on Gotland to strengthen their island identity and also show that external interactions changed focus from east mainland Sweden to south Scandinavia.

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Pottery from the Volga area in the Samara and South Urals region from Eneolithic to Early Bronze Age

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ABSTRACT – *The paper presents the evolution of pottery from the early Eneolithic period to the Early Bronze Age in the Volga area in the Samara and South Urals in accordance with typological and technological characteristics of pottery from the Samara culture and the early stage of the Yamnaya (Pit-Grave) culture. It is established that the Early Bronze Age pottery represent various traditions of both local and migrating populations.*

IZVLEČEK – *V članku predstavljamo evolucijo lončenine na območju reke Volge v pokrajinah Samare in južno od gorovja Ural, in sicer od zgodnjega eneolitskega obdobja do zgodnje bronaste dobe. Ta razvoj gradimo na tipoloških in tehnoloških značilnostih posod iz kulture Samara in iz zgodnjega obdobja kulture Yamnaya (kultura jaškastih grobov). Za zgodnje bronastodobno lončenino je značilno, da predstavlja različne tradicije tako lokalnih kot priseljenih skupin ljudi.*

KEY WORDS – *Volga area in the Samara and South Urals; Eneolithic; Early Bronze Age; pottery; typological, technological and cultural analysis; radiocarbon dating*

Introduction

One of the most debatable problems in Early Bronze Age archaeology typical to the Volga-Ural steppes centres around the origin of metallurgy and cattle husbandry in the Dnieper-Volga-Ural steppes. These economic achievements of the steppe population are associated with the Yamnaya (Pit-Grave) culture of the Early Bronze Age (*Merpert 1974; Ivanova 2001; Morgunova 2014*).

The discovery of cultures from the Eneolithic (Copper) period, such as the Samara and Khvalynsk cultures between the Volga and the Urals, is important in archaeology for solving the problem of the origin of Yamnaya culture and the development of metallurgy in this region (Fig. 1). Sites dating to two stages of the Samara culture have been found in the forest-steppe part of the Volga-Ural area along the Samara River (the Samara and Orenburg regions): the early stage, called Sjezheye, and the later stage, called Ivanovo-Toksky. The Samara culture is represented by various sites, including burial grounds and settlements (*Vasilyev 1981; Morgunova 1995*). Most of the Khvalynsk culture sites have been found in the steppe zone of the Volga area, represented by both large cemeteries and settlements (*Vasilyev 1981; 2003*).

Srednestog culture sites lie to the west of the Volga, in the Don and Dnieper areas (*Telegin 1973; Kotova 2006*). It has been established that the second stage of the Samara culture was contemporaneous with Khvalynsk and Srednestog cultures. The populations of these three cultures were engaged in settled cattle husbandry (*Telegin 1973; Vasilyev 1981; Morgunova 1995; 2014*).

The matter in question can also be reduced to the controversy about the role of various Eneolithic groups in the development of Yamnaya culture in the Volga-Ural region. Some researchers believe that it appeared during the Eneolithic period (*Merpert 1974*) in the eastern part of the east European steppes on the basis of the Khvalynsk and Srednestog cultures (*Merpert 1974; Telegin 1973; Vasilyev 1981;*

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Morgunova, Khokhlova 2013; Morgunova 2014). Therefore, the theory offered by Maria Gimbutas about the massive migration of Yamnaya tribes from east to west as far as the Balkans in the Early Bronze Age has gained greater acceptance (*Gimbutas 1979; 1980; Merpert 1965; 1974*). Other researchers maintain that the Yamnaya culture community formed over a larger area that included the western Black Sea and Balkan areas (*Ivanova 2009; Manzura 2006*).

In order to solve this problem, it is of paramount importance to thoroughly study pottery of the Eneolithic period and those of the Yamnaya culture. The ceramics in question have been analysed typologically to determine the shape and proportions of the vessels, their neck and bottom decoration, and special motifs. An important addition to the typological method was the technological study in accordance with the method suggested by Alexander Bobrinsky (*1978*).

We studied the composition of clays, pottery, types of surface treatments and ornamentation with a binocular microscope (*Vasiljeva 1999; Salugina 2005; 2014*). The results of the study are important for obtaining historical and cultural evidence to show continuity (or its absence) among Eneolithic steppe cultures and the Yamnaya culture of the Early Bronze Age. This focus is central in understanding the transfer of technological choices of potters from generation to generation which was most probable related to kinship relations. Pottery studies were assisted by radiocarbon dating, which enabled us to establish the chronology of the Samara, Khvalynsk and Yamnaya cultures (*Morgunova* et al. *2010; Morgunova 2011; 2014*).

Pottery of the Samara culture

The first stage in the development of the Samara culture is represented by the burials at the village of Sjezheye. The burials exhibit certain rituals, as well as decorations made of shells and the fang of a wild boar, stone axes and other goods (Fig. 2.7–10) that are similar to those found in burials at Mariupol in Ukraine (*Makarenko 1933*).

Pottery from the Sjezheye burials at can be divided into two types. The first includes high vessels with a small flat bottom (Fig. 2.1–3). The rim-like collars are rather pronounced. The technological study showed that the vessels were made of clay containing silt with an admixture of shell and with some organic solution added to the clay. The vessels were shaped using plastic molds. It has been experimentally established that clays with ground shells were fired in a special way. The surfaces

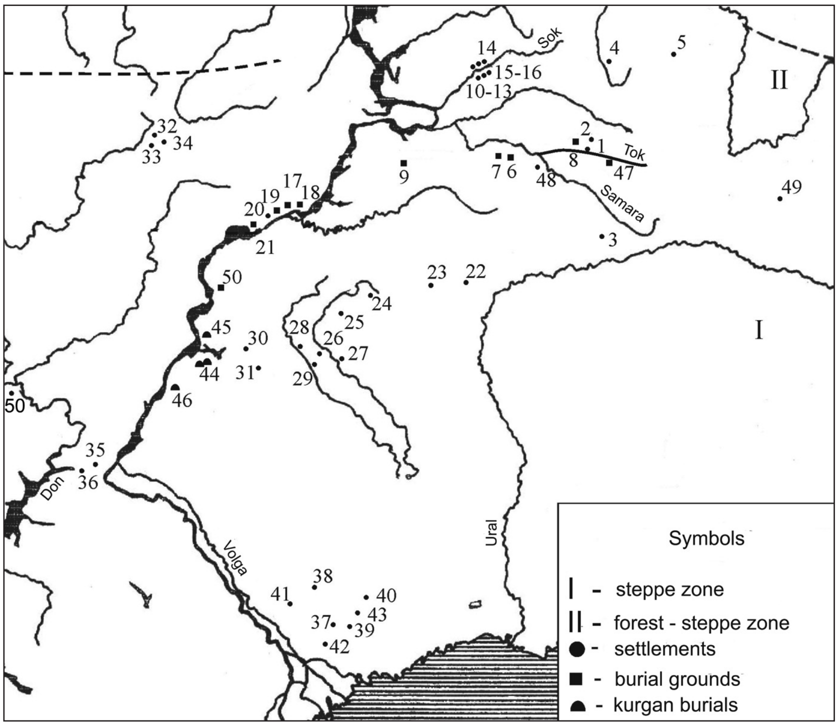

Fig. 1. Eneolithic settlements (1–5, 7, 10–16, 20, 22–43, 48, 50), burial grounds (6, 8–9, 17–19, 21, 47, 49) and kurgans (44–46) of the steppe Ural-Volga region: 1 Ivanovka; 2 Turganik; 3 Kuzminki; 4 Mullino; 5 Davlekanovo; 6 Sjezheye (burial ground); 7 Vilovatoe; 8 Ivanovka; 9 Krivoluchye; 10–13 LebjazhinkaI-III-IV-V; 14 Gundorovka; 15–16 Bol. Rakovka I-II; 17–18 Khvalunsk I-II; 19 Lipoviy Ovrag; 20 Alekseevka; 21 Khlopkovskiy; 22 Kuznetsovo I; 23 Ozinki II; 24 Altata; 25 Monakhov I; 26 Oroshaemoe; 27 Rezvoe; 28 Varpholomeevka; 29 Vetelki; 30 Pshenichnoe; 31 Kumuska; 32 Inyasovo; 33 Shapkino VI; 34 Russkoe Truevo I; 35 Tsaritsa I-II; 36 Kamenka I; 37 Kurpezhe-Molla; 38 Istay; 39 Isekiy; 40 Koshalak; 41 Kara-Khuduk; 42 Kair-Shak VI; 43 Kombakte; 44 Berezhnovka I-II; 45 Rovnoe; 46 Politotdelskoe; 47 burial near s. Pushkino; 48 Elshanka; 49 Novoorsk; 50 Khutor Repin.

were painted with ochre (*Vasilyeva 1999; 2006*). The pottery has complex motifs with meander patterns and zigzags, which were made with incisions and comb stamps.

The pottery of the second type differs from the former both typologically and technologically (Fig. 2.4–6). Here, not all the vessels have collars and the necks are prominently made with the help of rows of deep pits and grooves; the bottoms are large and flat. Since they were made from silt produced in water basins, these vessels had a natural admixture of small shells; the material also contains some organic solution (*Vasilyeva 1999*). The surfaces are covered with motifs made with comb stamps. These distinctive features point to the connection of the second group of pottery to the local Neolithic cultures and their active participation in the development of the Eneolithic Samara culture in the Volga-Ural area (*Morgunova 1995; Vasilyeva 2006*).

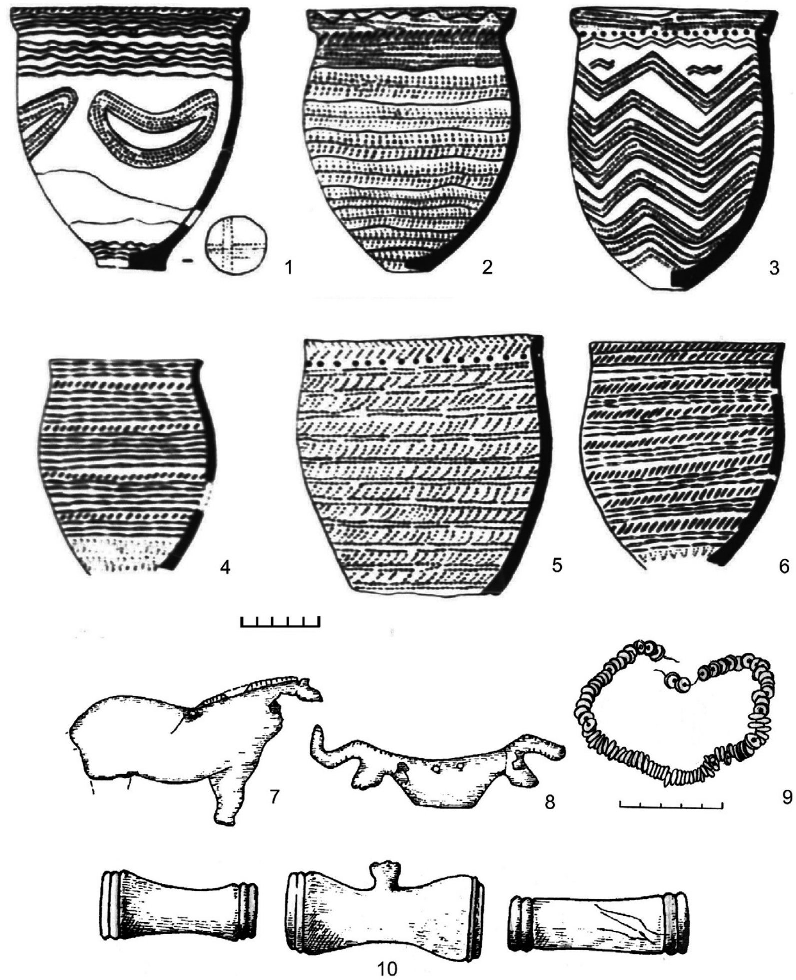

Fig. 2. Materials from the Sjezheye burial ground: 1–3 pottery I group; 4–6 pottery II group; 7–8 bone amulets; 9 shell beads; 10 ornament from wild boar fang.

As to the ceramics of the first type, they are supposed to indicate that people of some outlandish culture had entered the areas near the Volga and the Urals. As bearers of different cultural traditions, as evidenced by the pottery excavated at Sjezheye burial ground, the outlandish group appeared to be in a vulnerable position because it was not numerous (*Vasilyeva 2006*). It had to be assimilated into the local environment by the group that produced the second type of pottery which is found at other sites in the Volga area, such as at the Lebjazhinka III settlement. Consequently, the Samara culture emerged, which marked the onset of the Eneolithic period in the Volga area.

Where did the outlanders who prompted the Eneolithic period in the Volga-Urals region come from? Considering the complex motifs of the pottery in question, which have some prototypes in the Azov-Dnieper culture and at the early stage of the Tripolsky culture (*Kotova 2006*), they most probably arrived from the west, *i.e.* from the north Black Sea area. This is suggested by a certain similarity between the grave goods from burial grounds at Sjezheye and Mariupol (*Vasilyev 1981*). The presence of close contacts between the population of the Volga area and that of the north-western Black Sea region manifests itself in the similarity in burial practices (large burial grounds, the supine position of the dead, places for sacrifice) and decoration of burial clothing. This evidence testifies to regular links between these groups.

Since this period, one can trace regular ties between the population of the Volga-Urals region and that around the Balkan-Carpathian centre of early metallurgy. During the Eneolithic period, the Volga-Ural population made use of imported metal from the Balkans (*Ryndina 1998*).

Radiocarbon dates also show that the Sjezheye stage of the Samara culture and the culture of Tripolye A coincided in time. The ceramics and human bones from three sites have all been radiocarbon dated to the same period (*Morgunova* et al. *2010*). Their values are shown in Table 1. If we proceed from the majority of dates that coincide, disregarding the most ancient and latest ones, the Samara culture at its Sjezheye stage can be dated from 5300 to 4800 BC. This interval appears to be correct, as it corresponds to the dating of the Azov-Dnieper culture and Tripolye Al (*Videiko 2004.85–95; Kotova 2002.95–97*).

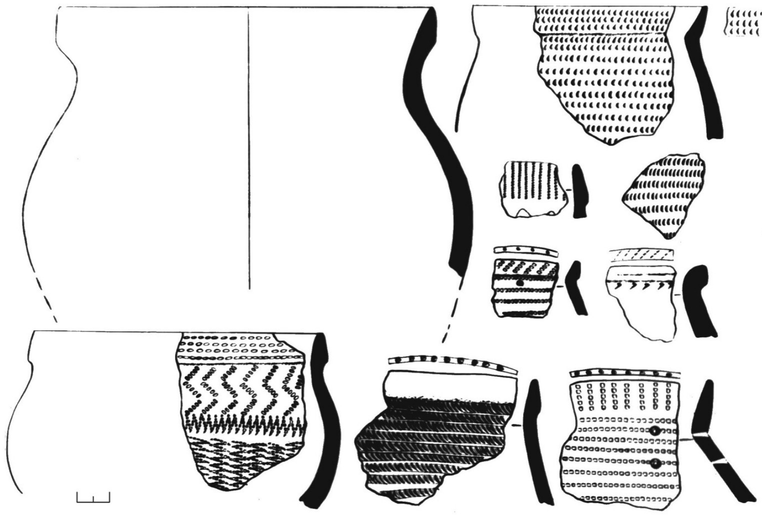

Fig. 3. Ivanovka settlement. Pottery of Ivanovka type.

The earlier Sjezheye stage of the Samara culture is also contemporary with the Near Caspian Eneolithic culture in the Low Volga area. Radiocarbon dates of pottery from Varfolomeevka settlement (layer 2A) as well as from other settlements in the North Caspian region show approximately the same interval in the calibrated age (*Vybornov* et al. *2008*).

The second stage in the Samara culture is represented by a number of settlements, among which Ivanovska and Turganic in the Orenburg region are of the greatest interest (Fig. 1). Here we also find two groups of pottery. The first (*i.e.* Ivanovka type) includes vessels with a collar on the rim (Fig. 3), which continues the pottery tradition typical for the Sjezheye stage. The technological characteristics of Ivanovska pottery confirm this conclusion. Pottery traditions continued from the Sjezheye to the Ivanovska stage in the composition of clays, the shape and proportion of vessels and their ornamentation with comb stamps. But at the same time, the Ivanovska pottery also includes some changes both in the variety and technological features, such as missing grooves under the rim and meander compositions, different shapes of collars *etc.*

The second group (*i.e.* Toksky type) of pottery typical to the second stage of the Samara culture includes profiled vessels without collars. It generally has the same technological traditions as the second group of pottery typical to the Samara culture at its Sjezheye stage, but with some changes (Fig. 4).

The changes during the second stage of the Samara culture could be the result of influences from the Khvalynsk culture (*Morgunova 2011; Vasilyeva 2006.22*). The evidence below testifies to close contacts between the populations of the Khvalynsk and Samara cultures. Pottery of the Khvalynsk type was found in the form of imported items at all sites related to the second stage of the Samara culture. Some grave goods were found which were similar to those found at the Khvalynsk burial ground (such as beads and shell decorations, stone bracelets, *etc.*). In addition, the technological study showed that the Ivanovka pottery had features typical of the Khvalynsk culture (*e.g.*, clays containing silt, wicker elements in ornamentation, *etc.*) which is evidence of contacts between these two groups of the Volga population (*Morgunova 1995; Vasilyeva 2006*).

Complex	Index	Material	Age BP	Age BC 68%
Sjezheye (burial ground)	Ki 14525	pottery	6760 ± 80	5730–5610
Sjezheye (burial ground)	Ki 14526	pottery	6580 ± 100	5630–5470
Sjezheye (burial ground)	Ki 14527	pottery	5890 ± 90	4860–4670
Lebjazhinka III (settlement)	Ki15580	pottery	6035 ± 80	5040–4800
Lebjazhinka III (settlement)	Ki15577	pottery	5930 ± 80	4910–4870
Lebezhinka III (settlement)	Ki15582	pottery	6055 ± 80	5060–4840
Lebjazhinka III (settlement)	Ki15578	pottery	6140 ± 80	5210–5160
Lebjazhinka V (burial ground 9)	Ki 7657	man bone	6280 ± 90	5350–5100
Lebjazhinka V (burial ground 12)	Ki 7661	man bone	6510 ± 80	5680–5450

Tab. 1. Radiocarbon dates for the early stage of Samara culture (Sjezheye type).

Thus, we can ascertain the synchronic character of the materials typical to the second stage of the Samara culture and those excavated from the Khvalynsk burial grounds in the Lower Volga area and, therefore, the materials of the Srednestog culture in the nearby Dnieper steppes (*Vasilyev 1981*).

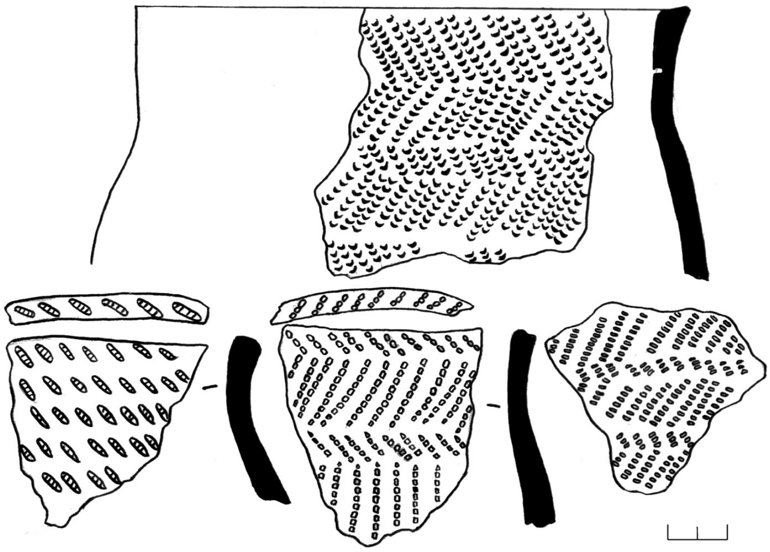

Fig. 4. Ivanovka settlement. Pottery of Toksky type.

The later date of grave goods belonging to the Ivanovka and Toksky type with respect to those characteristic to the Sjezheye stage of the Samara culture is confirmed by radiocarbon dating (Tab. 2). The calibrated period of the Samara culture at its second stage is 4850–3640 BC. Chronologically, the Ivanovka type corresponds to the Khvalynsk and Srednestog cultures (*Morgunova* et al. *2010; Kotova 2006*). Considering these dates, the technological tradition characteristic to the Ivanovka type ends around 4300–4400 BC, while the features of the Toksky type pottery continue into the first half of the 4th millennium BC.

Pottery of the Early Bronze Age

The Turganik pottery type continued the tradition of the Samara culture. This is seen in a number of features in both the shapes of the vessels as in their decorations (Fig. 5). On the whole, the pottery is distinguished by its originality, while the pronounced profiled neck and presence of ground shell in the clay make it possible to date them contemporaneously with artefacts from sites of the Repin stage of the Yamnaya culture and those of Mikhailovka II in the nearby Dnieper area (*Morgunova 1995*). This is confirmed by radiocarbon dates (Tab. 3); their calibrated age is estimated at 3930–3510 BC.

The Repin artefacts, as many researchers believe, belong to the early stage of the Yamnaya culture in the Bronze Age (*Merpert 1974; Vasilyev 1981; Triphonov 1996; Nicolova 2002; Morgunova 2014*). Repin types were found both at transitory camps and burial mounds (kurgans) in the nearby Volga and Ural areas. The name comes from grave goods found at the Repin Khutor settlement in the nearby Don area.

The Repin pottery is quite original (Fig. 6). In terms of typological features, they comprise high vessels with profiled necks and spherical or flat bottoms. The technological study showed that the vessels were made with silt or clay containing silt, with an admixture of ground shells and some organic solutions. The surface of the vessels was smoothed and then decorated with comb stamps in different motifs. The vessels were formed with the help of molds (*Salugina 2005*).

They combine the characteristic features of all the Eneolithic pottery that was present in this area as well as some elements characteristic to the Khvalynsk and, especially, Srednestog cultures. The study of the Repin pottery shows continuity in the methods of pottery technology and morphology practiced by other Eneolithic steppe cultures of the Volga-Ural and Near Don areas. It indicates the process of active blending and integration that took place among the steppe people at that time and resulted in the Yamnaya culture spreading over a vast area.

