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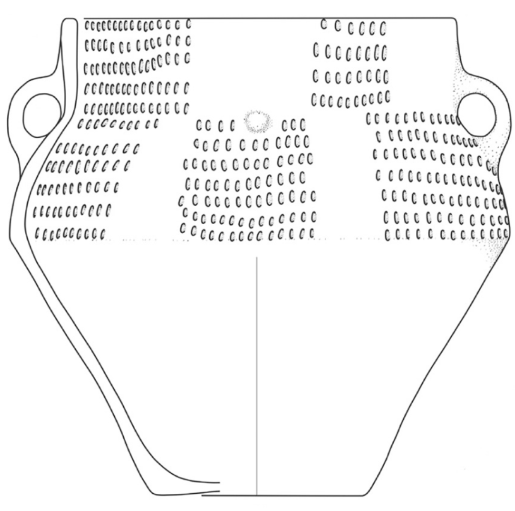

Contents

Neolithisation of the Aegean and Southeast Europe during the 6600–6000 calBC period of Rapid Climate Change

Bernhard Weninger[1], Lee Clare[2], Fokke Gerritsen[3], Barbara Horejs[4], Raiko Krauß[5], Jörg Linstädter[1], Rana Özbal[6] and Eelco J. Rohling[7,8]
b.weninger@uni-koeln.de
1 Institute of Prehistory, University Cologne, Köln, DE
2 Deutsches Archäologisches Institut, Orient-Abteilung, Berlin, DE
3 Netherlands Institute in Turkey, Beyoğlu, TR
4 Institute for Oriental and European Archaeology, Austrian Academy of Science, Vienna, AU
5 Institut für Ur- und Frühgeschichte und Archäologie des Mittelalters, Eberhard Karls Universität, Tübingen, DE
6 Koç Üniversitesi, Arkeoloji ve Sanat Tarihi Bölümü, Rumeli Feneri Yolu, Istanbul, TR
7 Research School of Earth Sciences, The Australian National University, Canberra, AUT
8 Ocean and Earth Science, University of Southampton, National Oceanography Centre, Southampton, UK

ABSTRACT – *In extension of the recently established 'Rapid Climate Change (RCC) Neolithisation Model' (*Clare 2013*), in the present paper we demonstrate the existence of a remarkable coincidence between the exact (decadel-scale) entry and departure dates of the Neolithic into/from the Aegean (~6600/6050 calBC) with begin/end of RCC-conditions.*

IZVLEČEK – *Članek predstavlja razširitev nedavno vzpostavljenega modela neolitizacije v povezavi s hitrimi klimatskimi spremembami – t. i. 'Rapid Climate Change (RCC) Neolithisation model' (*Clare 2013*). V članku opozorimo na izjemno sovpadanje med natančnimi (v merilu desetletij) vstopnimi in izstopnimi datumi za širjenje neolitika v/iz Egejskega prostora (~6600/6050 calBC) in začetkom/koncem razmer hitre klimatske spremembe (RCC).*

KEY WORDS – *Neolithisation; radiocarbon chronology; Rapid Climate Change*

Introduction

The paper is organised as follows. In Section 1 (Neolithic Dispersal), we provide an overview of archaeological research of the Neolithisation process undertaken in the past decade. As is well known, there is a strong temporal gradient between the earliest appearance of Neolithic lifestyles in the Near East and their spread to other regions (*e.g.,* Europe). Although contemporary archaeological research is now focussing on the accompanying economic, socio-cultural and cognitive transformations, an urgent need remains for continued chronological research.

As we discuss in the first section, we observe an increasingly critical attitude of contemporary research towards the so-called 'wave-of-advance' description of Neolithic dispersal. We address here the three main 'core-elements' of this widely applied model: (1) the basic notion that the expansion of farming from the Near East to Europe can actually be described as a continuously advancing cultural-demographic wave; (2) the specific result that Neolithic lifestyles expanded from the Near East into Europe with an average speed of ~1 km/yr; (3) the assumption that both (1) and (2) are supported by radiocarbon dating.

In Section 2 (Rapid Climate Change – RCC), we address some results of ongoing palaeoclimatological research. We provide an overview both of regional, mainly lower resolution RCC-records for the Eastern Mediterranean, as well as global high-resolution records, with a focus on the time of the Hudson-Bay outflow. In this section, we also examine some pro-

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blems relating to our previous timing of RCC-periods (*Weninger* et al. *2009a*). These periods were based on the temporal distribution and clustering of major peaks in the Greenland GISP2 [K+]-record (*Mayewski* et al. *1997*). It still now appears possible to define these periods on a wider scale according to the (smoothed) Greenland GISP2 [K+]-record (*Mayewski* et al. *2004*). However, a set of historical records for drought and precipitation anomalies in the Eastern Mediterranean during the Little Ice Age (LIA) does not correlate well with the sequence of individual peaks in the GISP2 [K+]-record, at least not for the period 1500–1900 AD. Instead, the two strongest [K+]-peaks (~1523 AD and ~1640 AD) are coincident (within error limits of ~2yrs) with the two strongest historically documented dust storms in the north Chinese plains (*Hui* et al. *2013*). In combination, the Eastern Mediterranean and Chinese historical data agree well with recent meteorological evidence (*Tubi, Dayan 2012*) for the existence of two distinct geographic corridors for the outflow of cold air masses from the polar regions at times of pronounced Siberian High (SH). The first cold air corridor has an easterly direction (over China, directly connected with Greenland via the Westerlies). The second corridor follows a westerly direction (into the Eastern Mediterranean, related to Greenland via changes in major atmospheric circulation modes; *e.g.*, *Josey* et al. *2011*).