Complex	Index	Material	Age BP	Age BC 68%
Kuzminki settlement	Ki 15066	pottery I type	5630 ± 70	4540–4360
Turganik settlement	Ki 15067	pottery I type	5660 ± 70	4590–4440
Turganik settlement	Ki 14516	pottery I type	5790 ± 90	4730–4530
Gundorovka settlement	Ki 14523	pottery I type	5840 ± 80	4790–4590
Ivanovka settlement	LE 8413	animal bone	5870 ± 130	4851–4550
Turganik settlement	Ki 14517	pottery II type	5830 ± 70	4780–4590
Ivanovka settlement	Ki 15068	pottery II type	4930 ± 80	3800–3640
Ivanovka settlement	Ki 15070	pottery II type	5070 ± 80	3960–3780
Ivanovka settlement	Ki 15089	pottery II type	4940 ± 80	3800–3640
Lebjazhinka IV settlement	Ki15583	pottery II type	5420 ± 70	4350–4220
Gundorovka settlement, burial 10, type II of pottery	GIN 9041	man bone	5120 ± 140	4080–3720
Gundorovka settlement, burial 11, type II of pottery	GIN 9039	man bone	5130 ± 50	3982–3812

Tab. 2. Radiocarbon dates for the second stage of Samara culture (Ivanovka and Toksky types).

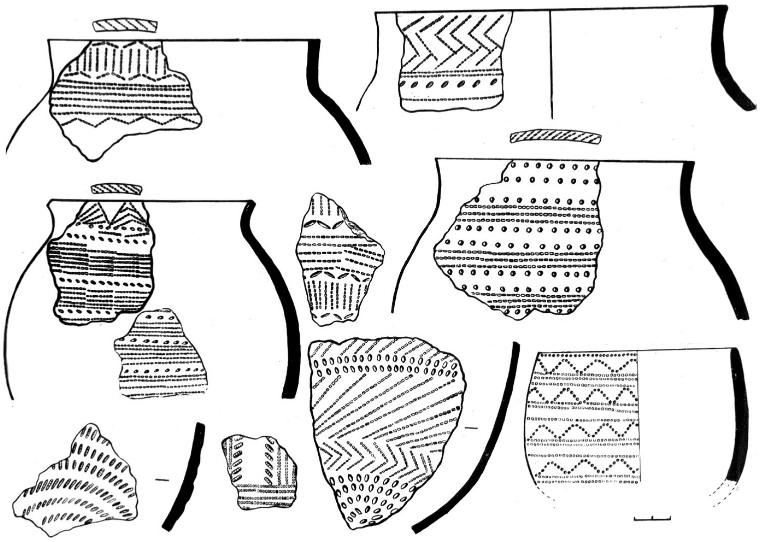

Fig. 5. Ivanovka settlement. Pottery of Turganik type.

During that period, the life of the entire Volga-Ural population underwent fundamental changes. A completely novel method of cattle breeding appeared in addition to the changes in pottery technology (*Merpert 1974; Morgunova 2014*). Settlements in the Repin period were few and short-lived, while the ritual of burying under kurgans became more widespread. This means that cattle breeding gradually acquired a nomadic character. The materials from the Yamnaya culture show all the signs of nomadic cattle breeding: natural climatic conditions and the scope for adaptation to them; the character of herds (sheep, horse, cattle); technological means: the character of homes and means of wheeled transport, effective household utensils and implements (*Morgunova 2014*).

But especially important in the progressive development of the regional economy was the establishment of its own metal-working centre on the basis of the Kargala copper mines in the Ural area (the Orenburg region). A number of Repin sites yielded metal artefacts produced at this centre (Fig. 6). By this stage, Balkan metal was no longer used in the region in question, which nevertheless retained some of Balkan technologies in the local production of metal items (*Degtyareva 2010*).

Conclusion

The study of the Eneolithic and Early Bronze Age ceramics in the Volga and the Urals areas is of great importance. The typological and technological analysis of pottery found at a number of sites related to the Samara and Khvalynsk cultures, on the one hand, and the early (Repin) stage of the Yamnaya culture, on the other, made it possible to show continuity in the production of pottery from the Eneolithic period to the Early Bronze Age, which means that an autochthonous line of development prevailed in the region. The studies were supported by radiocarbon dates.

According to the evidence from the early stage of the Eneolithic Samara culture, we can identify two typological groups of pottery, because the difference between them is confirmed technologically. One of them predominates and finds its origin in the traditions of the local Neolithic culture. The other group is considered outlandish, connected with the Azov-Dnieper and Tripolsky cultures from the northern Black Sea region.

The outlandish settlers, who were not as numerous, must have been assimilated, but they added originality to the Samara culture and gave rise to the Eneolithic period in the Volga-Ural area. Thereafter, regular economic ties with the northern Black Sea and Balkan region developed, supplying ready-made copper products throughout the Eneolithic period.

The later stage of the Samara culture is also characterised by two types of pottery, both of which continue the traditions of the earlier period. Some of the novel features of the Ivanovka and Toksky pottery resulted from the close contacts of the forest-steppe population with the Khvalynsk and Srednestog cultures of the steppes, which was caused by greater mobility and integral processes in the southern part of east Europe at that time.

In its early period, the Yamnaya culture of the Early Bronze Age is represented by transitory settlements and burial mounds of the Repin type. Their pottery is a combination of vessels characteristic to the late

Complex	Index	Material	Age BP	Age BC 68%
Ivanovka settlement	Ki 15069	pottery	4860 ± 80	3760–3620
Ivanovka settlement	Ki 15088	pottery	4790 ± 80	3660–3510
Gundorovka settlement, burial 9	GIN 9042	man bone	5010 ± 50	3930–3712

Tab. 3. Radiocarbon dates for the Turganik type.

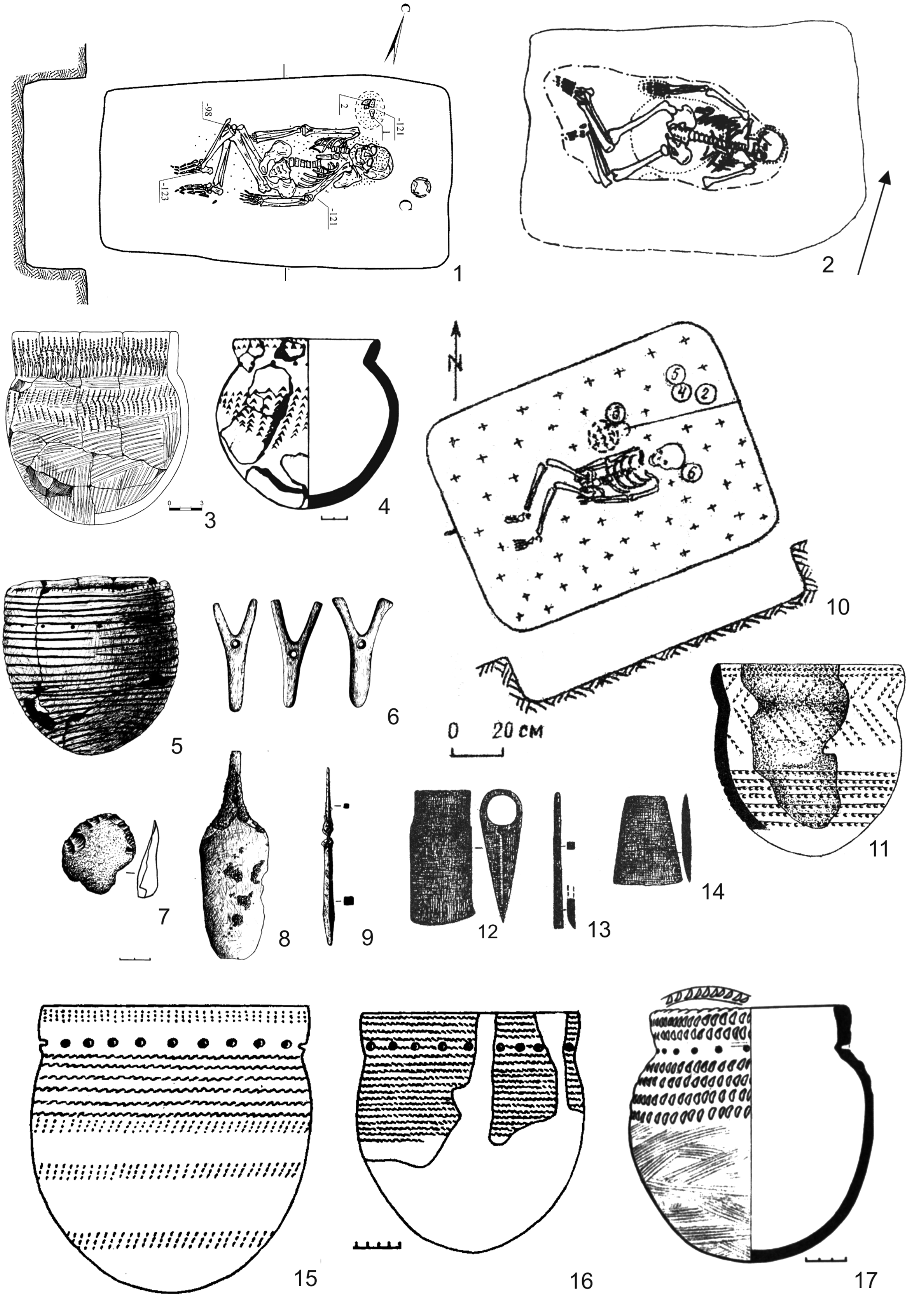

Fig. 6. Materials of the Repin type: 1, 2, 10 burials under kurgans; 3–5, 11, 15–17 pottery; 6 bone; 7 stone; 8–9, 12–14 copper.

period of the Samara and Khvalynsk cultures. At the same time, the pottery typology reflects some of the features typical to the Srednestog culture, which proves the active role played by all Eneolithic cultures from the Ural to the Dnieper in the development of the Yamnaya culture. Side by side with the predominant Yamnaya culture population, the forest-steppe areas continued to be populated by Eneolithic groups, as represented by pottery of the Turganik type.

Complex	Index	Material	Age BP	Age BC 68%
Kyzyl-Khak II settlement	Ki 15075	pottery	4730 ± 70	3540–3490
Kyzyl-Khak I settlement	Ki 14542	pottery	4510 ± 80	3350–3100
Turganik settlement	Ki 15597	pottery	4710 ± 80	3630–3370
Turganik settlement	SPb 1493	animal bone	4900 ± 80	3786–3635
Turganik settlement	SPb 1490	animal bone	4887 ± 80	3786–3631
Khutor Repin settlement	Ki 16486	pottery	4830 ± 80	3710–3520
Khutor Repin settlement	Ki 16542	pottery	4640 ± 70	3600–3300
Khutor Repin settlement	Ki 16541	pottery	4630 ± 80	3600–3300
Lopatino I, Kurgan 31, b.1	Ki 7764	man bone	4560 ± 80	3300–3100
Lopatino I, Kurgan 31, b.1	Ki 14544	pottery	4750 ± 70	3700–3300
Lopatino I, Kurgan 31, b.1	Ki 14545	pottery	4800 ± 80	3700–3300
Petrovka, Kurgan 1, b.1	Ki 14521	pottery	4730 ± 90	3640–3490
Orlovka I, Kurgan 2, b.2	LE 7896	man bone	4790 ± 150	3700–3400
Skvortsovka Kurgan 5, b.2	Ki 16268	pottery	5140 ± 70	4000–3800
Skatovka, Kurgan 5, b.3, vessel 2	Ki 16487	pottery	4890 ± 70	3770–3630
Skatovka, Kurgan 5, b.3, vessel 3	Ki 16488	pottery	5080 ± 80	3970–3790

Tab. 4. Radiocarbon dates for Repin sites.

Thus, the comprehensive study of pottery based on radiocarbon dates over two periods – the Eneolithic and the Early Bronze Age – made it possible to define the periods and chronology of the cultures of the time more exactly. Moreover, it allowed us to trace the continuity and role of interactions, ties and migration in the cultural and economic development of the population in the Volga-Urals steppe-forest and steppe zone from the Late Neolithic up to the Early Bronze Age.

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Fifth and fourth millennium BC in north-western Iran: Dalma and Pisdeli revisited

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ABSTRACT – *This paper discusses the nature of Dalma and Pisdeli cultures, their regional and inter-regional interactions and expansions in 5th millennium BC. It discusses old and new excavations and surveys as well. According to the importance of the material from these periods found at newly-excavated sites such as Kul Tepe Jolfa, Dava Göz Khoy, Lavin Tepe, and Qosha Tepe, we briefly describe the main stratigraphic and material data from these sites. Old and new data from excavations and surveys eventually lead us to a new chronological table for the 5th millennium BC in north/western (NW) Iran. The implications of the finds are discussed along with their limitations and future research directions.*

IZVLEČEK – *V članku razpravljamo o naravi kultur Dalma in Pisdeli, o njunih regionalnih in med-regionalnih interakcijah in širjenju v 5. tisočletju pr. n. št. Predstavljamo tudi rezultate starih in novih izkopavanj in terenskih pregledov. Na kratko opišemo tudi stratigrafijo in najdbe iz novo izkopanih najdišč Kul Tepe Jolfa, Dava Göz Khoy, Lavin Tepe in Qosha Tepe, ki predstavljajo pomemben material za to obdobje. S pomočjo starih in novih podatkov iz izkopavanj in pregledov smo lahko oblikovali nove kronološke tabele za čas 5. tisočletja pr. n. št. na območju severo-zahodnega Irana. Razpravljamo tudi o implikaciji teh najdb, o njihovih omejitvah in usmeritvah za prihodnje raziskave.*

KEY WORDS – *Dalma; Pisdeli; ^{14}C; updated Chalcolithic chronological table; NW Iran*

Introduction

The period between the end of the Hajji Firuz and the beginning of the Kura-Araxes phenomena is one of the least known, yet most important eras in the ancient history and chronology of NW Iran. Previous studies demonstrated that the Chalcolithic is still among the least understood periods of prehistoric development in the region (*Hamlin 1975; Dyson, Young 1960; Burney 1964; Pecorella, Salvini 1984; Voigt 1983*).

In the 5th and 4th millennium BC, complex societies developed in Eastern Anatolia, Northern (Upper) and Southern (Lower) Mesopotamia. This era, which is often referred to as the 'Post-Ubaid' period, was marked by major structural changes, such as the rise of social hierarchies, technological innovations and economic reorganisation, which eventually led to the emergence of proto-states and cities (*Frangipane 2001; Marro 2012; Stien 2012*). Some archaeological cultures and traditions that appeared during this period (5th millennium) have been brought to light in NW Iran. According to the latest data and material, it is impossible to draw a clear picture of the archaeology of the region during this period. Therefore, the real obstacle is the dramatic lack of absolute dating (with some exceptions), which makes it impossible to define the chronological extent of the Chalcolithic and construct a solid internal periodisation and properly articulated timeline for regional developments in this phase.

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Recent excavations outside Southern Mesopotamia provide a welcome opportunity to rethink the significance of the Post-Ubaid horizon from a different angle: several sites located in the Caucasus (*Achundov 2007; 2011; Müseyibli 2007; Lyonnet 2007b; Lyonnet* et al. *2008; 2012; Marro 2010; 2012; Helwing 2012*), central Anatolia or Cilicia (*Caneva* et al. *2012*) have indeed yielded a number of features that are traditionally associated with the Post-Ubaid horizon: interestingly enough, however, these findings come from settlements whose cultural sequence seemingly developed from a totally different, that is non-Ubaid, background.

Our discussion focuses mainly on two well-excavated sites: Kul Tepe Jolfa at the confluence of the Southern Caucasus, NW Iran and Eastern Anatolia, and Dava Göz Khoy, 5km north of the modern town of Dizaj Diz in the Khoy Plain in the Urmia Basin (Fig. 1). Together, these two sites span a chronological range encompassing the Dalma, Pisdeli (LC1 = Post-Ubaid), and LC2-3, roughly from 5000–3700 calBC. The two sites overlap in the LC1 and LC2 period (*c.* 4500–3750 calBC). The discussion also draws on data from key contemporaneous sites such as Tepe Lavin, Dagirmen Tepe Bostanabad, Qosha Tepe, Tepe Idir and Köhne Pasgah Tepesi to show the position of NW Iran during the 5th millennium BC on the basis of new discoveries. The paper also attempts to establish the settlement patterns and the dispersal of archaeological sites in NW Iran at Dalma, Pisdeli, and Chaff-Faced Ware/Chaff-Tempered Ware cultures, and highlights some of the fundamental changes that occurred in the structure of 5th millennium sites. The study reviews previous studies in Azerbaijan (NW) in the form of archaeological excavations, surveys and data recovered in the aftermath of Iran's Islamic Revolution. As such, new surveys at NW not only explain the causes of changes in socio-cultural patterns, but also clarify the undisclosed archaeological situation in eastern parts of Lake Urmia, and help to complete the Chalcolithic chronological table and the distribution map of the region during the periods mentioned.

In our discussion, we prefer to use the important modified LC1-5 chronological terminology (*Rothman 2001.5–9*) as proposed by Gil Stein and Catherine Marro (*Stein 2012; Marro 2012*), and specific local sequences in order to avoid projecting a Southern Mesopotamian chronology and modes of organisation onto northern regions which developed social complexity through processes that were largely, if not completely, indigenous and different from those that characterised Southern Mesopotamia.

A history of archaeological research in NW Iran

The initial excavation in north-western Iran was made by Frank Earp, who opened four Bronze Age tombs in 1903 (*Crawford 1975*), and Theodore Burton Brown, who spent six weeks excavating eight separate trenches at Geoy Tepe in western Lake Urmia in 1948 (*Burton-Brown 1951*). Their work continued, with new methodologies, by Charles Burney, whose work focused on the very famous Yanik Tepe site. With his excavations at Yanik Tepe, Burney produced the first evidence for the appearance of the Kura-Araxes culture in north-western Iran (*Burney 1961a; 1961b; 1962; 1964*; see also *Summers 2013a–b*).

Long-term archaeological investigations in north-western Iran continued at other sites, such as Hasanlu in the western Lake Urmia region, directed by Robert Dyson (*Dyson 1965; 1968; 1972; Dyson, Muscarella*

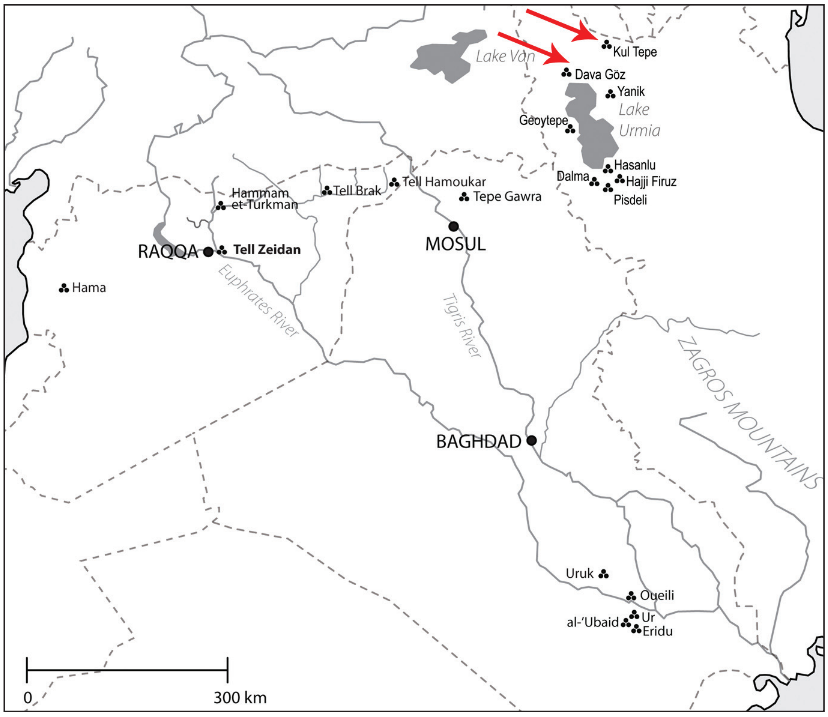

Fig. 1. Map showing the locations of Kul Tepe Jolfa and Dava Göz Khoy in NW Iran.

1989), Hajji Firuz (*Voigt 1983*), Dalma (*Hamlin 1975*) and Pisdeli (*Dyson, Young 1960*). Studies subsequent to these early excavations led to the identification of the Late Neolithic period in Hajji Firuz (6th millennium BC), previously regarded as belonging to the cultural horizon of Hasuan in Mesopotamia (*Voigt 1983*). Chalcolithic cultural material excavated at Dalma (5000–4500 calBC) was also comparable with that of the Halaf and Ubaid cultures in Southern Mesopotamia (*Oates 1983*). The Dalma period was followed by Pisdeli Culture (4500–3900/3800 calBC), which was contemporaneous with the Late-Ubaid/Post-Ubaid horizon. Geoy M/Gijlar C culture (4000–3500 calBC) is the final phase of the Chalcolithic period in north-western Iran, excavated and reported from Gijlar, Geoy M and Trench M at Yanik Tepe (*Helwing 2004*). The material culture of Yanik (Kura-Araxes), which takes its name from the Bronze Age Yanik Tepe site, belongs to the early Trans-Caucasian or Kura-Araxes culture (second half of the 4th to end of the 3th millennium BC), which spread through the Caucasus and the Urmia Basin. Its origin is unknown, but it has been observed in the valleys and foothills of three Caucasian republics (Azerbaijan, Armenia and Georgia), as well as north-western and western Iran, eastern Anatolia and the Levant (*Sagona 1984; Kushnareva 1997; Rothman 2003; Batiuk 2005; Kohl 2007; Gopnik, Rothman 2011; Batiuk 2013; Abedi* et al. *2014*). During the final phase of prehistory in north-western Iran, the Middle and Late Bronze Age culture (2200/2000 to 1500 calBC) known as Urmia Ware, including painted monochrome and polychrome pottery, prevailed in this region. In the first half of the 2nd millennium BC, Urmia Ware extended over the Urmia basin and has been found in Haftavan VIB (*Edwards 1981; 1983; 1986*). Despite the general similarity between Urmia pottery, different regional names are used; for example, in eastern Georgia, pottery of this type is known as Trialeti-Vanadzor culture (*Smith* et al. *2009*), in Azerbaijan as Uzarlik culture (*Kushnareva, Lisitsyna 1986*), and in Armenia as Karmirberd-Sevan culture (*Abedi* et al. *2009*).

In addition to the above-mentioned projects in north-western Iran, other excavations and surveys carried out during recent decades in the Lake Urmia basin included Geoy Tepe (*Burton-Brown 1951*), Kordlar Tepe (*Kromer, Lippert 1976; Lippert 1976*), Tepe Dinkha (*Dyson 1967a; Hamlin 1974*), Haftavan Tepe (*Burney 1970a; 1970b; 1972; 1973; 1974; 1975; 1976a; 1976b; 1979a; Edwards 1981; 1983; 1986*), Tepe Ahranjan (*Tala'i 1983*), Tepe Gijlar (*Pecorella, Salvini 1984; Belgiorno* et al. *1984*), Kul Tepe of Marand (*Kroll 1990*), and Gol Tepe (*Tala'i 1984*). In addition, surveys were undertaken in north-western Iran (*Kambakhsh Fard 1967; Soleki 1969; Soleki, Soleki 1973; Swiny 1975; Pecorella, Salvini 1984*), the Salmas valley (*Kearton 1969; 1970*) and the Solduz plain (*Dyson 1967b*), around Lake Urmia (by a German team) (*Kleiss, Kroll 1979; 1992; Kroll 1984; 2005*) and in the Meshkin Shahr area (*Burney 1979b; Ingraham, Summers 1979*). Since the 1979 Revolution in Iran, archaeological research has included Early Bronze Age settlement patterns and site distribution in north-western Iran (*Omrani 2006; Omrani* et al. *2012; Summers 2013a*), a survey in Eastern Azerbaijan province (*Khatib Shahidi, Biscione 2007; Biscione, Khatib Shahidi 2006*), a systematic survey at Tepe Baruj (*Alizadeh, Azarnoush 2003a; 2003b*) and the Mughan plain (*Alizadeh, Ur 2007*), and excavations at Lavin Tepe (*Nobari* et al. *2012*), Nader Tepesi (*Alizadeh 2007*), Qosha Tepe in the Meshkin Shahr area (*Nobari, Purfaraj 2005*), Kohne Pasghah Tepesi (*Maziar 2010*), the Iron Age cemetery of Masjed Kabood in Tabriz (*Nobari 2000 [1379]; 2004 [1383]*), the Qale Khosrow and Ardebil Survey (*Azarnoush* et al. *2006*), Qalaychi and Tepe Rabat (*Kargar 2005; Kargar, Binandeh 2009*), Zardkhaneh of Ahar (*Niknami 2011*), and Köhne Shahar (Ravaz) (*Alizadeh* et al. *2015*). Apart from these excavations and surveys, many others have yet to be published.

The main problems for archaeology in north-western Iran are the lack of systematic and intensive long-term excavations and surveys and a shortage of reliable publications, as well as inaccurate and uncalibrated dating of old excavations and a shortage of multidisciplinary works. In recent years, most excavations in north-western Iran have taken place in the course of salvage and dam construction projects.

Kul Tepe Jolfa and Dava Göz Khoy in NW Iran

Kul Tepe Jolfa

The Kul Tepe site (E 45° 39' 43"– N 38° 50' 19", 967m a.s.l.; Figs. 1–2) is located near the city of Hadishahr, 10km further to the south of the Araxes River. Kul Tepe is a multi-period *tell*, about 6ha in extent and rising 19m above the surrounding land. The site was originally discovered by an expedition in the province of East Azerbaijan in 1968 under the supervision of Sayf Kambakhsh Fard (*Kambakh Fard 1968*), and was later reported by other authors as well (*Kliess, Kroll 1992; Kroll 1884; Edwards 1986; Omrani 1994*). Kul Tepe is located precisely in the north-western corner of Iran, which is the gateway between the Southern Caucasus and north-western Iran, about 50km from the famous Kültepe site at Nakhichevan. Kul Tepe is located next to a broad valley, at the centre of the highlands and at the crossroads of major routes linking the Iranian plateau to Anatolia and the Caucasus to Northern Mesopotamia (Fig. 1). This strategic location is further enhanced by the region's wealth in natural resources, which include rich copper and salt deposits. The first season of excavation at Kul Tepe were carried out from June to August in 2010 (*Abedi* et al. *2014*). Because of the huge quantity of material and deposits at Kul Tepe, the site needs more research and excavation to better understand the cultural situation in the region. The second season of excavation was from August to October 2013 in order to answer certain questions about the region and extend the studied areas.

The first and second seasons of excavation were primarily aimed at clarifying the chronology and settlement organisation, and answering some fundamental questions (such as the transition process from the Late Chalcolithic to the Early Bronze Age), identifying different cultural horizons, including the Proto-Kura-Araxes and Kura-Araxes I periods, and also outlining the cultural situation in the region during prehistoric and historical periods. The initial aims were to establish periods of occupation and to obtain a stratigraphically controlled ceramic sequence for the Jolfa region and the northern part of north-western Iran. More specifically, Kul Tepe, was excavated for two main reasons:

❶ to determine the presence of Late Chalcolithic followed by Early Bronze Age occupation levels;
❷ more importantly, to test for the presence of a probable 'transition' period between the Late Chalcolithic and Early Bronze Ages and the existence of Proto-Kura-Araxes and Kura-Araxes I periods.

Kul Tepe periods	Cultural phases	Range (calBC)
VIII	Early Chalcolithic (Dalma) 3m deposit	5000–4500
VII	LC1: Pisdeli/Hasanlu VIII 1.5m deposit	4500–4200
VIB	LC2: Chaff-Faced 3m deposit	4200–3900
VIA	LC3: Chaff-Faced 3m deposit	4000/3900–3750
V	Kura-Araxes I 3.5–4m deposit	3400/3350–3100/3000
IV	Kura-Araxes II, III 7.5–8m deposit	3000/2900–2500
III	Middle Bronze Age (Urmia Ware) 1m deposit	1st half of 2nd millennium
II	Iron Age III, Urartian 50cm deposit	8th–6th century
I	Achaemenid 1m deposit	6th–4th century

Tab. 1. Sequence at Kul Tepe based on excavations in 2010 and 2013.

Based on the results of the first and second seasons of excavation, eight main periods were identified, which provide evidence of a continuous sequence (except in the Iron Age I and II periods) and significant material was found from the Dalma (Period VIII), Pisdeli (= LC1: Period VII), Chaff-Faced Ware horizons (LC2-3: Period VIB and VIA), Kura-Araxes I (Period V), Kura-Araxes II (Period: IV), Middle Bronze/Late Bronze Age (Urmia Ware, Period: III), Iron III (Period II), and Urartian/Achaemenid (Period I) periods. As a result of the excavation of 24m deposits it was established that it consists of 3m deposit of Dalma, 1.5m of Pisdeli, 6m of CFW horizon (Kul Tepe VIB and VIA), 3.5–4m of Kura-Araxes I, 7.5–8m of Kura-Araxes II, 1m of Middle and Late Bronze Age with typical Urmia Ware and finally 1.5m of Iron III with Urartian and Achaemenid materials (*Abedi, Omrani 2013; Abedi* et al. *2014*) (Figs. 3–4, Tab. 1).

Interestingly, Mary Voigt and Robert Dyson, based on Pisdeli Tepe materials and site sequence, suggested a transition between the Dalma and Pisdeli periods, with no gap between them. They proposed that Pisdeli culture developed locally (*Voigt, Dyson 1992. 174*). The Kul Tepe excavation supports this notion. Late Chalcolithic layers were discovered in the deep sounding, in Trench III, with no break after the Dalma (Fig. 5) materials. Based on pottery type, form, design and surface treatment and the sequence in which they occur, and on other Late Chalcolithic materials at Kul Tepe, three sub-phases were identified: Kul Tepe VII = Pisdeli (LC1 = Post-Ubaid), Kul Tepe VIB = LC2 (Chaff-faced/Chaff-tempered), and Kul Tepe VIA = LC3 (Chaff-tempered) cultures.

The lowest Late Chalcolithic layers (LC1, Post-Ubaid: 4500–4200 calBC) include black-on-buff, so-called Pisdeli-type painted pottery. This pottery repertoire is almost entirely limited to geometric or non-representational designs; emphasis is on horizontal banding made with straight lines, which may border some design elements. All

Fig. 2. General view of Kul Tepe, view from the north.

the painted pottery of this period bears monochrome and matte paint, with colours ranging from brown to black. Generally, painting is limited to bowls and small pots. Most of the pottery of the Late Chalcolithic consists of buff to reddish chaff-tempered fabric. All of the painted sherds are painted black and brown on buff or brown and red (reddish-brown), and include geometric designs such as oblique and diagonal lines beneath the rim. Another diagnostic design is hatched and plaid on jars and bowls (Fig. 6).

Late 5th millennium Chaff-Faced Ware appears alongside Ubaid-related (Pisdeli) black on buff during LC 2-3. Two main periods can be distinguished, mainly based on ceramic evidence, but supported by additional information from other kinds of artefact. These periods are LC2=Chaff-faced Ware (4200–3900 calBC), termed Kul Tepe VIB, and LC3 = Chaff-faced Ware (3900–3700 calBC), termed Kul Tepe VIA. According to the stratigraphic section in the upper part of Trench III and the lower part of Trench II, 6 m of deposits relate to Kul Tepe periods VIB (LC2) and VIA (LC3) (Fig. 7).

The chronological framework presented here is based on three lines of evidence: (1) rim and decoration typology (embedded within the stratigraphic sequence), (2) pottery technology, (3) radiocarbon dates.

Late 5th millennium Chaff-faced or Chaff-tempered ware appears alongside Ubaid-related black on buff during LC 2–3 (*Helwing 2012*). In the later phase of the Chalcolithic, most of the pottery production is buff, chaff-tempered and chaff-faced. The repertoire of shapes consists mainly of simple everted bowls, pots and jars, sometimes decorated with a row of bosses below the rim or an annular coil around the shoulder. Rims decorated with incisions or impressions are common to most pottery of this LC2 and 3 type at this site.

Chaff-faced and chaff-tempered pottery with combed surfaces is typical of the Late Chalcolithic of Southern Azerbaijan in general and the Nakhichevan region and north-western Iran in particular, where it has been termed 'Kültepe culture'. Similar pottery was found at Kültepe I, Khalaj, Erebyengicesi, Sederek (*Bakhshaliyev* et al. *2009; Marro* et al. *2011*), Kul Tepe of Marand (*Kroll 1990*), Tepe Baruj (*Alizadeh, Azarnoush 2003b*) and Tepe Dava Göz Khoy (*Abedi, Omrani 2013*). But close comparisons may also be made over a much wider area, which includes Eastern Anatolia, the Urmia basin and Northern Mesopotamia, where similar traits are designated as part of the 'Marand culture' in Iran (*Kroll 1994*), or 'Chaff-faced ware culture', also called 'Amuq (E)-F', in Turkey and Northern Syria (*Braidwood, Braidwood 1960*).

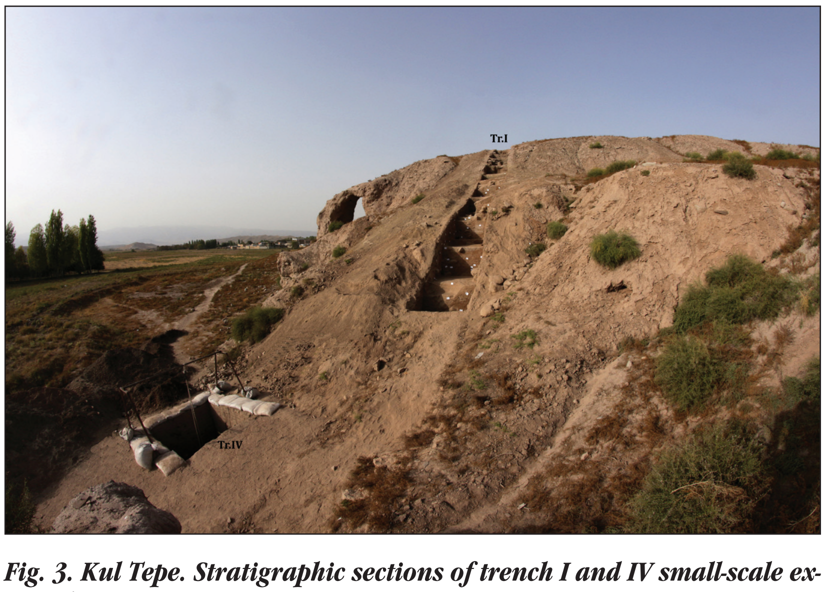

Fig. 3. Kul Tepe. Stratigraphic sections of trench I and IV small-scale excavations.

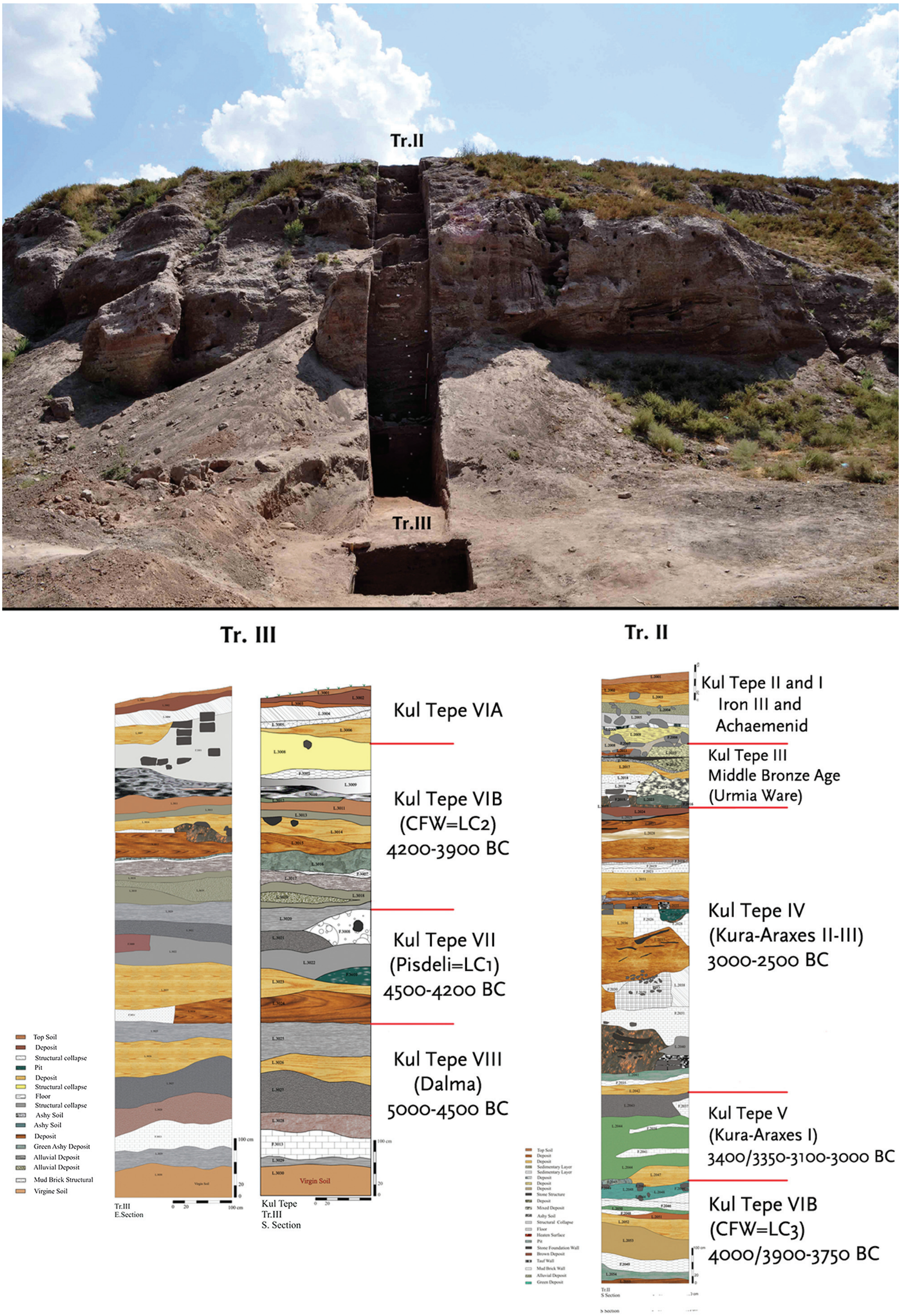

Fig. 4. Kul Tepe. Step trench II and deep trench II; stratigraphic section of trench II and III soundings.

However, if we focus on the main features of the pottery assemblage from Kul Tepe, it is clear that this repertoire shares close similarities with sites located in the northern parts of the Araxes River, especially sites like Ovçular Tepesi, Kültepe, Alikömek Tepesi, Mentesh Tepe and Leila Tepe in Azerbaijan, Sioni and most related sites in Georgia, Aratashen in Armenia, and some sites in eastern Turkey and northern Mesopotamia.

Dava Göz

The settlement of Dava Göz is situated about 10km south-west of Khoy and 5km north of Dizaj Diz town. Dava Göz is a small site, measuring about 100x100m (approx. 1ha). The site has been completely destroyed by modern agricultural activities, which prevents mapping of the whole topography (Fig. 8). The stratigraphy of the settlement is now well understood, and covers the Late Neolithic/Transitional Chalcolithic (Hajji Firuz/Dava Göz I = Period I) and Chalcolithic (Pisdeli = LC1 = Period II and CFW horizon = LC2 = Period III) phases of the regional culture north of the Lake Urmia basin (Fig. 9–10). The first season of excavation at Dava Göz lasted from June to August 2012. Dava Göz is a horizontal site that relates to the Hajji Firuz, Dava Göz (Transitional Chalcolithic), Pisdeli and CFW cultures. Hajji Firuz materials are mainly located at the centre of the site. It seems clear that during Hajji Firuz Period this was seasonal camp site, because the layers are no more than 0.5m thick. However, the Pisdeli materials were mainly in the western part of the site, with a cultural layer of 2.5–3m.

Actually, Dava Göz is one of the few well-excavated settlements to yield new information on developments in the Lake Urmia basin communities between the 6th to 4th millennium BC, and on their relationships with contemporary Caucasian cultures, as well as with those located further west and south in Eastern Anatolia and in the Syro-Mesopotamian region.

Dava Göz overlaps in the LC1 and 2 periods with Kul Tepe VII and VIB (*c.* 4500–3900 calBC). Like Kul Tepe, the Dava Göz pottery repertoire is divided into two, painted and unpainted, through LC 1 and 2. The pottery assemblage is the same as at Kul Tepe and encompasses cultural layer at the site (Fig. 10).

5th millennium BC and the problem of chronology in NW Iran

Obviously, the (absolute and relative) chronology and internal periodisation of the Chalcolithic period have been, and still are, the subject of much research and debate. It would appear that the difficulties encountered in establishing the chronological time limits of this cultural phenomenon, which still continue to fluctuate, are mainly due to the dearth of absolute dating in the Southern Caucasus (with only a few exceptions), while over the course of time there seems to have been a general tendency, supported by new dating, to shift the time limits of (or at least the starting time) higher up the time scale.

After three decades of stagnation in archaeological activities in NW Iran, valuable work has been done in recent years. Almost all the excavated sites in this region are situated around the Lake Urmia, while information about other parts of the region is lacking, and different parts of the region and its prehistory have received unequal attention. While a considerable area of the western and southern parts of the Lake Urmia basin has been explored relatively comprehensively, eastern and northern parts remain largely archaeological *terra incognita*.

Previous studies put the Dalma period in the second half of 5th millennium BC (*Hamlin 1975; Hole 1987*), although only one date was available from this period (*Hole 1987*). The rare scientific excavations carried out concerning the Dalma period in its homeland (NW Iran) with only one ^{14}C date has limited our ability to establish a solid chronological table for the whole of the Dalma period. The same limitation has also risen for the Pisdeli period, for which only rare radiocarbon dates are available, and with an imprecise and faulty time span (late 5th to early 4th millennium BC). Prior to the Kul Tepe Jolfa and Dava Göz Khoy excavations, it was not possible to establish appropriate and precise periodisation and chronology between Hasanlu VIII and VII in the chronological sequence of NW Iran (Tab. 2).

The 5th millennium is considered as the largest lacuna in our understanding of the developmental sequence in NW Iran, although new excavations with absolute radiocarbon dates have shed some new light on the Chalcolithic period in the region.

Dalma period in NW Iran (5000–4500 BC)

In the first half of the 5th millennium BC (Early Chalcolithic), the remarkably homogeneous Dalma ceramic assemblage spread throughout much of north-west and western Iran. Dalma is an unusual ceramic phenomenon for this time range: a widespread, but technically and stylistically homogeneous material cultural tradition, at home in a topographically severe highland region. The Dalma period is particu-

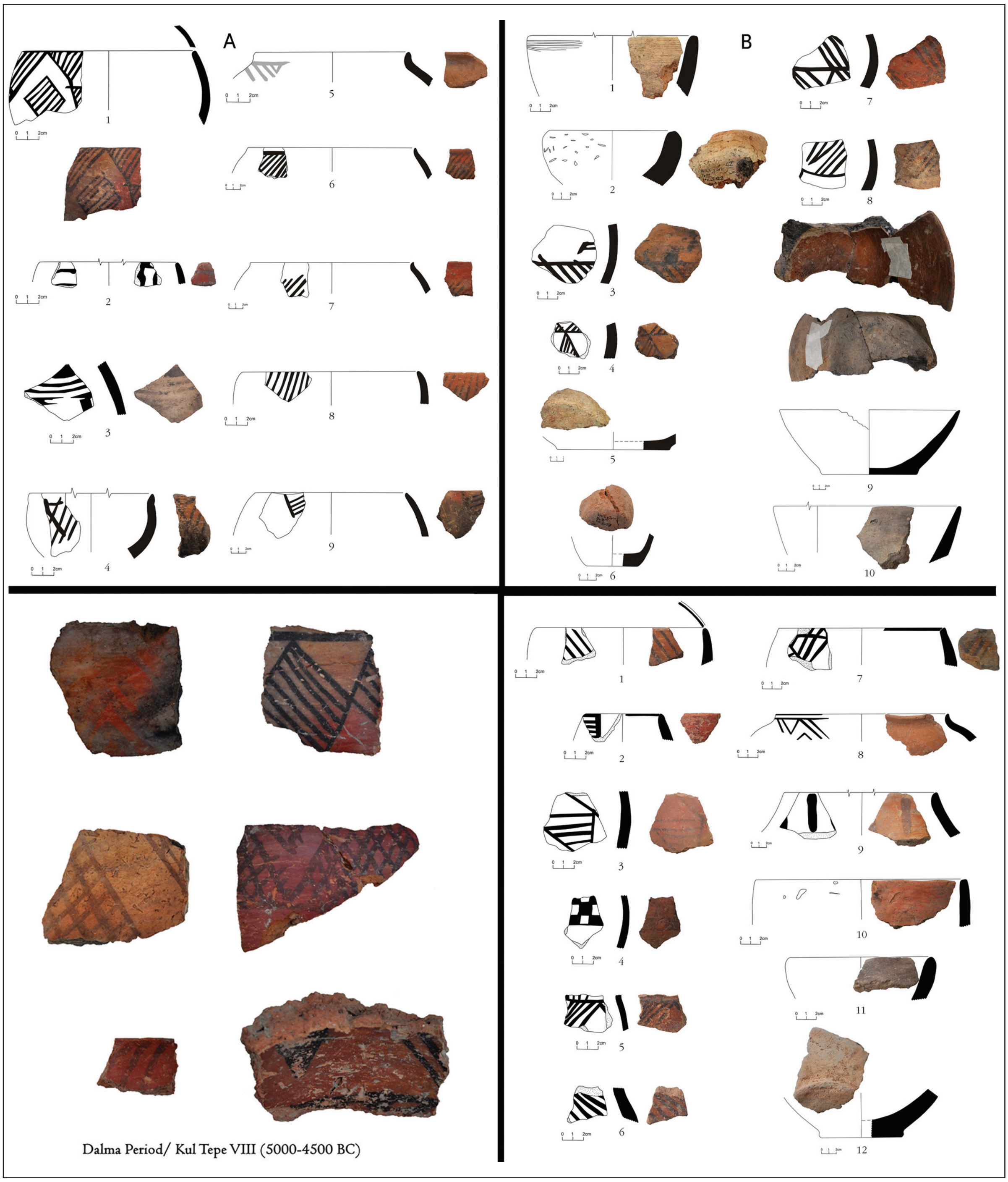

Fig. 5. Kul Tepe VIII (Dalma) pottery, Tr. III and IV.

larly interesting because of the extremely large geographic spread of its ceramics, ranging from the 'widely separated mountain plains such as the Urmia basin and the Mahidasht and the Kangavar regions' to the Hamrin region of eastern Iraq, where it occurs in combination with typical Halaf and Ubaid pottery. Similar ceramic types have also been found in the Caucasus Mountains. The first evidence of Dalma culture was found at the south-west end of Lake Urmia, at Tepe Dalma and Hasanlu in 1958. Dalma materials have also been reported from Hajji Firuz, Pisdeli and Tepe Seavan. Apart from the mentioned excavations, various surveys have been carried out by different expeditions (*Dyson 1962; Hamlin 1975; Henrickson, Vitali 1987; Hole 1987; Levine, Young 1987; Solecki, Solecki 1973; Vandiver 1985; Voigt, Dyson 1992; Young, Levine 1974; Pecorella, Salvini 1984; Kroll 1984; 1994; Tonoike 2009; Vitali, Henrickson 1987; Hamlin 1975; Hole 1987b; Oates 1983.261; Voigt, Dyson 1992*).

Fig. 6. Kul Tepe VII (LC1) Pisdeli type pottery.

The series of radiocarbon dates now available from Kul Tepe Jolfa, Tepe Dava Göz and one calibrated date from Tepe Dalma, make it clear that the frequently mentioned date of 4215 ± 84 calBC from Tepe Dalma (second half of 5th millennium), and suggested dates of 4100–3700 calBC for Dalma culture said to date the Middle Chalcolithic, are much too recent in NW Iran and should now be revised (*Hamlin 1975; Voigt, Dyson 1992; Henrickson 1985.70*). New radiocarbon dates from Kul Tepe Jolfa and Dava Göz suggest the first half of the 5th millennium calBC for the Dalma period in NW Iran (5000–4500 calBC) (*Abedi* et al. *2014; Abedi, Omrani 2013*). The available dates argue that the Dalma tradition flourished during first half of the 5th millennium calBC in NW Iran, spreading south to the Central Zagros in the second half of 5th millennium.

Valuable work has been done on prehistoric archaeology in Iranian Azerbaijan in the form of archaeological excavations, surveys and data recovered in the aftermath of Iran's Islamic Revolution. Recent excavations at Kul Tepe Jolfa (*Abedi* et al. *2014; 2009*), Tepe Ahranjan (*Talai 1983; Kargar 1994*), Tepe Lavin (*Nobari* et al. *2012*), Qosha Tepe (*Nobari, Purfaraj 2005*), Tepe Idir (*Hesari, Akbari 2007*), and Tepe Baruj (*Alizadeh 2001; Alizadeh 2003a; 2003b*) have yielded fascinating new information about Dalma culture. Apart from these excavated sites, more than 100 Dalma and Dalma-related sites have been brought to light by old and recent surveys in NW Iran.

Recently, scholars have suggested a combination of factors, such as trade and exchange, the movement of material goods and information, migration, diffusion, and local emulations of foreign styles to explain Dalma cultural phenomena (*Voigt 1983; Tonoike 2009*). The settlement pattern and distribution of Dalma sites in NW Iran suggests it can be divided into two types: (1) permanent settlements in fertile inter-mountain valleys, and (2) temporary seasonal camp sites in the highlands of Zagros, the Caucasus and other highlands of north-west Iran. Yukiko Tonoike (*2009*) concluded that a village-based form of seasonal migration (transhumant pastoralism) was the most likely scenario, whereby small groups of nomads moved between villages with which they maintained relationships, possibly through kinship. Transhumance is a specialised form of pastoralism that is still based on permanent settlements, but involves the seasonal movement of the herd between pastures (*Abdi 2003*).

What is important in this respect is the chronological differences between north-western Iran and the Central Zagros regions, where the Dalma period ranges from 4100 to 3700 calBC, whereas this time coincides with the LC 2 and 3 (Chaff-Faced Ware Cultures) periods in north-western Iran.

Pisdeli (Hasanlu VIII/LC1 Post-Ubaid) period (4500–4300/4200 BC)

During the mid-5th millennium or slightly later (LC1, Post-Ubaid: 4500–4200 calBC) black-on-buff, so-called Pisdeli culture was gradually replaced throughout the southern, western and northern regions of the Lake Urmia basin. Pisdeli, also known as Hasanlu VIII or middle Chalcolithic, and was first defined at Pisdeli (*Dyson, Young 1960*) and reported from Hajji Firuz (*Voigt 1983*) and Hasanlu (*Dyson 1958*). Interestingly, based on Pisdeli Tepe materials and its sequence, Mary M. Voigt and Robert Dyson (*1992. 174*) suggested a transition between Dalma and Pisdeli with no gap between these two periods, and proposed that Pisdeli culture developed locally. Most studies of the Pisdeli period relate to the few famous typical sites, including Pisdeli (*Dyson, Young 1960*), Geoy Tepe (*Burton-Brown 1951*), Yanik Tepe (*Burney 1961a; 1961b; 1962; 1964*), and Tepe Gijlar (*Belgiorno* et al. *1984*). Apart from these excavations, various surveys have been brought to light prominent data concerning this period (*Belgiorno* et al. *1984; Kroll 1984; 1990; 2005*).

Recent discoveries in NW Iran have yielded fascinating new information about Pisdeli culture. Excavations at new, well-stratified sites at Kul Tepe Jolfa (*Abedi* et al. *2014*) and Tepe Dava Göz Khoy (*Abedi, Omrani 2013*) provided new information about the Pisdeli period with new radiocarbon dates. At Kul Tepe Jolfa 3m deposits of Pisadeli period were unearthed. Kul Tepe VII relates to this phase with both painted and unpainted pottery. New radiocarbon dates from Kul Tepe VII give dates around 4500–4300/4200 calBC for the Pisdeli period. The excavation at Dava Göz Khoy has also yielded very strong materials related to this period, with complete typical Pisdeli ware. ^{14}C absolute dating from Dava Göz II suggests the same date for this time span. In the course of recent work, Tepe Ahranjan (*Kargar 1994*) and Tepe Lavin (*Nobari* et al. *2012*) have provided new information about this period. Apart from the recent excavations mentioned, new surveys have produced new insights and perspectives on the chronological enigma of NW Iran during the Pisdeli period.

Barbara Helwing (*2004*) suggests a threefold chronological break-down for the Late Chalcolithic in NW Iran and places Pisdeli Tepe in the LCH1 period as the oldest assemblage (= Hasanlu VIII) preceding both Yanik Tepe M, and Geoy Tepe phases N and M and even Gijlar C. She also proposes that the Grey Burnished Ware of Geoy Tepe N is an early stage of LCH2 and eventually Chaff-faced/Chaff-tempered ware for the developed stage of LCH2. This division was later approved by Michael Danti *et al.* (*2004*).

Excavations at Kul Tepe Jolfa and Dava Göz Khoy shed some new light on Pisdeli dates in NW Iran. These dates, accompanied by new recalibrated old samples from the Hasanlu project (*Danti* et al. *2004*), lead us to a comprehensive chronology for the Pisdeli period. New radiocarbon calibrated dates from all Pisdeli-related sites suggested a date of 4500–4300/4200 calBC for the Hasanlu VIII (LC1, Pisdeli, Kul Tepe VII, Dava Göz II) period.

Fig. 7. Kul Tepe VIA (LC3) Chaff-faced pottery.

LC2; Chaff-faced/Chaff-tempered ware; Kul Tepe VIA/Dava Göz III (4300–3800/3700 calBC)

At present, the Chaff-faced Ware (CFW) or LC2 period is the largest lacuna in our understanding of the developmental chronological sequence in NW Iran. Excavations and published material on CFW or after Pisdeli material in NW Iran are rather scant, and raise many questions. Recently, new data from Kul Tepe Jolfa (*Abedi* et al. *2014*), Dava Göz Khoy (*Abedi 2013*), Köhne Pasgah Tepesi (*Maziar 2010*), Dagimentepe Bostanabad (*Chaichi, Omrani 2010*) have shed some new light on LC2-3 CFW period in NW Iran. Apart from excavations, old and new surveys have provided results regarding the distribution and expansion of CFW phenomena in NW Iran. More than 100 sites were brought to light from all surveys in Iranian Azerbaijan from different districts, such as: Jolfa, Marand, Khoy, Shabestar, Salmas, Urmia, Ushnaviyeh, Naqadeh, Piranshahr, Mahabad, Bukan, Shahin Dezh, Tekab, Malekan, Bonab, Maragheh, Ajabshir, Azarshar, Tabriz, Ahar, Heris, Bostanabad, Hashtrood, and Sarab.

Prior to the Kul Tepe Jolfa and Dava Göz Khoy excavations, only scant materials related to this period had been reported and published (*Burton-Brown 1951; Burney 1964; Kroll 1990; 2005; Helwing 2005; Maziar 2010*). Recent ^{14}C radiocarbon dates from Kul Tepe Jolfa VIB and VIA and Dava Göz Khoy III suggest a date of *c.* 4200–3700 BC for the LC2-3 CFW tradition in NW Iran. Recently, fresh dates from adjacent regions – the Southern Caucasus and Northern Mesopotamia – have confirmed this date for CFW (*Marro 2010; 2012; Stien 2012; Helwing 2012*).

The stratigraphic section at Kul Tepe revealed that 2–5m of strata belong to LC1 and LC2-3, respectively. Kul Tepe VII revealed both black-on-buff painted and unpainted assemblages. Painted samples comprised a small percentage of the pottery repertoire; the situation was the same at Dava Göz, where unpainted ware accounted for the majority of the assemblage.

Discussion

The Chalcolithic is one of the most important, but also a very ambiguous period in NW Iran. Only sparse and scant studies have been done around the Lake Urmia basin at Geoy Tepe (*Burton Brown 1951*), Pisdeli Tepe (*Dyson, Young 1960*), Yanik Tepe (*Burney 1961a; 1961b; 1962; 1964*) and Tepe Dalma (*Hamlin 1975*), and some other sites are known from surveys (*Pecorella, Salvini 1984; Kroll 1984; 1990*) but information is limited to surface collection. The most significant obscurity is due to the lack of accurate ^{14}C dating in chronology of NW Iran. Only scant ^{14}C uncalibrated dates were available from Pisdeli and Tepe Dalma during the 1960s and 1970s and with one or two samples it is impossible to construct a chronology of the region. So the real obstacle is the dramatic lack of absolute dates (with some exception) which makes it impossible to define the chronological extension of the Chalcolithic and build up a solid internal periodisation and properly articulated timeline for regional developments in this phase.

After three decades of stagnation in archaeological activities in NW Iran, valuable work has been done on the prehistoric archaeology of the region in recent years. Almost all excavated sites in the region are around Lake Urmia, while information about the other parts of the region is lacking, and different parts of the region and its prehistory have received unequal attention. While a considerable area of the western and southern parts of the Lake Urmia basin has been explored relatively comprehensively, the eastern and northern parts remain largely archaeological *terra incognita*. However, the advance of research at well-stratified sites at Kul Tepe Jolfa,

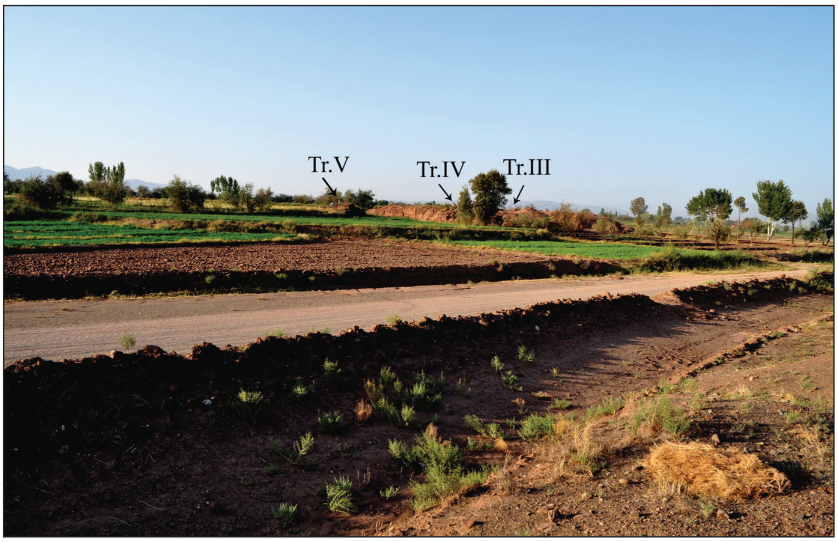

Fig. 8. General view of Dava Göz, View from north-east.

Dava Göz Khoy with ^{14}C radiocarbon dates has shed some new light on this hitherto poorly understood chronology.

The Dalma culture is one of the most intriguing phenomena of NW and Western Iran. The broad outlines of Dalma material culture are well known by now, and it is renowned for its elaborately decorated pottery. Other aspects of Dalma society, however, are still poorly understood. The chronology and the origin of Dalma society is a matter of much debate, and likewise our insights into Dalma economic or social organisation are generally based on mere speculation.

In the light of the available data, especially the pottery repertoire and recent radiocarbon dates, it demonstrates that the Dalma phenomena or tradition emerged after the Hajji Firuz period (*c.* 6000–5400 calBC) with a short gap in NW Iran. From this point on, two scenarios are possible for the spread of Dalma in NW Iran; first, we can surmise it as a foreign (alien) imported tradition from outside the NW region (western or southern region), or it can be seen as a local derivative of a previous culture (Hajji Firuz). In this respect, it is felt that Dalma in the Urmia Basin of NW Iran was the ultimate result of a long and locally founded sequence of late Neolithic (Hajji Firuz) development. As mentioned above, with new radiocarbon dates for the Dalma tradition (*c.* 5000–4500 calBC) it seems likely that some sites can fill this 400-year gap between the two periods, which we regard as a transitional period. A similar conclusion can be drawn from the survey results in the region. Provenance analysis has also shown that all Dalma ceramics were produced locally (*Vitali, Henrickson 1987; Tonoike 2009*). It seems clear that only pottery production changed during the Dalma period compared with the preceding Hajji Firuz, but not all Dalma sites clearly suggest any marked discontinuity in other aspects of the material culture.

Obsidian analysis in NW Iran (*Khademi Nadooshan* et al. *2013*) indicates that during the Chalcolithic period an extensive and local obsidian trade was practiced by some transhumant or pastoral groups between the Lake Urmai basin and the highlands of the Caucasus. Local regional and inter-regional trade played an important role in the distribution of Dalma culture to adjacent regions. In addition to trade, easy access to main routes, the exploitation of various resources, interaction between lowland settlements and highland pastoral sites by some transhumant or pastoral groups can be considered key factors in the distribution of Dalma culture.

Excavations at Kul Tepe Jolfa and Dava Göz Khoy unravelled the problem of the Chalcolithic of NW Iran after the Dalma period and divided it into two main periods: Pisdeli (LC1 = Kul Tepe VII; Dava Göz II) (4500–4200 calBC) with typical painted pottery (black-on- buff); and the Chaff-Tempered/Chaff-Faced Ware tradition (LC2 and 3 = Kul Tepe VIB and VIA; Dava Göz III) (4200–3700 calBC). Recent discoveries in NW Iran make it possible to draw precise conclusions about the final phases of the Late Chalcolithic. The new excavations in the last decade concerning the Chalcolithic in the Southern Caucasus (Ovcular Tepesi, Leyla Tepe) (*Achundov 2007; 2011; Müseyibli 2007; Lyonnet 2007b; Lyonnet* et al. *2008; 2012; Marro 2010; 2012; Helwing 2012*), Eastern Anatolia (*Frangipane 2012*) and Northern Mesopotamia (*Stient 2012*) enable scholars to define the chronological range of the Chalcolithic and build up a solid internal periodisation and properly articulated timeline for regional developments in this phase (*Marro 2012*).

Recent excavations in NW Iran substantiate that post-Ubaid finds come from settlements whose cultural sequence seemingly develops from a very different, that is, non-Ubaid background. In her most recent publication, Marro (*2012*) used the term ‘post-Ubaid’

Hasnlu sequence	NW chronology	Kul Tepe sequence	Dava Göz sequence	Date
Hasanlu VII	Kura Araxes II	Kul Tepe IV	–	3000–2500 calBC
–	Proto-Kura Araxes/Kura-Araxes I	Kul Tepe V	–	3400/3500–3000 calBC
–	LC 3, CFW	Kul Tepe VIA	–	3900–3700 calBC
–	LC 2, CFW Horizon	Kul Tepe VIB	Dava Göz III	4200–3900cal calBC
Hasanlu VIII (Pisdeli)	LC 1, Black-on-Buff	Kul Tepe VII	Dava Göz II	4500–4200 BC
Hasanlu IX (Dalma)	Dalma	Kul Tepe VIII	–	5000–4500 calBC
Hasanlu X (Hajji Firuz)	Late Neolithic/ Transitional Chalcolithic	Kul Tepe IX	Dava Göz I	5400–5000 calBC

Tab. 2. Chronological table for NW Iran with new chronology from Kul Tepe and Dava Göz.

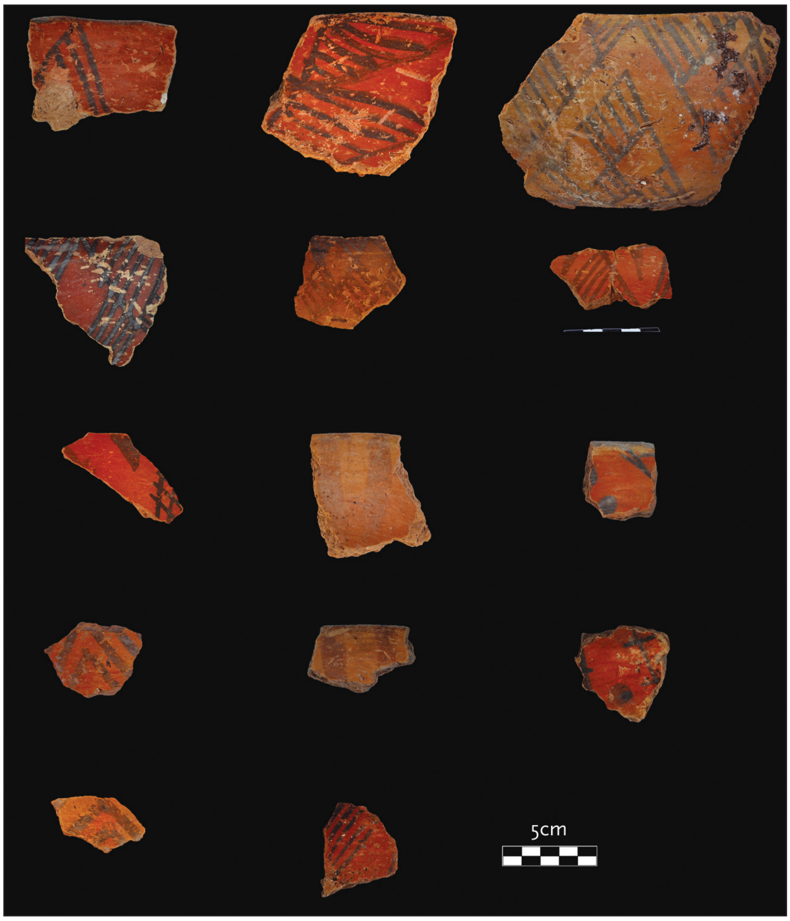

Fig. 9. Typical Late Neolithic / Transitional Chalcolithic pottery from Dava Göz.

for the period from 4500 to 3800 calBC. She divided this phenomenon into 'Ubaid' and 'non-Ubaid' land. She focused on interactions between the lowlands and the highlands, with a reassessment of the available data from a non-Mesopotamian perspective. She used different terms for this spreading phenomena – 'Chaff-Faced Ware *oikoumene*' (*Marro 2010*), 'Standardized ware *oikoumene*' (*Marro 2012*) – for a period after Ubaid as a result of both interruptions and continuity. She suggests that this widespread expansion of CFW may have been the result of, or is related to the economic and productive sphere (*Marro 2012*). According to the available data, post-Ubaid CFW culture in the Southern Caucasus and NW Iran is indeed related to Mesopotamia, but it is not a Mesopotamian culture *per se*. Rather, the centre of gravity of this culture probably lies between the Upper Euphrates, the Kura Rivers and the Lake Urmia basin. The CFW cultural horizon encompasses the highlands and Upper Mesopotamia, which are thus part of the same *oikoumene*. However, it should be stressed that the CFW sites attested over this vast territory probably had different functions and were constituents of a complex economic system (*Marro 2010*).

For the post-Ubaid horizon, six major 'ceramic provinces' or 'cultural provinces' were grouped by Marro (*2012*): (1) Southern Caucasus; (2) Upper Euphrates province; (3) western Euphrates province; (4) Khabur cultural province; (5) the Balikh region; and (6) the Cilician province. With new excavations in NW Iran (at Kul Tepe Jolfa, Tepe Dava Göz Khoy and Köhne Pasgah Tepesi), a seventh group can be suggested, with typical Pisdeli (LC1 = Kul Tepe Jolfa VII and Dava Göz II) and CFW (LC2 and 3 = Kul Tepe Jolfa VIB and VIA and Dava Göz III) materials. We think this group is similar to the Southern Caucasus group and is homogeneous in many aspects, but it seems that this was the case only during the LC2 and LC3 periods, while LC1 is absent in most parts of the Southern Caucasus. During LC1, a close relationship can be clearly seen with the Upper Euphrates (sites Norsun Tepe, Korucu Tepe and Tulin Tepe), Khabur (Gawra XII) and Balikh regions (sites Tell Zeidan LC1 and LC2, and Hammam et-Turkman IVD and VA). Throughout LC2, contacts increased with sites in the Southern Caucasus (Ovcular Tepesi, Leyla Tepe, Mentesh Tepe *etc.*), Upper Euphrates (Norsun Tepe IIA), Khabur (Gawra XI-IX) and Balikh regions (Tell Zeidan LC2 and Hammam et-Turkman).

Recent excavations show that the development from Pisdeli (LC1 = Kul Tepe Jolfa VII and Dava Göz II) to CFW (LC2 and 3 = Kul Tepe Jolfa VIB and VIA and Dava Göz III) took place without interruption in NW Iran, which is the case in Balikh and Khabur 'cultural province'.

After the LC 3 period onwards, the CFW tradition was superseded in NW Iran by a widespread expansion of famous Kura-Araxes phenomena, which flourished from the highlands of Transcaucasia and NW Iran. Settlement stratigraphy accomplished with new radiocarbon dates from Kul Tepe Jolfa show that period V (Proto-Kura-Araxes-Kura-Araxes I) with 3400 calBC launch into this period without any interruption. According to the pottery and other materials, it seems probable that a transition occurred between the end of the Chalcolithic and beginning of Kura-Araxes culture (*Marro 2009*). We think this is what occurred in most parts of NW Iran. Only some parts of the southern end of Lake Urmia (Little Zab River) saw a different scenario, with new materials from the middle or late Uruk periods.

Fig. 10. Typical Late Chalcolithic (Pisdeli Type) pottery from Dava Göz.

However, the Zagros highland region (including the Urmia basin) was clearly not a monolithic 'Ubaid-related' culture area throughout most of the 5th and the beginning of 4th millennium BC, but rather an environmentally and culturally diverse mosaic with its own strong local ceramic and, presumably, cultural tradition (*Henrickson 1983.379*).

Conclusion

Although we are now in a much better position than before to discuss the Chalcolithic period of NW Iran and its subsequent developments, there is still much to be learned about the development and meanings of the material culture and the processes of change and distribution patterns during the 5th millennium calBC.

The available data, new ^{14}C radiocarbon dates from recent excavations in NW Iran, provide a welcome opportunity to rethink 5th and 4th millennium calBC chronology. From what is currently available, we suggest that the Dalma period lasted some 500 years, and dates to between *c.* 5000–4500 calBC. During the mid-5th millennium or slightly later (post-Ubaid: 4500–4200 calBC) black-on-buff, so-called Pisdeli culture (LC1 = Kul Tepe Jolfa VII, Dava Göz II) was gradually replaced throughout the southern, western and northern regions of the Lake Urmia Basin. Late 5th millennium chaff-tempered or chaff-faced ware appears alongside Ubaid-related black-on-buff during LC 2–3 (Kul Tepe VIB and VIA, Dava Göz III: 4200–3800 calBC) in NW Iran.

To sum up, the emerging picture suggests that the CFW system, whose focus was the highlands, was progressively challenged during the 4th millennium in the north as in the south, by the Kura-Araxes and Uruk expansions, respectively. After a period of co-existence with both, the CFW culture was superseded in the highlands by the Kura-Araxes phenomenon, whose driving forces probably had some decisive advantage over its regional neighbours: judging by the importance of metallurgy and mining activities in the Kura-Araxes world, this advantage could have been technological.

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Some remarks on the cognitive impact of metallurgical development in promoting numerical and metrological abstraction in Europe

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ABSTRACT – *If we accept the thesis that advanced metrological systems existed in Bronze Age societies, described and analysed as weight standards by many authors, we should also consider its simple consequence; these weight standards were the successors of earlier and rather simpler systems of value that developed within Eneolithic societies. Dealing with the issue of early metallurgy in Europe, some authors have traced patterns and proliferation cycles of copper for this period that allow us to see that the introduction of metal to the main regions in Europe was the subject of growth, spread, and changing social perspectives rather than a crisis in metal production and hiatus. This is the point, I think, at which we can embed one source of Bronze Age weight standards on the one hand, and earlier simpler methods of measuring copper, on the other.*

IZVLEČEK – *Če pristanemo na trditev, da so v bronasti dobi že obstajali napredni merski sistemi, ki so jih mnogi avtorji opisali in analizirali skozi standardizirane utežne mere, potem moramo pristati tudi na izpeljavo trditve: ti utežni sistemi so se razvili iz preprostejših merskih sistemov, ki so nastali v eneolitskih skupnostih. Mnogi avtorji so ob preučevanju zgodnje metalurgije v Evropi prepoznali vzorce razvoja rabe bakra, ki kažejo, da je bila uvedba kovin v Evropi bolj kot krizi in prekinitvi proizvodnje podvržena rasti, razširjanju in družbenim spremembam. To je tudi točka, kjer lahko po mojem mnenju povežemo izvor bronastodobnih utežnih standardov na eni strani in zgodnjih preprostih metod tehtanja bakra na drugi strani.*

KEY WORDS – *Eneolithic measure concepts; copper; Bronze Age weight standards; linear measures; cognitive development; Central Europe*

The beginnings of metal production

Conceptualisations of the development of early metallurgy in Europe have been strongly influenced by processual and Marxist-oriented ideas intended to expose technology and society in mutual relations. This approach can be traced back to the work of Vere G. Childe (*1944*), who at the time was influenced by Marxism (*Trigger 1989.254– 263*), and Theodore A. Wertime (*1964*). Christian Strahm (*1994.5–7*) sketched some significant points of this process. In the 6th millennium BC there is slight evidence of copper processing in south-eastern Europe, limited mainly to small cold-forged copper ornaments which had no significant impact on the economy or society. This phase he described as preliminary. Already at the beginning of the 5th millennium BC, intense development of copper production in the Kodžadermen-Gumelnitsa-Karanovo VI cultural complex occurs, whereby massive copper implements such as adzes, axes and chisels become a conspicuous element of local culture (*Todorova 1981*). In the Vinča culture, however, copper ores might have been utilised from the earliest phases in the last centuries of the 6th millennium BC (*Borić 2009.238*). Macroscopic, microstructural and compositional analyses have revealed a

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particular preference for black and green copper minerals by prehistoric communities inhabiting Balkan settlements between 6200 and 4400 BC (*Radivojević 2015.333*). But still the most prominent example of this development is provided by the Varna culture cemeteries in Bulgaria (*Lichardus 1991; Ivanov 1991; Lichter 2001*).

Technologically speaking, copper production at the time was still in the experimental stage (*cf. Klassen 2001.235*). It is important to note that early techniques of copper processing are in almost every respect identical to lithic and flint processing technologies. Budziszewski performed a comparison of the two technological paths. He wrote that both metallurgy as well as macrolithic technology from good quality sources were practiced on a similar socio-economic basis. The person who received a copper product did not have to know how it was made, as his role was only to participate in the exchange. A similar process occurred with macrolithic blades and axes. On the one hand, there was specialised production in separate settlements that generated prestigious flint goods, and on the other home production based on local traditions and resources, which focused mainly on makeshift production and altering tools by means of primitive techniques. This was clearly separated from specialist activity, which always had a cross-regional, and often cross-cultural, distribution (*Budziszewski 2006.275*). Casting techniques were used to produce tools and ornaments only rarely, with plastic working (forging, bending, cutting) playing the main role (*Sherratt 1997*). New techniques lending copper processing the true character of metallurgy appear only in later stages. We can thus say that the detachment of the new technology from the older Neolithic production traditions and contexts was a gradual process, and that this technology progressed to becoming a new cultural, social and economic quality only after the passage of a certain time.

The new technology eventually spread to other parts of Europe. It reached the Black Sea steppes; an important metallurgical centre developed in Hungary (Carpathian Basin), initially linked to the Tiszapolgar culture and later to the Bodrogkeresztur culture. This centre turned out the same forms and employed the same production techniques as the Balkan centres (*Mohen 1990; Lichardus 1991; 1991a; Strahm 1994; Sherratt 1997*). Others emerged almost simultaneously with the one in the Carpathian Basin: in the Balaton culture in Transdanubia and further to the west. Intensive copper production is in evidence in the eastern Alpine regions at the beginning of 4th millenium BC or even earlier where the local cultures used a characteristic copper and arsenic alloy displaying metallurgic properties superior to that of pure copper (*Barteilheim* et al. *2002; Höppner* et al. *2005*). A typical representative of this tradition is the Mondsee culture, which produced massive quantities of copper artefacts in a variety of forms and left behind copious traces of production that indicate beyond any doubt that copper was intensively processed by these people (*Ottaway 1982*). The mutual contacts between these centres were continuous and probably lasted several centuries (*Ottaway 1981*).

After a period of intensive development of metallurgy in the Carpathian-Balkan centres, some break in metal production is observed, which is interpreted by Strahm as a collapse in copper production due to the exhaustion of easily accessible ore deposits and to problems in switching to sulphide ores (*Strahm 1994*). Versions of this interpretation have been also formulated by Sherratt and Shennan (*Sherratt 1993; Shennan 1993*), who describe the character of early metallurgy as 'boom and bust', which caused cycles of production, exchange and the search for new and more advanced techniques of mining and smelting in the 'bust' phase. However, no such hiatus in metallurgical production is observed in central Germany in the period from 3500 to 2700 BC (*Müller 2001*). This region abounds in rich easily accessible deposits of copper and tin ores, and researchers agree that the communities inhabiting the area continued to develop traditional technologies originally developed more than a thousand years earlier (*Bartelheim, Niederschlag 1998*). Müller (*2001.Fig. 254*) sees also cycles in copper production, but he highlights the steadily growing presence of copper artefacts in central Germany as evidence of this, noting the two-fold increase in their numbers at the turn of the 4th and 3rd millennia BC. This author also believes that a fully developed copper technology already existed at the time, raising socio-economic complexity to new levels (*Müller 2001.414–416*). The communities inhabiting central Germany in those days had long been exposed to intensive exchanges of ideas, establishing close and long-lasting cultural relationships discernible in archaeological materials in culturally mixed assemblages such as those from Walternienburg, Bernburg and Schönfeld (*Müller 2001*).

Anticipating what follows below, it is important to add that central Germany gradually evidenced development of Bronze Age societies and constituted one of the earliest and strongest centres of bronze production in Europe. In this context, we should also place the finding from Kelsterbach (near Frankfurt), where a corded ware amphora containing a copper hoard were found. The vessel, besides a large amount of metal artefacts, yielded a collection of copper beads which revealed a clear metrological structure based on a concept of weight (*Behn 1938; Witter 1941; Dzbyński 2008a*). The beads were produced by the very simple technique of pouring small quantities of molten metal into previously drilled holes with sticks inserted in their middle. This earliest appearance of this kind of material in Europe together with clear indications that also corded ware vessels in central Germany were produced according to certain metrological rules (*Dzbyński 2004*) makes a thought-provoking contribution to the problem discussed in this paper.

The existence of a hiatus in other regions has been also questioned by Timothy Taylor (*1999*). He takes a new look, focusing particularly on the nature of the evidence of a hiatus, dealing with the question: how did copper become bronze? Focusing on Lewis Binford's middle-range theory (*1983*) and the concept of site formation processes from Michael B. Shiffer (*1976*), he tries to elaborate a mix of both approaches to propose a new understanding of metal proliferation in Europe. By analysing approximations of copper production in Europe presented by various authors, he concludes that a vast amount of metal is missing from the archaeological record. Stating that answers to this discrepancy will not be found without theorising some mechanisms whereby metal was moved into and out of potentially preserving contexts, he explicitly cites three general phenomena (mechanisms) that should be taken into consideration: (1) legitimate recycling, (2) illegitimate cycling and (3) skeumorphism.

Legitimate cycling refers to when most of the metal was never deposited in the archaeological record, but recycled and reused in a continuous chain reaching deep into later periods. This mechanism is accepted by most scholars. Its weakness, however, is that while it is clear that metal was in circulation, it is not as clear whether this was directional trade or some other form of exchange and reworking.

Illegitimate cycling is just as important, but not widely acknowledged. It covers such behaviour as theft, booty-taking, discovery and appropriation of the hoards of others and grave robbing (*Taylor 1999. 25–28*). Grave robbing is the most recognisable activity in the archaeological record, appearing as an organised mass phenomenon (*Jankuhn 1978*). Taylor cites the example of the early Bronze Age cemetery of Gemeinlebarn, where only 15 of 258 graves had not been robbed in antiquity (*Neugebauer 1991*). Concerning, the Eneolithic period, he notes that the relatively frequent evidence of disarticulated skeletons in Eneolithic cemeteries from the Carpato-Balkan and steppe regions, although direct evidence of theft may seem slight is suggestive.

In the light of illegitimate cycling, it may be suggested that metal artefacts in the Eneolithic were initially seen as symbolically powerful grave goods; they had magical and transformative qualities and they rapidly became a liability (*Taylor 1999*). As metal came to play an ever greater economic role, so greater social control was placed on it, because metal could be more easily accumulated than other objects (*Chapman 2000.128–130*). Depositing metal in graves carried certain risks. Therefore, for Taylor it is clear that theft was seen as desecration by the relatives of the deceased, even if that was not the primary intention of the thieves. "*It is thus entirely consistent that, after an early and enthusiastic inception, metal should suddenly become more elusive in the archaeological record. Not only was it being dug out from cemeteries as the highest quality, pre-smelted, raw material, but communities were taking the decision to remove it themselves, either before burial or between the initial and final funerary rites*" (*Taylor 1999.27*). Finally he proposes viewing the transition from the Eneolithic to the Bronze Age, solely because of grave robbing, as one reason for the development of a characteristic type of grave which can be termed 'a defended burial', of which the first were tumuli in Hungary and in Yamnaya societies on the steppe. Once the burial contexts were made more secure, writes Taylor, metal was again more frequently placed in them. However, Kristian Kristiansen came to a similar conclusion about the Bronze Age (*Kristiansen 1991*).

In summarising the two mechanisms of metal cycling, it can be said that "*whether legitimately cycled above-ground, through curation, inheritance, and prestige exchange, or illegitimately liberated from below-ground funerary contexts and hoards, the lateral cycling of artefacts is probably the principal reason that only 0.01–0.1% of the copper produced in the Eneolithic has been archaeologically recovered*" (*Taylor 1999.28*).

Skeuomorphism has been described in the context of the emulation of metal forms in flint production. From the Bronze Age, highly elaborate flint products in the form of metal knives and even swords are widely known (*Zich 2004*). The same has been suggested for the earlier flint blades and axes from the Eneolithic. Thus Janusz Budziszewski points out that the establishment of macrolithic industries was linked to the development of early metallurgy, as the manufacture and organisation of the distribution of macroliths was the same as that used for copper products (*Budziszewski 2006*, and above in this text). This phenomenon has been recognised in Scandinavia, as well as France, a region where another distinct hiatus has been observed: Carpathian copper reaches Scandinavia early and then vanishes from the archaeological record until the first bronzes appear (*Klassen 2001; Taylor 1999*). The question for Taylor is whether copper was 'swamped out' by the development of local flint exchange economies or simply not archeologically perceived. It is worth noting, however, that skeuomorphism in pottery is one of the most striking features of ceramic production in Europe between 3500 and 3000 BC.

It is hard to imagine that such widespread skeuomorphism means that metal objects were totally absence from those societies. Taylor (*1999*) argues that it is rather evidence of direct metal activity. After his analyses, Taylor (*1999.28*) concludes that "*the relative absence of metal is rather a sign of its developing worth and its growing association with*". This is not to posit a crisis or hiatus as many researchers do. "*Metal use developed within communities in an embedded way, not as a secular, economic add-on …*" writes Taylor (*1999.30*). For him, it was a process of evaluation which can be described as follows: "*Copper was soft; yet, for all that, it changed everything, allowing a multitude of tasks to be accomplished in a different manner; even a soft-edged axe might have its uses. It is the first truly cyclable artefactual product, which could be unmade and remade at will virtually ad infinitum without any necessary loss of basic material value. I believe that it is to be expected that there will be dramatic shifts in the depositional pattern of such a revolutionary material through time, and especially during the period of its inception. Such shifts would be underscored by the fact that the new material was also 'good for thinking'. It was not treated in a dis-embedded, secular manner: the act of making it and the remains of making it were as significant as the product itself. Even slag was treasured*" (*Taylor 1999.29*).

Later metal: the Bronze Age

A confirmation that metal was 'good for thinking' as formulated by Taylor is very clearly visible in the Bronze Age when complex societies with strong economic pressure on metal emerged (*Kristiansen 1987; Sherratt 1993; 1994; Harding 2000; Pare 2000*). Metal was without doubt a central focus of Bronze Age societies. Kristiansen discerns a distinctly hierarchical social system already in the early stages of the Bronze Age, with rival chiefs vying for access to prestige goods in the form of specific bronze objects. In conditions of excessive consumption of prestige goods, the best strategy for retaining one's position is to gain control of important branches of the economy and routes of exchange of exclusive objects produced by specialists. Accordingly, competing chiefs must have employed some forms of force and perhaps also controlled the production of selected commodities (*Kristiansen 1987; Knapp 1999*). From then onwards, an increasing amount of control and administration occurs, with the use of rationalised communicative mechanisms that had already evolved in large measure in the preceding period. What we have at the stage we are considering here is in fact an initial form of the state (*Kristiansen 1991*).

In this kind of social system, we can expect to see an integration of rationalised communicative actions involving the use of advanced measures of value, profit and loss calculations, *etc.*, into power relation structures (*Kristiansen 1987; Primas 1997*). Therefore, an inalienable element of Bronze Age culture became the knowledge not only of how to produce metal in great quantities and numerous forms, but how to measure it within complex systems of exchange that emerged in this period (*Pare 2000*). Researchers seeking weight standards and related phenomena in the European Bronze Age made a valuable contribution by showing that this was a widespread, protracted and crucial process characteristic of rationalisation and the development of civilisation.

Bronze Age weight standards

Majolie Lenerz-de Wilde (*1995; 2002*) performed detailed analyses of numerous bronze finds showing that highly rationalised communicative and exchange systems did exist in the European Bronze Age. She analyzed the weights of ring bars (ger. *Ringbarren*) from Central Europe and suggested that a highly abstract concept of weight/mass of the bronze raw material had to be involved in their making, so that we may speak of the standardisation of weight (Fig. 1). The standardisation of ring bar weights, however, varied over time and from region to region. Moreover, the chronological evolution consists of the emergence of increasingly lighter weight standards. A consequence of this process appears to have been the severe fragmentation of bronze objects, mainly sickles, which thus assumed pre-monetary functions in the Middle and Late Bronze Age (*Sommerfeld 1994; Primas 1986*).

Let us assume that the form of the ring bar was quite new in Central Europe. Similar artefacts were discovered in a hoard in Byblos dated to between 2130 and 2040 BC, prompting some researchers to interpret the oldest ring bars in Europe as evidence of imports from the Levant (*Schäffer 1949*). Eventually it transpired, however, that many of the European ring bars are in fact older that the Levantine ones, which this suggested that any transfers of this form would have to have been in the opposite direction (*Lenerz-de Wilde 1995.300*). It has also been pointed out, however, that very similar objects made from copper were previously present in the Baden culture in Austria (*Ottaway 1982.293*). Despite a hiatus between the early copper form and the later bronze bars, Lenerz-de Wilde admits the possibility that this suggests the continuous presence of a ring ornament form. This hypothesis is additionally supported by the fact that the bronze ring bars first appeared precisely in Austria.

Ring bars, however, are not the only artefact standardised according to weight. Neugebauer (*2002*) describes in detail hoards that feature bronze cauldrons whose weights were 'adapted to fit' the weight of ring bars. The hoards from Ragelsdorf and Unterradlberg thus illustrate the next metrological leap marked by heavy necklaces (ger. *Ösenhalsreifen*) weighing twice as much as the ring bars.

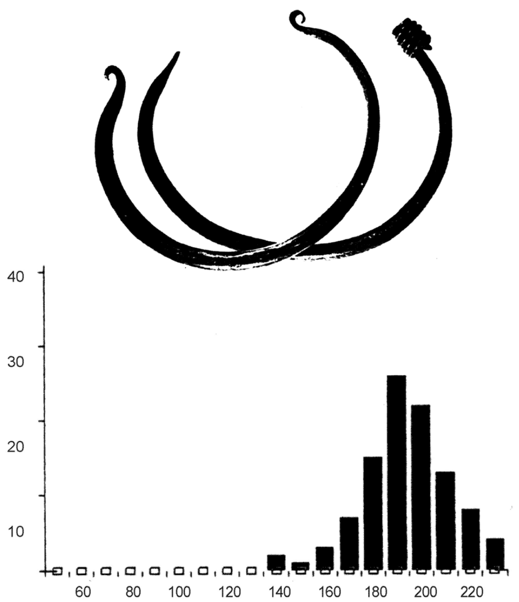

Fig. 1. Weight analysis of ring bars from southern Germany (after* Lenerz-de Wilde 1995*).

In light of the above, many researchers see it as probable that the miniature bars served as money equivalents already in the final stages of the Early Bronze Age. Some hoards from that period provide evidence of their intentional fragmentation. This practice gains great momentum in the Middle Bronze Period, from which we have scores of hoards in which fragmented bronze objects (the vast majority of which are sickles) are a regular feature. However, as Margarita Primas (*1986*) believes, they were not fragmented in order to make pieces of some standard weight. In her opinion, the fragmented sickles recovered from many settlements and hoards were also not the result of accidental occurrences or material prepared for re-melting. She notes that foreign forms recovered at sites far removed far from where they were produced are broken up into small pieces. Primas (*1986.40*) believes that sickles were fragmented intentionally, but with little attention paid to the weights of the individual pieces which circulated as an early form of currency.

This turning point is especially stressed by Christoph Sommerfeld (*1994; 2004*). In the Urnfield period (from *c.* 1200 BC onwards) we observe a radical change in the composition of bronze hoards, with bars and axe-heads being replaced entirely with sickles. Researchers are fairly confident that the fragmentation of these implements was intentional. The fragments remained in circulation for long periods, as suggested by their signs of wear (*Pare 1999.444*). Sommerfeld agrees with Primas that the fragmentation had nothing to do with technological considerations, but completely disagrees as to the interpretation of this practice. While Primas believes that the bronze objects were broken up more or less haphazardly, Sommerfeld is of the opinion that the broken-off fragments were intended to meet a specific weight standard (*Sommerfeld 199.57; 2004; Primas 1986.40*).

Some Middle and Late Bronze Age graves in Central Europe also contained objects interpreted as balance weights that were probably compatible with the Late Bronze Age system in the Aegean (*Pare 1999.491; Petruso 1992*). Aegean balance weights, which were usually lead plates, represented a basic weight unit of 61g. The bigger weight units in this system were the mina (488g) and the talent (29kg), both known in antiquity. The 61g unit is thus one-eighth of the mina. Most of the balance weights recovered from graves dating to the Middle and Late Bronze Age were probably derived from the Aegean system or, rather, were compatible with. The best evidence of this compatibility comes from the weights from Gondelsheim (*Pare 1999.436*).

Most balance weights from Central Europe are dated to the Late Bronze Age, while those analysed by Petruso are some 200 years older (*Petruso 1992*). However, there is no straightforward link between the European weights and their Aegean predecessors, if only because of the typological differences between the two. The most popular Aegean balance weights were flat, circular discs made from lead or stone, whereas their Central European equivalents are made from bronze and usually in the form of rectangular bars (*Petruso 1999; Rahmstorf 2010*). Pare concludes from this that the shape of the latter is the result of an original development process in Central Europe; parallels are not common in the East Mediterranean (*Pare 1999.492*). This is a significant observation, in that it emphasises the role of the European communication area, in which, as I also tried to demonstrate (*Dzbyński 2008*), specifically directed rationalisation processes were active since the Neolithic.

Pare wonders here about the kind of social context that would require precise measurements with balance weights that were practiced at the time in Europe. He notes that this phenomenon, as well as the existence of complex and diverse metrological systems, were also technological achievements which, in theory, could have found diverse applications in, for example, exchange systems, administration, ancient medicine and metallurgy. Exploring this issue, Pare mentions analyses of social aspects of ancient metrology in Europe and points out that weight measurement implements were rare in graves throughout the ancient world. Equipment of this kind was deposited in graves in only a handful of periods and in a limited territory. It is important to note here that in all periods and in all territories which provided archaeological evidence of such practices, it is likely that this evidence is linked to a special form of economy which we may call the 'Weighed Currency' economy. This kind of economy flourishes most on the peripheries of Iron Age economies with minted coins, in areas lacking strong rulers who could lend credibility to the currency, and where value had to be measured according to individually devised scales (*Pare 1999.511*). The origin of a system of this kind is also obvious to Mats Malmer. The Bronze Age economy in Greece relied on exchange and trade, and trade is difficult without rational measurement solutions such as weight systems. Solutions of this kind are part of the intellectual achievements of societies engaged in intensive communication and exchanges of ideas. Malmer therefore expects to see Bronze Age weight measurement systems in territories as far apart as Greece, Central Europe and Scandinavia. It is quite obvious that the picture painted by Malmer clearly refers to a common cognitive frame of reference which prevailed over almost half of Europe (*Malmer 1999; Peroni 1998*).

What about copper?

The phenomenon of Bronze Age weight standards as described above points to the fact that they obviously present some element of why they were 'good for thinking' in the course of developing the value of metal as suggested by Taylor. But Taylor states that already copper was 'good for thinking' (*Taylor 1999.29*)!

The Bronze Age systems of measures are systems for conceptualising weight. They are highly abstract, as weight is an abstract measure. It is worth considering how the notion of weight could have come about in the first place. Colin Renfrew in his studies says that weight must first have been apprehended through physical experience. "*It could only be experienced and apprehended in the first place by the physical action of holding a heavy object in the hand and perceiving that it was heavy, more so than other similar objects. If you have a symbolic relationship, the stone weight has to relate to some property that exists out there in the real world*". Renfrew (*2004; 2007.120–129*) refers here to the known findings of the Harappa Culture, where stone balance weights were found. In a sense, these stone clubs, he writes, serving, as weights are symbolic of themselves: weight as a symbol of weight.

Similar evidence is found in Europe, at the latest from the Middle Bronze Age onwards, where stone weights and balance weighing are recorded in archaeological studies (*Pare 1999; 2000; Rahmstorf 2010*). They were probably partly adopted from the eastern Mediterranean, but already in the early Bronze Age there is enough evidence of weight standards being used, so that we can follow a certain evolution of complexity of this process (*Lenerz-de Wilde 1995; 2002; Rahmstorf 2010*). We do not know how the earlier weight standards were measured without using balance weights. Lorenz Rahmstorf speculates in this way that many simple weights have probably not yet been identified in Europe (*Rahmstorf 2010.98*); or perhaps they were rather symbols of themselves and not weighed properly in early phases?

To me, the question of how such systems came about in the light of the undeniable assertion that both copper and bronze were 'good for thinking' seems far more important. It is quite important to stress that, in fact, what Taylor proposes it not an isolated voice in publications (*Pernicka* et al. *1997; Shennan 1993; Staaf 1996*). It is important, however, to shed light on the characteristic vocabulary that is used to describe metallurgical development. So Björn M. Staaf (*1996*), for example, in studying copper axes from Central Europe, traced one pattern that appears persistently. The introduction of metal in the main regions of manufacturing copper in Europe was subject to growth and dissemination. In the first stage, it affected the Balkan-Carpathian region and, subsequently, central and west Europe. What Staaf (*1996.152*) basically suggests is that by the end of the Eneolithic period, certain norms of perception and specific activity towards metal were being formed, which he called "*a general common understanding of metallurgy*", something close to the formation of a 'new mind' in the cultural discourse.

The context of weight systems is a good starting point for our considerations, although my aim is to go a bit deeper into prehistory. As Renfrew states, weight systems can be seen to have developed independently in different societies along different trajectories of development. In many cases, they emerged in quite complex societies, sometimes in state societies, and are not usually found earlier in the trajectory of development (*Renfrew 2007.125*). This seems to be the evidence of Europe, where weight systems emerged in complex Bronze Age societies, but not earlier. In her study, Lenerz-de Wilde (*1995*) analysed some copper artefacts from the Eneolithic period primarily axes) coming to the conclusion that they were not perceived through their weight, as was the case of numerous latter bronze objects. This fact gave her the opportunity to reject the hypothesis about their metrological structure. Is weight, we may surely ask, the only way to measure?

Before moving on to the next section, let me recall Renfrew's statement. He concludes that weight has to be perceived as a physical reality in the hands and arms, not only in the brain within the skull, before it can be conceptualised and measured. The mind works through the body. He refers to a theoretical branch of archaeology that is covered by such themes as material engagement, extended mind, incorporated mind *etc.*, rooted in the philosophy of Martin Heidegger and Maurice Merleau-Ponty (*Heidegger 1962; Merleau-Ponty 1945; Malafouris 2013; Lakoff, Johnson 1980*). If this is true, can we define other measures that are perceived even in a more embodied fashion?

Other ways to measure

Actually, we do not have any single reason to claim that metal was perceived and measured from the very beginning only by weight. Although weight is the best way to measure metal, there can be other ways to perceive it – for example as a linear measure. Remember that a linear measure is also conceptualised in the way described by Renfrew: as a physical entity experienced by people. However, it can be not symbolic of themselves what makes them less abstract. A linear measure should refer to other things, for which the best option is reference to human body (*Lakoff, Núñez 2000*). Moreover, a linear measure has the advantage over weight that it can be used in the more primitive circumstances that are supposed for early copper processing phases (*Strahm 1994*). Last, but not least, a linear measure is also 'good for thinking', as it is rational enough, although less abstract than weight. Let us take a look at some indications of this method of measuring metal in the Eneolithic.

Let us begin with Baden materials, where we find the copper rings mentioned by Lenerz-de Wilde as being a model of later bronze bars that served as weight standards. Lenerz-de Wilde emphasises the typological resemblance of these two ring forms. Earlier examples from the Baden culture are made of copper wire and are very simple in form. There is a hiatus of hundreds of years between them and the later bronze rings, which was probably also, why Lenerz-de Wilde did not analyse them in terms of weight. In my opinion, it would have been unjustified as it would regard any copper artefact from the Eneolithic period, because they were not yet conceived in this way. Let us look at some examples.

Some Baden copper rings (Fig. 2A) were placed in graves in the following manner: as a complete ring and a half (*Menke 1982; Sachße 2010.Taf. 86*). Unfortunately, graves with copper rings in the Baden culture are rare, but there are other examples. Similar artefacts and finds are known from the Alps, where they are called Ösenhalsband. A juxtaposition of some exemplars from different places shows that they can be reduced to a segment or to a length which was divided into a half and a quarter (*Löffler 2010.Taf. 23*). They date to the end of the 4th millennium and belong together with the Baden copper rings of the same period (Fig. 2B).

Copper beads from the Cortaillod culture which were manufactured according to the same method as the above-mentioned artefacts are dated slightly earlier (Fig. 2C). Several sites in Switzerland and Alsace that yielded this type of bead, although the best known are Seeberg, Burgaschisse-Sud, Colmar, and Gerolfingen (*Sangmeister, Strahm 1974; Ottaway, Strahm 1975; Ottaway 1982; Löffler 2010; Lefranc* et al. *2012*) The beads were made from a copper rod which was divided into specific fragments (*Ottaway, Strahm 1975*). The rod has undergone plastic forming, resulting in the final small bars, which then were knotted to form a bead. Some fragments of the rod

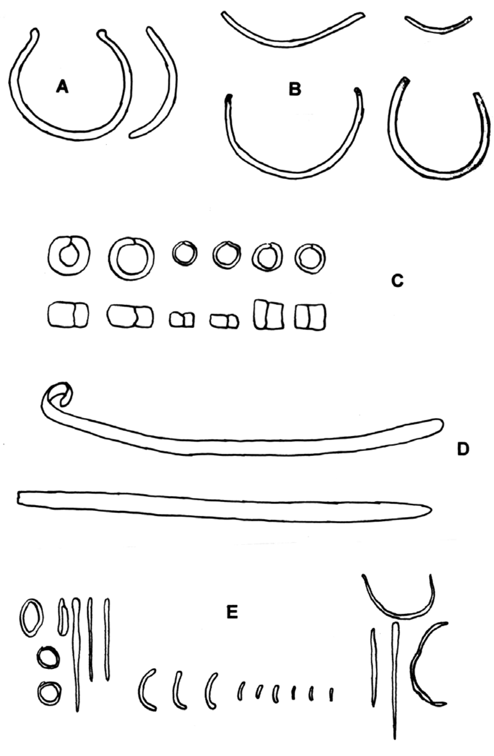

Fig. 2. Examples of artefacts that could be perceived according to a linear measure in the Eneolithic period (after various authors): 2A – copper rings of the Baden culture; 2B – examples of necklaces from the Alpine region dated to the end of 4th millennium; 2C – copper beads of Cortaillod culture; 2D – examples of the sheet and wire industries of the later Eneolithic in the Alps; 2E – objects made from copper wire of the Epi-Corded Ware communities.

had to be subsequently stretched to twice or four times their original length to produce an appropriate amount and value of beads. In other words, the production of such items was an example of the appropriate manipulation of a metal rod and application of simple rules of mathematical proportion (*Dzbyński 2013*).

The best known example of these beads comes from Seeberg, Burgäschisee-Süd (*Sangmeister, Strahm 1974*). They emphasise two important observations concerning these objects. Firstly, the specific number of beads on both strings reflected a simple mathematical proportion. Secondly, they clearly differ in weight in such a way that there are twice as many lighter than heavier beads, which can be viewed as a form of separation of the beads' values on the strings. We should not be disturbed by the fact that it is their weight that was studied and analysed. The weight of the beads has been used only to clearly indicate that a mathematical calculation lies behind their production (*Dzbyński 2014*). Obviously, they were reworked by their maker and folded in order to be ready for transport, so that a *chaîne opératoire* applied in their making is no more clearly visible. This issue has already been alluded to above. In a later study, it was proposed that the beads be treated as special purpose currency, as they actually present an early form of copper ingots (*Ottaway, Strahm 1975*).

Clear evidence as to how these beads/ingots were perceived has come from Colmar (Alsace), during rescue excavation research, where an Eneolithic burial with the type of copper beads with a characteristic feature of Cortaillod society was found (*Lefranc* et al. *2012*). Three necklaces were placed around the skeleton of an adult man placed in an atypical prone position. One necklace with 25 beads was found near the feet of the deceased. A second consisting only of light pieces was found at his waist. The third group, of four medium heavy beads, was discovered under the skeleton (Fig. 3). This localisation of the three groups suggests that the beads were on strings similar to those from Seeberg and attached to the deceased in some way or simply placed around him. They were not attached at random however; each size category was intentionally placed around the man's body (*Dzbyński 2013*).

Moreover, as Philippe Lefranc, the researcher of the Colmar site, noticed, both necklaces in Seeberg and in Colmar comprise quite similar amounts of metal, which is about 400g (*Lefranc* et al. *2012*). This weight is quite typical, more or less of course, for an average, non-broken copper axe from this period in the Alpine region (*Lefranc* et al. *2012.713*). Taking the notion as well as the fact that copper axes are the most popular copper artefact within European Eneolithic/Copper Age, we are confronted with a situation where a copper axe could have been 'counted' quite precisely, although it could not yet have been weighed. In other words: this possible 'counting procedure' was still based on a linear measure, not on the concept of weight.

There are not only beads, however, that should be taken into consideration in future research to make the claim presented more credible or to re-examine them. One characteristic feature of the sheet and wire industries of the later Copper Age are artefacts that actually fit very well to the thesis presented. They were deliberately made to be extended, long and thin (*Endrizzi, Marzanico 1997*; Fig. 2D). Last, but not least, there is much to suggest that on the peripheries of the Bronze Age world, similar mechanisms of measure that could survive longer as objects made from copper sheet and wire continued to be used by Epi-Corded Ware communities (*Machnik 1984; Baczyńska 1994*). We could make here formal comparisons with the earlier mentioned artefacts (Fig. 2D). Actually, many artefacts of the sheet-and-wire industry formally resemble the Cortaillod culture beads in their differentiation.

The beads from Seeberg and Colmar as well as other objects described in this paragraph seem to present an early stage of measuring and counting of metal, so that we can say that we are dealing with tangible evidence of an ongoing discourse on the value of metal in the Eneolithic society. One could admit that this stage was very strange. Metal was not yet weighed, but measured according to a linear measure, according to the measuring stick idea (*Lakoff, Núñez 2000*). Dividing a rod of metal into a particular number of small bars by means of linear proportions was the only method of producing the given categories of beads, since the weighing of metal is not evidenced until the Bronze Age (*Lenerz-de Wilde 1995; Pare 1999. 477; Rahmstorf 2010*); and not only this: the beads also shed light on macrolithic flint industries that are viewed as examples of skeuomorphism by some researchers because copper and flint were conceptualised on the same socio-technical level (*Taylor 1999; Budziszewski 2006; Dzbyński 2008; 2011*). This kind of processing is partly rooted in the Stone Age, not the Metal Age, which agrees with conclusions of other researchers (*Strahm 1994; Krause 2000. 225–241*). Manipulations of certain copper objects before the introduction of weight standards as well as on the peripheries of the civilised world could have been performed on the same cognitive plane for a long time.

Summary

To make the thesis presented in this article more clear we should ask: how is it possible that advanced systems of valuing metal through weight appeared so suddenly at the beginning of the Bronze Age

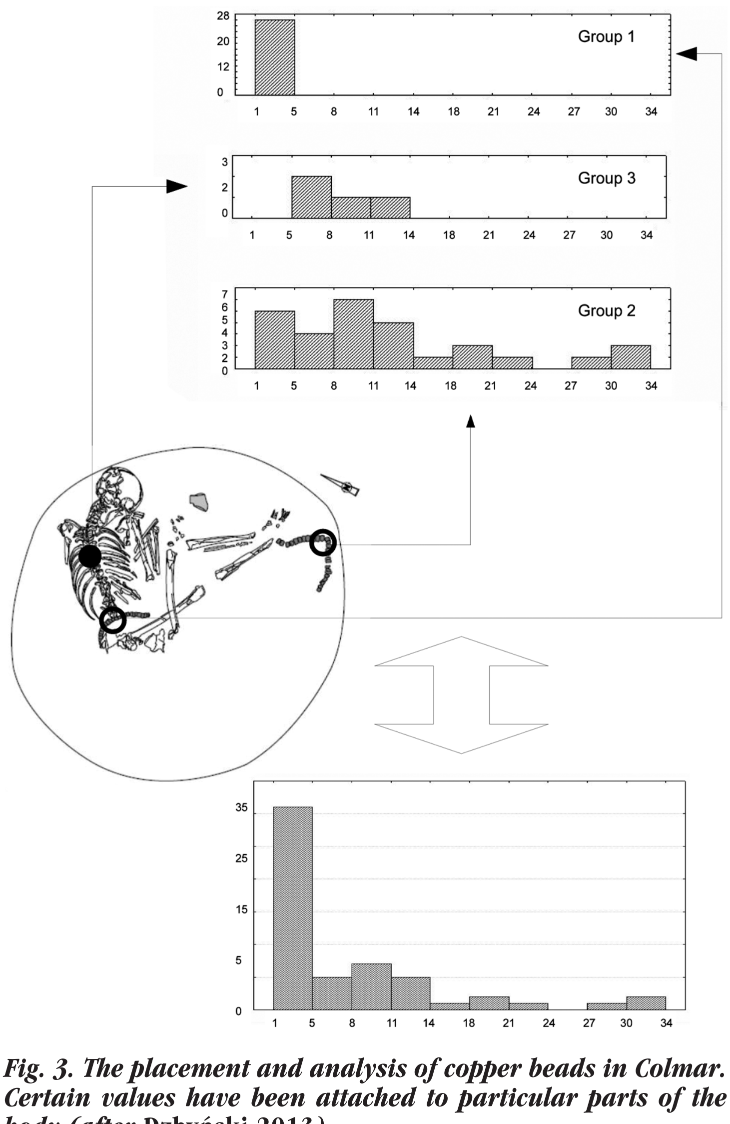

Fig. 3. The placement and analysis of copper beads in Colmar. Certain values have been attached to particular parts of the body (after* Dzbyński 2013*).

period without evidence of external influences? In the case of diffusion, we would expect similar forms of relevant artefacts, but there are no such examples; the opposite is the case. The relevant artefacts (weights and balance weights) differ in form from their adjacent counterparts, but conform in substance (*Petruso 1992; Pare 1999; Rahmstorf 2010*). Let me make this question more vivid and imagine that we are art historians who have just discovered the sculptures of Polykleitos and are delighted with the human figure, a dynamic counterbalance between the relaxed and flexed body parts and between the directions in which the parts move. After making this conclusion, we decide to end our research, saying that it was the pure ingenuity of human mind that created these sculptures out of nothing at the very beginning of art history. We know today that it would be nonsense to say such things.

Let me turn back to the problem highlighted by Taylor in seeking to fill the hiatus in metallurgical production in Europe by different cycling mechanisms. His efforts are supported by Staaf, who also suggested that by the end of the Eneolithic, some new norms for perceiving metal appeared, which he called 'a general common understanding of metallurgy', something close to forming a 'new mind' in the cultural discourse. So we can finally ask: what is this 'general understanding of metallurgy', this 'new mind' as formulated by Staaf? And, finally, what does it mean that metal was 'good for thinking' in the context of its developing value, as Taylor states? Were stone artefacts not good enough for thinking? In order to answer this question clearly, I will add only one word to refine this statement: the metal was good for thinking in measures. It was good for thinking in measures and numbers because metal actually must be perceived only this way if it has to be used more rationally within growing social complexity (in exchange, in tool production *etc.*). At the beginning, however as several materials from the Eneolithic suggest, metal could have been perceived with a less abstract linear measure, not by weight, and conceptualised in a more concrete manner.

Therefore, in the core of a general common understanding of metallurgy, of this new mind, there were the first European measures, early metrological systems, rational systems of value, no matter precisely what we call them now. We have to assume, however, that these metrological systems of the Eneolithic could have been very different from the later complex and abstract weight systems of the Bronze Age. Nevertheless, having to deal with the latter logically requires an assumption that there were concepts of number in use earlier than in the Bronze Age, and above all that a numerical scale was in use which gave the right perspective to measuring. The scale, which is in fact linear, as we should expect, comes from the Eneolithic or even earlier. In my opinion, this goes much further. It was a cultural and cognitive achievement of those societies that manufactured both silex and metal tools within the growing social complexity of the period (*Dzbyński 2013*). The cycling mechanisms proposed by different authors can only support the emergence of early concepts of measure, as there was a strong tendency to deal more efficiently and economically with desired material in exchange. Additionally, skeuomorphism created a continuous connection between flint artefacts and metal, as they were permanently compared according to their value. As I have written elsewhere, flint artefacts, mainly macroliths and axes, were a sort of alter ego of metal at a time when metal was preparing society for its complete acceptance, with which many economic, ideological, cognitive and other consequences were connected, and at a time when both technologies were continued as part of the same complex of words, metaphors and concepts (*Dzbyński 2011; 2013*; Fig. 4). Therefore, measurement became the basic landmark element in the communication process, which corresponded on the plane of the metaphorical network, along with such features as specialised production centres, copper, precious resource extraction from the ground, value, prestige, *etc.*

I suggest that Bronze Age societies were cognitively prepared to adopt abstract weight measures because earlier societies also used counting and measuring, although without abstract numbers and with limited arithmetic, as shown by the example of Near Eastern recording systems and ethnological research (*Barrow 1999; Schmandt-Besserat 1992; Ifrah 1985; Saxe 1982*). Before the development of the abstract concept of weight, which is the most adequate description of metal value in complex social relations, and which did not fully occur until the Bronze Age, more specific assessment mechanisms were in use which we see as markers of the fragmentation of copper objects, as well as the forming of copper into bars or ingots according to a linear measure, as in the case of Cortaillod beads, copper rings, copper wire *etc.* However, we would have great difficulty in establishing those units of measurement. We should rather assume that they had not yet been detached from the concrete, which several virtually different measures discovered in Europe seem to suggest (*Thom 1967; Rasch 1987; Nikolov 1991; Rotländer 1999; Karlovsky, Pavuk 2002*). Their dissimilarities probably result from the fact that they were anthropogenic measures taken on the spot. They had a strong connection with the body, perhaps with many bodies or with different body parts which were a reference for different areas of myth and ritual (*Dzbyński 2013*). Another possibility is that some artefacts were perceived as a reference unit of themselves, which is suggested in the correspondence between Cortaillod beads and the copper axe. This assumption is very interesting in the context of Strahm's (*1994.19*) studies, where he noticed that within the individual workshops there may have been a need to produce uniform axes, pointing to the handful of recorded wooden axe models in the Alps.

Fig. 4. The macrolithic blade was both a requisite of prestige as well as a mental image of the metal bar (after* Dzbyński 2013*).

The examples and interpretations mentioned above make us aware that the process of reaching some truths, which are obvious from our perspective, took place in a time and space of which we still know little. We may surely assume, however, that mathematics did not appear spontaneously in the heads of our ancestors and was not introduced to them from the outside, but was a long-lasting process, which continues to this day. At this point, we have discussed only a part of this process, the very early part. The evidence presented confirms the generally accepted hypothesis that the process of forming mathematical ideas went from the concrete to the abstract. As to Europe, this was also a process of transforming a linear measure, a measuring stick, into an abstract number which belonged to a new vocabulary, describing the metal's weight (*Dzbyński 2013*). According to Renfrew (*2004*), weight is a material-symbolic fact. It does not develop as an embodiment or materialisation of earlier mental concepts, but through the development of the concept-construct itself in connection to experience of the material world. This process took place on a human communication level in interaction with material culture development in prehistory.

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New Neolithic cult centres and domestic settlements in the light of Urfa Region Surveys

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ABSTRACT – *The present study concerns Neolithic period cult centres and settlements discovered recently during surface surveys in the central district of Urfa (Şanlıurfa) region in south-eastern Turkey. The presence of T-shaped pillars was ascertained at Ayanlar Höyük and Kurt Tepesi cult sites. Other settlements are domestic settlements arranged around cult centre settlements. Some sites belong to Pre Pottery Neolithic, and the others to Pottery Neolithic. They are believed to be coeval with Göbekli Tepe and Nevali Çori cult sites.*

IZVLEČEK – *V študiji predstavljamo neolitska naselja in kultna središča, ki so bila nedavno odkrita med terenskimi pregledi v osrednjem delu regije Urfa (Sanlıurfa) v jugovzhodni Turčiji. Tako imenovani T stebri so bili dokumentirani v kultnih središčih Ayanlar Höyük and Kurt Tepesi. Okoli središč so bila odkrita običajna naselja, nekatera datirana v pred-keramični, druga v keramični neolitik. Sočasna so s kultnima središčema Göbekli Tepe in Nevali Çori.*

KEY WORDS – *Şanlıurfa; Pottery and Pre-Pottery Neolithic (PPN); cult buildings; round buildings; domestic buildings*

Introduction

The important role played by the South-eastern Anatolia region in the emergence of precursor settlements and cult centres during the Pre-Pottery Neolithic Period is better comprehended every day as new settlements are discovered. The discovery of settlements such as Nevali Çori (*Hauptmann 1993.37–69; 1999.66–86*), Göbekli Tepe (*Beile-Bohn* et al. *1998.5–78; Schmidt 2001.45–54; 2002.8–13; 2007.115–129*), Şanlıurfa-Yeni Mahalle (*Çelik 2000a.4–6; 2007.165–178; 2011a.139–164*), Karahan Tepe (*Çelik 2000b.6–8; 2011b.241–253*), Sefer Tepe (*Çelik 2006a.23–25; Güler* et al. *2012.161–162, 168–169*), Hamzan Tepe (*Çelik 2004.3–5; 2006b.222–224; 2010.257–268*), Taşlı Tepe (*Çelik* et al. *2011.225–236; Güler* et al. *2013.292–293*), İnanlı Tepesi (*Güler* et al. *2013.291–304*), Kocanizam Tepesi (*Güler* et al. *2012.160, 167–168*), Başaran Höyük (*Güler* et al. *2012.158–159, 165–166*) and Herzo Tepe (*Güler* et al. *2012.159–160, 166–167*) as a result of surveys conducted in recent years particularly in the Urfa region constitutes the best evidence for this fact (Map 1).

It is believed that, at such settlements recently discovered in the Urfa region, especially the Neolithic societies adopted a predominantly hunter/gatherer way of life. Today, excavations of this period are being carried out only at Göbekli Tepe, Nevali Çori and Şanlıurfa-Yeni Mahalle. Other settlements in the region with identical characteristics, such as Hamzan Tepe, Karahan Tepe, Sefer Tepe and Taşlı Tepe, have not been excavated yet. The common feature of such settlements is the presence of T-shaped pillars, like at Göbekli Tepe and Nevali Çori. Finds that are either similar or the successors to such pillars were also unearthed in the Adıyaman (*Hauptmann 2000.5–9; 2012.13–22*) and Gaziantep (*Bulgan, Çelik 2011.85–90; Çelik 2005.28–29*) regions located on the western banks of the Euphrates, proving that the phenomenon was even more widespread than previously thought.

Nineteen Neolithic sites were examined as a result of the studies conducted in the Urfa region, at Kurt Tepesi, Guhera Abid Mevkii, Selamet Kuzey Mevkii, Se-

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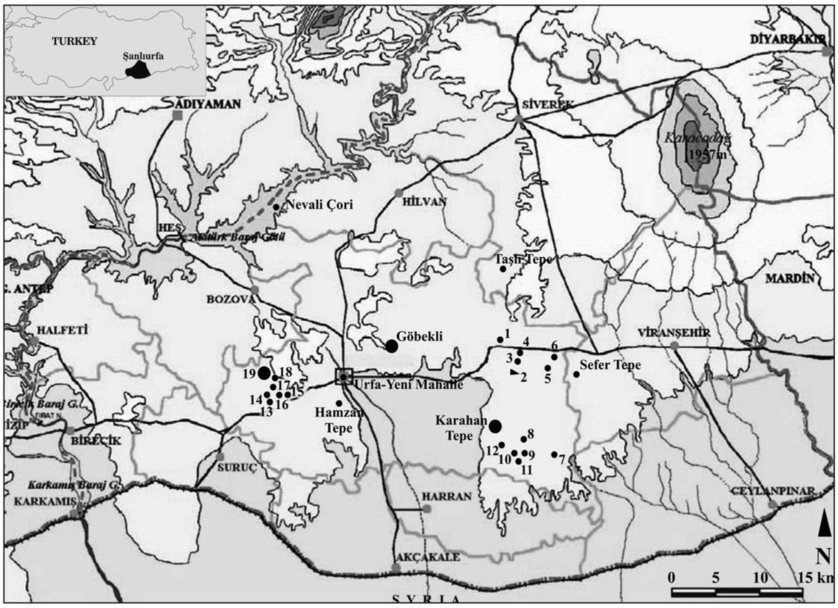


Map 1. Map illustrating the Neolithic sites in Urfa province.

lamet Kuzey Höyüğü, Çamçak Tepesi, Terzi Village Batı Mevkii, Sıluba Tepesi, Aşağı Yazıcı Güney Mevkii, Mınzilit Feriş, Mınzilit Hıleyil, Mınzilit İsa, Karakuş Kuzeybatı Mevkii, Çillo Mevkii 1, Çillo Mevkii 2, Domuzcurnu Tepesi, Nebi Tarlası, Ömer Altundağ Tarlası, Hasan Sırtı and Ayanlar Höyük, respectively. Among these sites, T-shaped pillars were discovered at Kurt Tepesi. At Ayanlar Höyük, on the other hand, a pedestal piece of what are thought to be T-shaped pillars and a lion head used for cult purposes have been unearthed. Based on these finds, Ayanlar Höyük is also thought to be a cult centre. Flintstone tools and ceramics with characteristics of the Neolithic have been found at other sites. Selamet Guhera Abid Mevkii is one of the interesting sites discovered, and is thought to be a large snare area designed for catching animals during this period.

Kurt Tepesi

The mound, known locally as Kuça Gur, is located 45km east of Şanlıurfa province and 3km south of Sumaklı village (Map 1.1) at 730m above sea level (a.s.l.). It is located on a hill dominating Çoban Deresi Boğazı (Çoban Creek Pass), which functions as a passageway between the Harran plain and the Viranşehir region (Fig. 1). It is a small mound established on a ridge formed by high calcareous plateaus, which is very poor in terms of soil. Several sacked tumuli from the Roman period were located around this mound, covering an area of approx. 1ha. The mound is distorted due to illegal excavations; moreover, a high voltage transmission line pole is located at the north end Small cavern groups and pools carved into the bedrock were found in the calcareous rocks surrounding the mound (Fig. 2). Negative traces of a T-shaped pillar are apparent at an illegal excavation pit in this area, which is thought to date to the Pre-Pottery Neolithic (Fig. 3). During the investigation conducted in the region, pillars which had been removed from their original site were discovered at Kösecik village, approx. 6km southeast of Kurt Tepesi (Fig. 4)[1]. Only flint and very scarce obsidian finds were unearthed at the settlement; the finds include scrapers and drills and flint arrowhead fragments (Pl. 1.a–h). Moreover, stone beads, and pestle parts made from basalt stone were also discovered.

Guhera Abid Mevkii

This site is located 48km east of Şanlıurfa and 500m northwest of Selamet village (Map 1.2) at 700m a.s.l. Two large trap sites for hunting wild game were discovered here (Bar-Oz on-line), laid out on the eastern slope of a hill and extending to form a triangle starting from the hill towards the valley plain (Fig. 5). The trap site has walls made from large flagstones, which are irregular and form a triangle with angles of approximately 50°. There are no wall remnants at the short edge of this triangle extending down from the hill. A wall remnant in the form of a circle of approx. 5m in diameter is present at the end of both converging long edges. Flint blades and flakes were discovered during the research in this area. Guhera Abid locality, where the traps are located, is approx. 3.5km southeast of the Kurt Tepesi settlement.

Selamet Kuzey Mevkii

This site is located 48km east of Şanlıurfa and 1 m north of Selamet village (Map 1.3). The settlement is on south-facing slope (Fig. 6) at 645m a.s.l., and covers approx. 0.5ha. Four tumuli were destroyed due to illegal excavations. Flint blades, flakes, and

1 The pillars were brought from Kuça Gura settlement by Hüseyin and Sinan Eyyüboğlu, who live in Kösecik village. (Private interview with İbrahim Eyyüboğlu, 20.10.2013.) The pillars are now in the Şanlıurfa Museum.

Byblos and Nemrik type arrowheads were discovered during research in this area (Pl. 1.i–l).

Selamet Kuzey Höyüğü

The mound, which is very small, extends over only approximately 0.2ha. It is located 1.5km north of Selamet village on a hill (Map 1.4) at 672m a.s.l. A remnant of a circular plan structure unearthed as a result of illegal excavations has been found here present (Fig. 7). Also, flint blades and flakes, as well as Babylos points and scrapers as fragments were discovered as a result of research. A Paleolithic open-air site was found 100m west of the settlement, where research yielded a Levallois core and points.

Çamçak Tepesi

This site is located 1km south of Kuşharabesi village and 61km east of Şanlıurfa (Map 1.5), at 676m a.s.l. The site covers approx. 0.8ha. The settlement is situated on a calcareous hill (Fig. 8). Circular architectural remains were unearthed by illegal excavations (Fig. 9). Blades, flakes, waste products and some point fragments were discovered by researchers. This site is approx. 7km northwest of the Sefer Tepe settlement.

Terzi Batı Mevkii

This site, approx.1ha in area, is on a south-facing slope, approx. 1km west of Terzi village and 63km east of Şanlıurfa at 645m a.s.l. (Map 1.6). Research revealed that the settlement was inhabited during the Early Byzantine period, and the Chalcolithic and Neolithic period. Neolithic flint blades, flakes and point fragment were discovered at the site. This settlement site is approx. 6km northwest of Sefer Tepe.

Sıluba Tepesi

This site is situated approx. 1.4km northeast of Yıldızlı village and 90km southeast of Şanlıurfa, at 522m a.s.l. (Map 1.7). Lying between two hills, the site is covering an area of approx. 2ha. It has an earth embankment approximately 1m high. During research at this site, a sacked tumulus from the Roman period was discovered on the western hill. The surface survey revealed flint flakes, blades and unipolar cores (Pl. 1.m–r).

Aşağı Yazıcı Güney Mevkii

This site, 1.2km southeast of Aşağı Yazıcı village and 82km southeast of Şanlıurfa (Map 1.8), is covering an area of approx. 0.6ha, and is located at 56 m a.s.l. The settlement is on a slightly inclined crater area between two calcareous hills (Fig. 10), surrounded by calcareous hills to the north, east and south, with only the section facing west being open. During the survey of this area, small ponds carved into the calcareous rocks located east of the settlement were found; also, flint blades and flakes, some points and point fragments (Pl. 1.s–x), straw temper ceramics from the Pottery Neolithic period and ceramic fragments from later periods were discovered.

Mınzılıt Feriş

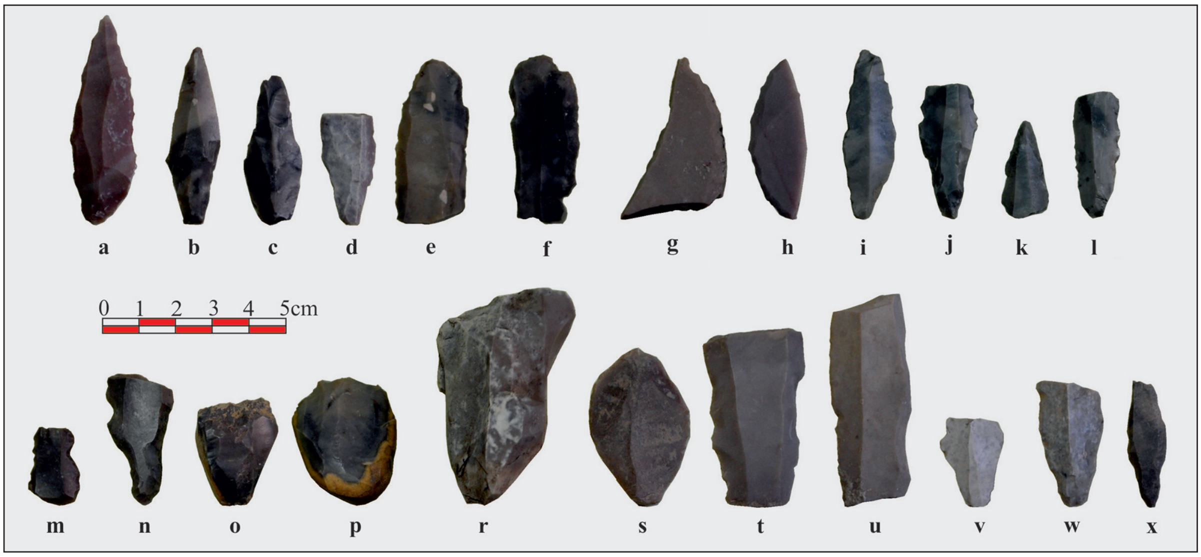
This site is approx. 1.6km west of Altıntepe (Resmeldehab) village, and located 77km southeast of Şanlıurfa, situated at 612m a.s.l. (Map 1.9). The settlement is on a slightly inclined crater area between two calcareous hills and surrounded by calcareous hills to the north, east and west, with only the section facing south being open. The site is approximately 0.1ha in area. The earth embankment of the settlement varies in height between approx. 50cm and 1m. No architectural remains were discovered here, but the survey yielded ceramics from the Neolithic, late Chalcolithic, early Bronze and late Byzantine periods. Flint blades and flakes, some scraper fragments, and a very small amount of obsidian were also found (Pl. 2.a–f).

Mınzılıt Hıleyil

This site is located approx. 1.3km west of Altıntepe village, 77km southeast of Şanlıurfa and at an altitude of 596m a.s.l. (Map 1.10). The site, covering approx. 0.5ha in area, is on a slightly inclined crater area between two calcareous hills (Fig. 11) and surrounded by calcareous hills to the north, east and west, with only the section facing south being open. No architectural remains were discovered at the settlement, as the area is currently in use as a field. The survey conducted here yielded ceramics from the Neolithic, late Chalcolithic, early Bronze, early Byzantine and Islamic periods. Moreover, flint blades, flakes, retouched blades, point fragments and scrapers were found (Pl. 2.g–j).

Mınzılıt İsa

This site is situated approx. 1km west of Altıntepe village and 77km southeast of Şanlıurfa, at 611m a.s.l. (Map 1.11). The settlement is on a slightly inclined crater area between two calcareous hills (Fig. 12), surrounded by calcareous hills to the north, east and west, with the section facing south being open. The site covers an area of approx. 0.2ha. The earth embankment of the settlement varies in height between 1–2m. No architectural remains were discovered here, as the settlement area is currently in use as a field. As a result of the survey of this area, ce-



Pl. 1. Finds from Kurt Tepesi (a–h), Selamet Kuzey Mevkii (i–l), Sıluba Tepesi (m–r) and Aşağı Yazıcı Güney Mevkii (s–x).

ramics from the Neolithic, Chalcolithic and early Byzantium periods were discovered. Moreover, flint blades and flakes made, some point fragments, scrapers, drills and obsidian were discovered as small finds (Pl. 2.k–r).

Karakuş Batı Mevkii

This site is located approx. 3km west of Karakuş village and 70km southeast of Şanlıurfa, at 539m a.s.l. (Map 1.12). Lying on the slope of a stream bed facing south, the settlement covers approx. 1.1ha (Fig. 13). A dry stream bed flowing east to west is located north of the settlement. No architectural remains were discovered here, as the settlement area is currently in use as a field. As a result of the survey in this area, ceramics from early Byzantine periods as well as flint blades, flakes, end scraper fragments were discovered (Pl. 2.s–x).

Çillo Mevkii 1

This site is a hillside settlement located approx. 1km north of Çıralı village and 24km west of Şanlıurfa, at 668m a.s.l. (Map 1.13). The settlement is covering an area of approx. 0.5ha (Fig. 14). No architectural remains were discovered, as the area is currently in use as a field. The survey yielded ceramics from the Early and Mid-Byzantium and Neolithic periods (Pl. 3.g–k) and a flint bifacial tool from the Middle Paleolithic as well as abundant amounts of blades and flakes, unipolar cores and scrapers (Pl. 3.a–f).

Çillo Mevkii 2

This is a hillside settlement located approx. 1.5km north of Çıralı village and 24km west of Şanlıurfa, at approx. 658m a.s.l. (Map 1.14). The settlement is covering an area of approx. 0.5ha (Fig. 15). No architectural remains were discovered, as the settlement area is currently in use as a field. As a result of the survey, ceramics from the Early Byzantine and Neolithic periods (Pl. 3.p–t) were discovered. Flint blades and flakes and scrapers and point fragments were also unearthed (Pl. 3.l–o).

Domuzcurnu Tepesi

This site is located 3.5km southeast of Kızılburç village and 28km west of Şanlıurfa, at 743m a.s.l. (Map 1.15). The settlement is covering an area of approx. 0.5ha (Fig. 16), lies on a low calcareous hill, and is surrounded by basalt deposits. It is a well-preserved site, with traces of some walls visible. As a result of the surveys, flint blades, flakes, unipolar core, core replacement fragments and hammer and some point fragments, scraper fragments, drills and blade with sheen were discovered dating back to the Pre-Pottery Neolithic (Pl. 3.u–z). A very small amount of obsidian blade and flake parts were also found.

Nebi Tarlası

This site is situated 2km southwest of Kızılburç village and 28km west of Şanlıurfa, at approx. 699m a.s.l. (Map 1.16). The settlement is covering an area of approx. 0.8ha. No architectural remains were discovered, as the settlement area is currently in use as a field. The survey yielded straw temper ceramics from the Neolithic and flint blades and flakes and scrapers were also discovered (Pl. 4.a–d). Also the usual amount of obsidian blades and flakes was also discovered.

Ömer Altundağ Tarlası

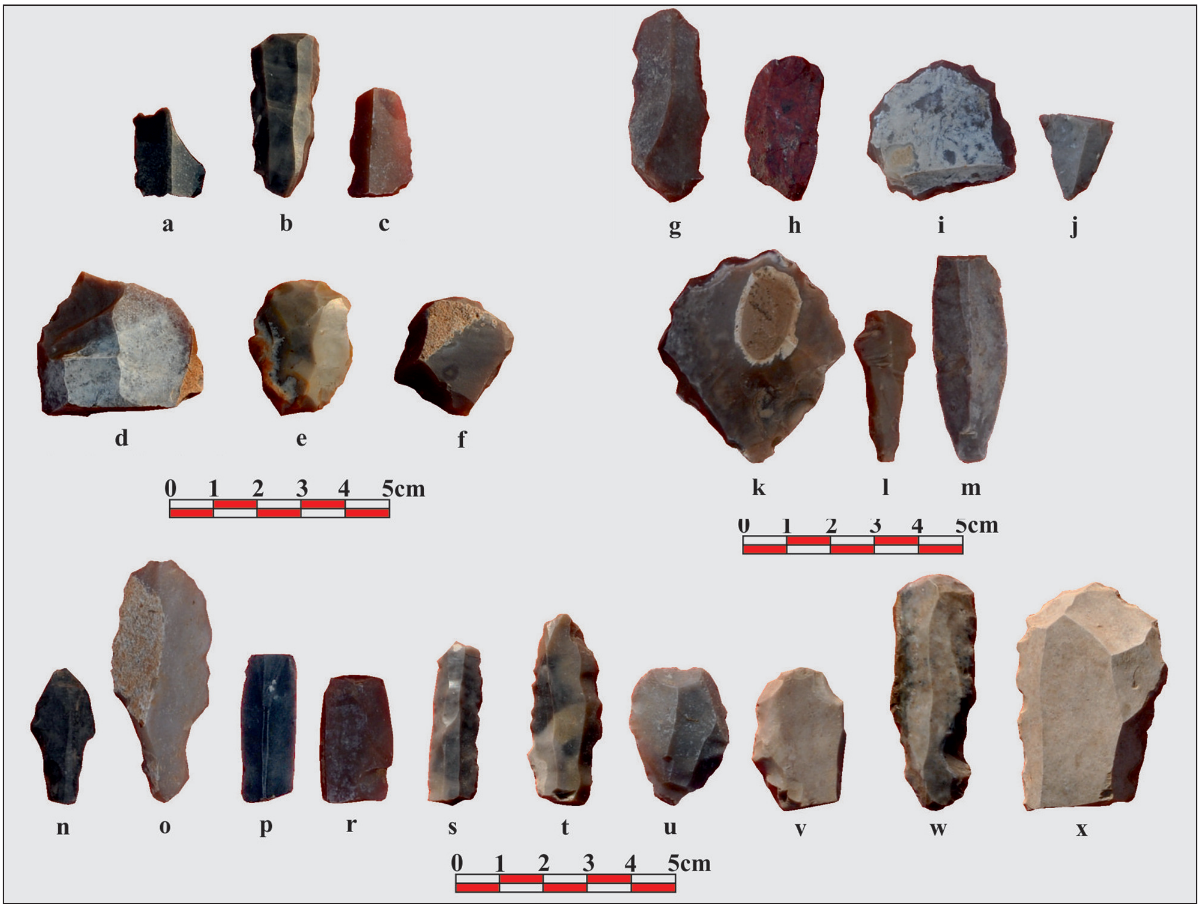
This site is located 1km south of Kızılburç village and 28km west of Şanlıurfa, at 701m a.s.l. (Map 1.17). The settlement is covering an area of approx. 0.1ha, on the slope of a calcareous hill; basalt deposits are available to the east. The settlement has been destroyed by agricultural activity. As a result of surveys, ceramics from the Neolithic and early Byzantium periods, and flint blades and flakes and core replacement fragments were discovered (Pl. 4.e–h).

Hasan Sırtı

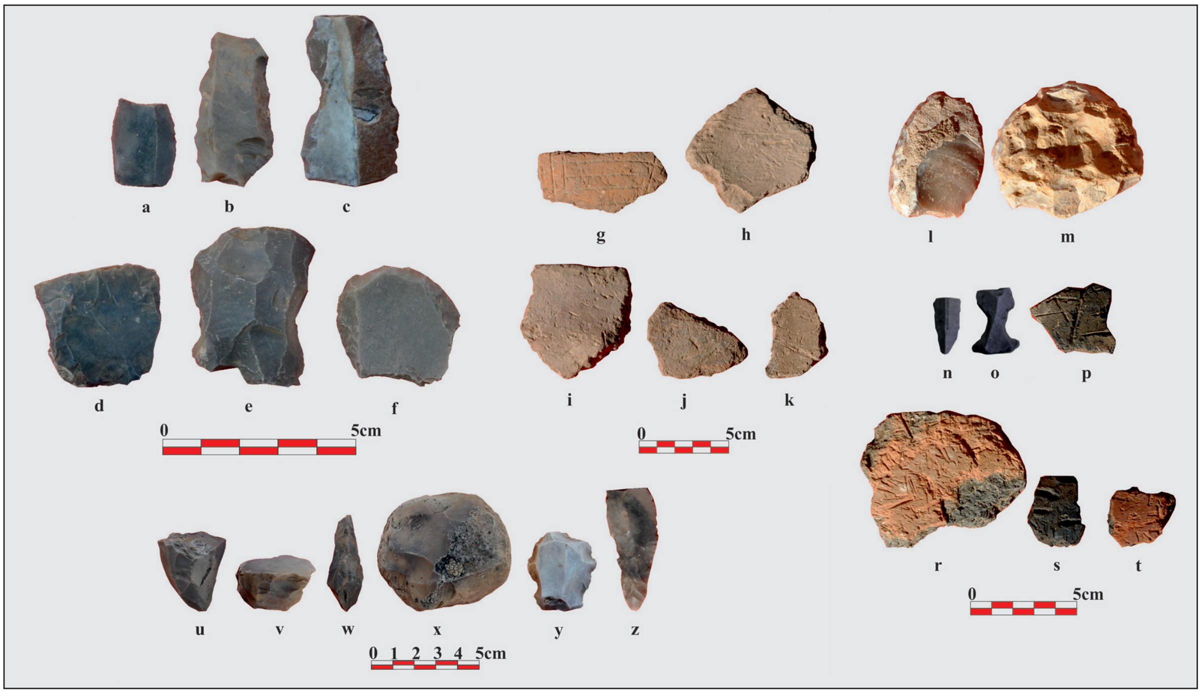
This site is located 1km north of Kızılburç village and 28km west of Şanlıurfa (Map 1.18). The settlement is approx. 0.6ha in area at 752m a.s.l. (Fig. 17). The settlement is on the western slope of a calcareous hill; basalt deposits are available to the east. The settlement was destroyed by agricultural activity. As a result of the surveys, straw temper ceramics from the Neolithic period and Early Byzantine ceramics were discovered. Flint blade and flake fragments and scraper fragments were also discovered (Pl. 4.i–l); a basalt stone upper grinding stone was also found.

Ayanlar Höyük

This site is located underneath and to the north of Ayanlar (Hut) village, 30km west of Şanlıurfa, at 733m a.s.l. (Map 1.19). It is covering an area of approx. 14ha (Fig. 18). The mound, which was destroyed by agricultural activity, is around 10m high. The village settlement is located on the southern section of the mound, which comprises five hills. Basalt deposits are available 2km to the east. The surveys revealed ceramics from the early and mid-Byzantine periods. Flint blades and flakes, unipolar and bipolar cores, core replacement fragments, scraper fragments, point fragments, hammer and rested blade fragments were discovered (Pls. 4.m–v, 5.a–b). Very small amounts of obsidian blade and flake parts were also revealed. Lower and upper basalt grindstones, stone bowl fragments, stone plate and pestles were among the other finds (Pl. 5.c–g). Limestone cubes and pedestal fragments from hollow stone, which we know were made for pillars (Fig. 19) were also discovered during surveys in the village. Also, small pole groups carved into the bedrock (Fig. 20), which are familiar from Göbekli Tepe (*Beile-Bohn 1998. Abb. 20*), Karahan Tepe (*Çelik 2011b.Fig. 5*) and Hamzan Tepe (*Çelik 2004.Figs. 2–3; 2006b.Figs. 3–*



Pl. 2. Mınzılıt Feriş (a–f), Mınzılıt Hıleyil (g–j), Mınzılıt İsa (k–r) and Karakuş Batı Mevkii (s–x).



Pl. 3. Flintstone finds from Çillo Mevkii 1 (a–f), ceramic finds from Çillo Mevkii 1 (g–k), flintstone finds from Çillo Mevkii 2 (l–o), ceramic finds from Çillo Mevkii 2 (p–t) and Domuzcurnu Tepesi (u–z).

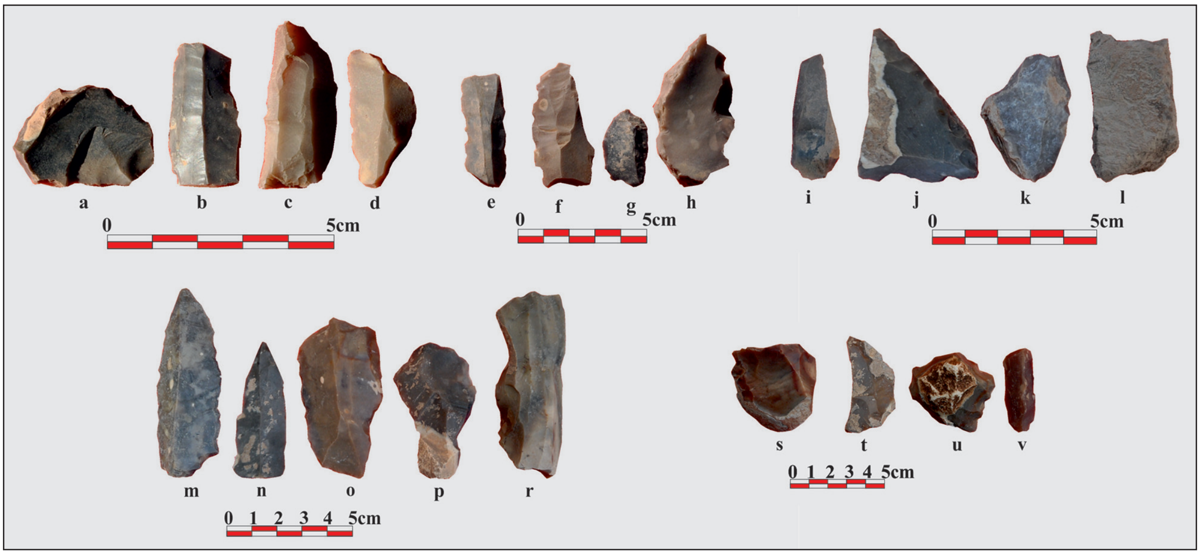
4; 2010.Figs. 6–8) were also discovered around the settlement.

Assessment and conclusion

Circular building architecture was unearthed at Selamet Kuzey Höyüğü and Çamçak Tepe amongst the recently discovered sites. The remains of circular buildings were observed at Herzo Tepe (*Güler* et al. *2012.Fig. 4*), İnanlı Tepe (*Güler* et al. *2013. Fig. 8*), Hamzan Tepe (*Çelik 2010.Figs. 3–4*) and Şanlıurfa-Yeni Mahalle (*Çelik 2000a.Fig. 3; 2007.162, Fig. 16; 2011a.142, Figs.14–16*) during studies conducted in the region in previous years. Both T-shaped pillars and remains of circular buildings were encountered at Hamzan Tepe (*Çelik 2004.Fig. 4; 2006b. Fig. 5; 2010.Fig. 2.4*). Likewise, a body piece of a T-shaped pillar as well as the remains of circular architectural buildings were also discovered at Yeni Mahalle (*Çelik 2014.20, Fig. 21*). The number of examples of this architectural tradition, which also resembles the circular cult buildings from Layers II and III of Göbekli Tepe, is gradually rising every day as a result of surface surveys (*Schmidt 2010. Fig. 2*). Examples of such buildings should date to the early stages of the Pre-Pottery Neolithic period. Similar buildings were also encountered at settlements such as Çayönü (*Erim-Özdoğan 2011.191–193, Fig. 6.9*), Hallan Çemi (*Rosenberg 2011.61–63, Figs. 2–6*), Gusir Höyük (*Karul 2011.2–4, Figs. 4–5. 11*), Hasankeyf Höyük (*Miyake 2013.40, 43, 46–47*) and Körtik Tepe (*Özkaya, Coşkun 2011.90–93, Figs. 2–5*).

The presence of T-shaped pillars is a feature common to the Göbekli Tepe, Nevali Çori, Karahan Tepe, Sefer Tepe, Taşlı Tepe, Hamzan Tepe and Adıyaman Kilişik settlements. These pillars were also encountered at Kurt Tepesi. One of the pillars unearthed at Kurt Tepesi has necktie-shaped groove and chevron pattern relief (Fig. 21) that we recognise from Göbekli Tepe (*Schmidt 2007.118, Fig. 11*) and Nevali Çori (*Hauptmann 1993.51–53, Abb. 16*). The chevron pattern on the pillar at Kurt Tepesi is distinct from the pattern on the pillars at Nevali Çori, as this pattern has a single strip. However, this pattern is similar to the single-strip pattern on pillar 18 at the centre of building D in Göbekli Tepe (*Schmidt 2010.Fig. 8*). In particular, the T-shaped pillars unearthed at Kurt Tepesi have several characteristics in common with Layer II of Göbekli Tepe and the cult building at Nevali Çori. Due to such similarities, Kurt Tepesi should be dated to the late PPPA and early PPNB.

Located approx. 10–15km southeast of Karahan Tepe, the Mınzilit İsa, Mınzilit Feriş, Mınzilit Hıleyil and Aşağı Yazıcı Güney Mevkii settlements present, due to their location, characteristics distinct from the

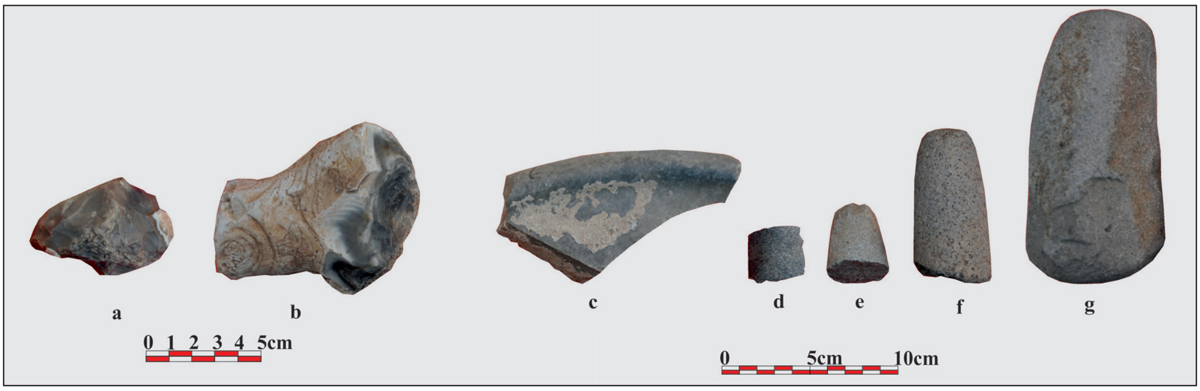


Pl. 4. Nebi Tarlası (a–d), Ömer Altundağ Tarlası (e–h), Hasan Sırtı (i–l), Ayanlar Höyük (m–v).

Neolithic settlements. The common feature of these settlements is that they are generally found on the southern slope of a rocky plateau and that they were inhabited in all periods. No architectural elements were encountered, as agricultural activities are being conducted on the land where the settlements are located. The fact that such small-scale settlements are located in the vicinity of Karahan Tepe, and that such settlements contain no cult finds suggest they might have been domestic settlements affiliated with Karahan Tepe cult centre.

Studies are being conducted at an area located approx. 25km west of Şanlıurfa city centre in order to understand the discovery site of two artefacts from the Pre-Pottery Neolithic brought to Şanlıurfa Museum in 2013 (*Ercan, Çelik 2013.Figs. 1a–d, 3a–d*). The studies conducted revealed that Ayanlar Höyük extends over an area of approx. 14ha. As a result of the research, the settlement was identified as a settlement inhabited during the Pre-Pottery Neolithic. Furthermore, seven additional satellite settlements thought to be affiliated to this settlement were also discovered during the surface survey carried out south of the Ayanlar Höyük. Domuzcurnu Tepesi, Nebi Tarlası, Ömer Altundağ Tarlası, Hasan Sırtı, Çillo Mevkii 1 and Çillo Mevkii 2 settlements, located at distances varying from 2–7km from Ayanlar Höyük. Finds from both the Pre-Pottery and Pottery Neolithic were unearthed at these settlements. These settlements are arranged in the form of a large settlement site at the centre with smaller domestic settlements arranged around it, as at Karahan Tepe and Kurt Tepesi.

Guhera Abid Mevkii was probably used for mass hunting and snaring of wild animals. The site is located approx. 3km southeast of the Selamet Kuzey Mevkii, Selamet Kuzey Höyüğü and Kurt Tepesi settlements. This large snare area, the largest encountered in the region so far, lies in a pass that separates the Harran Plain and Viranşehir plain. This site



Pl. 5. Finds from Ayanlar Höyük (a–g).

was most probably used for hunting antelope during the Neolithic period.

The Çamçak Tepesi and Terzi village Batı Mevkii Neolithic settlements are located approx. 7km northwest of the Sefer Tepe site. These settlements were also probably domestic settlements of Sefer Tepe, like the Kocanizam, Başaran Höyük, Herzo Tepesi and İnanlı Tepesi settlements.

The Kurt Tepesi site has T-shaped pillars. An interesting fact is that this settlement is located at equal distances from both Karahan Tepe and Taşlı Tepe. Karahan Tepe, Taşlı Tepe and Kurt Tepesi are aligned in a north-south direction, with 15km distance between the settlements. Another common aspect of these settlements, which are not yet excavated, is that probably all three were constructed only for cult purposes.

The studies conducted indicate that the number of settlements in the region from the Neolithic period is considerable. Moreover, the finds unearthed from several settlements not only represent the Pre-Pottery Neolithic but also the Pottery Neolithic period. The surface surveys revealed new cult buildings and domestic settlements that we believe were affiliated with such cult buildings. Research will continue in the future around the previously discovered cult buildings.

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Fig. 1. View of Kurt Tepesi settlement from the south.

Fig. 2. A pool chiseled to the bed rock at Kurt Tepesi.

Fig. 3. The site where T-shaped pillars were unearthed due to illegal excavations at Kurt Tepesi.

Fig. 4. T-shaped pillars excavated from Kurt Tepesi.

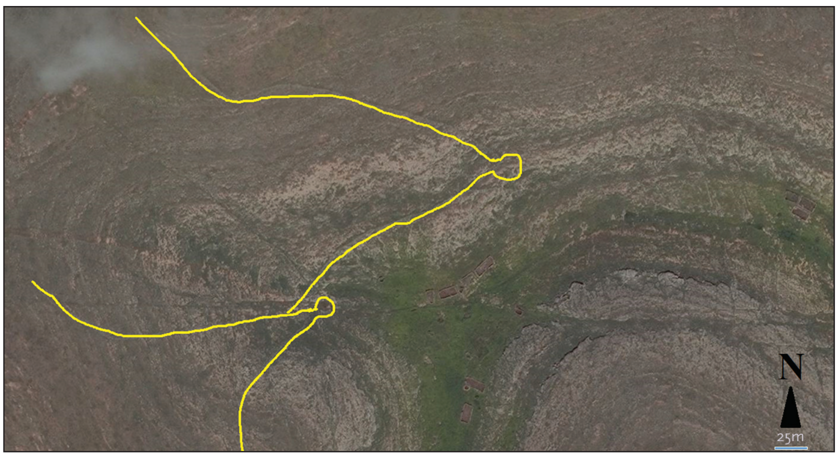

Fig.5. Selamet village Guhera Abid Mevkii triangle shaped snare areas.

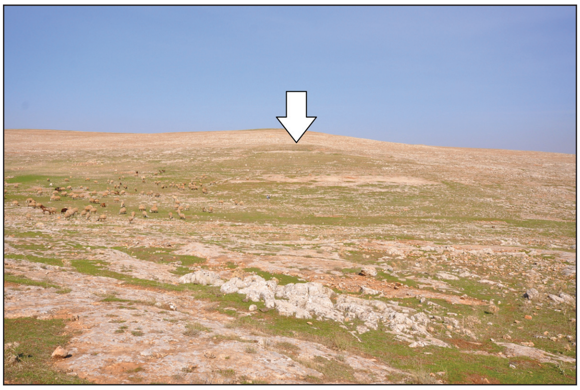

Fig. 6. View of Selamet village Kuzey Mevkii settlement from south.

Fig. 7. Remains of a circular building at Selamet village, northern mound.

Fig. 8. View of Kuşharabesi village Çamçak Tepe from the north.

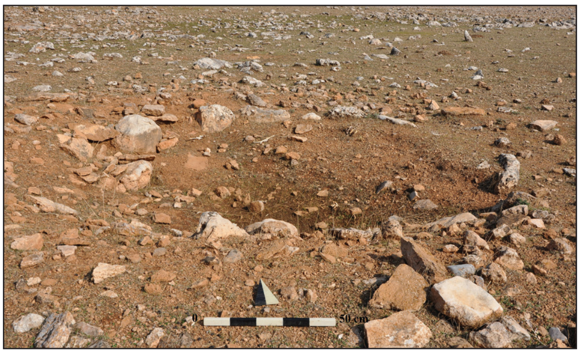

Fig. 9. Remains of a circular building at Çamçak Tepe.

Fig. 10. View of Aşağı Yazıcı Güney Mevkii from the north.

Fig. 11. View of Mınzılit Hıleyil from the west.

Fig. 12. View of Mınzılit İsa from the southwest.

Fig. 13. View of Karakuş village Batı Mevkii from the south.

Fig. 14. View of Çıralı village Çillo Mevkii 1 from the south.

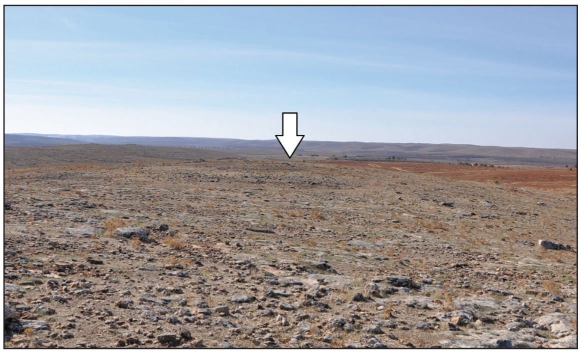

Fig. 16. View of Domuzcurnu Tepesi from the north.

Fig. 18. General view of Ayanlar Höyük from the north.

Fig. 20. Cut-put groups from Ayanlar Höyük, which are used for pool construction technique.

Fig. 15. View of Çıralı village Çillo Mevkii 2 from the north.

Fig. 17. View of Hasan Sırtı from the south.

Fig. 19. Pillar pedestal piece with hollow center discovered from Ayanlar Höyük.

Fig. 21. Pillar with chevron pattern and necktie shaped groove from Kurt Tepesi.