Section 3 (Cultural History 6600–6000 calBC) provides a condensed overview of cultural developments in the Eastern Mediterranean (Aegean, Anatolia, Levant) during the RCC study interval. To allow for quantitative errors of present ^{14}C-based site chronologies, which are typically in the order of 50–100yrs, this interval is artificially subdivided into an early RCC-phase A (6600–6300 calBC) and a late RCC-phase B (6300–6000 calBC). The results summarised in this section are based on a recently completed study (*Clare 2013*).

In Section 4 (Chronological Case Studies) we provide a compilation of high-resolution ^{14}C-chronologies for the Aegean and Southeast Europe in the Early Neolithic (Southeast European terminology). Altogether, four new chronologies are presented, three of which are for sites in West and Northwest Anatolia (Ulucak, Çukuriçi, and Barcın), and one for a site in north-central Bulgaria (Džuljunica). In addition, at Dikili Tash (North Greece) and at Sidari (Corfu) we have unique on-site evidence for the hydro-environmental impact of RCC-conditions both in the Northern Aegean (*Lespez* et al. *2013*) and in the southern Adriatic (*Berger* et al. *2014*). In addition to the respective site descriptions, this section contains a compilation of archaeological arguments (mainly pottery style comparisons), which further substantiate our conclusion that the spread of farming from the Near East into Southeast Europe proceeded in a step-wise and often delayed manner, with one of the most significant delays of around 500 years visible in the Aegean.

Section 5 (Conclusions) brings the new chronological results into context with ongoing interdisciplinary research. Previously, the majority of ^{14}C-based statistical/mathematical models for Neolithic dispersal (*e.g.,* dates-as-data, wave-of-advance) either concluded, or were already based on this assumption, that early farming spread fastest along the maritime routes. Our conclusion is that at certain times the terrestrial routes were equally rapid. This results from the 'super-fast' dispersal (>1000km in <200yrs) as documented for the spread of the Early Neolithic from the Aegean to Northeast Hungary. This speed is recognisable, already at low dating resolution, but becomes all the more evident from the archaeological case-studies that were performed at a higher dating resolution using the method of Gaussian Monte Carlo Wiggle Matching (Section 4). A similarly rapid Neolithic dispersal (>5km/yr: minimum average; obtained for <200yrs time-span and for >1000km distance) was previously known only for maritime expansion along the Western and Eastern Mediterranean (Fig. 10) coasts. Indeed, this dispersion is so fast, and is accompanied with such large spatial discontinuities, that it may inhibit (or at least complicate) further applications of the linear (continuous) differential equations typically used in contemporary modelling studies.

In a nutshell, we demonstrate a precise temporal coincidence (within given error limits) and strong social impact of RCC on Neolithic dispersal processes. Our conclusions are based on ^{14}C-data combined with insights gained from recent palaeoclimatological research, but above all on archaeological data that are analysed from the viewpoint of modern vulnerability theory.

Neolithic dispersal

Following the introduction of radiocarbon dating some 50 years ago, the chronology of Neolithic dispersal from its area of genesis in the Near East and Anatolia into Europe is today largely based on ^{14}C-dates. Advances in chronology have been achieved in: (1) dating precision, which increased from typical values of σ = 100 BP (around 1970) to σ = 40 BP today; (2) sample size, which decreased from grams to milligrams; and (3) in the quality of archaeological excavation techniques. Today, the majority of ^{14}C-AMS measurements are performed on short-lived ('single event') samples (*Ashmore 1999*). The scientific progress achieved in ^{14}C-dating is also apparent in the size and geographic scope of the archaeological ^{14}C-database, which ranges from the few dozen dates that were available to Clarke (*1965*), through hundreds of dates (*Quitta 1967*); and now into the thousands (*e.g., Breunig 1987; Reingruber, Thissen, 2004; Pinhasi* et al. *2005; Biagi* et al. *2005; Böhner, Schyle, 2006; Luca, Suciu, 2006; Bocquet-Appel* et al. *2012; Furholt* et al. *2009; Weninger* et al. *2009b; Hinz* et al. *2012*). The CalPal-database used in the present paper contains 21519 dates for 3239 Epipalaeolithic, Neolithic and Bronze Age archaeological sites from Europe and the Near-East, of which 82% are geo-referenced (*Weninger 2014*).

In a recent publication, Stephen Shennan *et al.* (*2013*) also studied the introduction of agriculture into Central and Northwest Europe based on insights gleaned from a large archaeological database (N = 13 658 ^{14}C-dates). Their main conclusion, based on the application of the 'dates-as-data method', is that the long-term growth of the European Neolithic population followed an approximately exponential trend, but this was interrupted at certain times by major declines in population size of the order of 30–60%. Based on this observation it is argued that the summed calibrated Neolithic radiocarbon data distributions, which show a number of conspicuous peaks and minima, can be used to deduce corresponding demographic booms and busts. Similar methods were applied to advance the idea that, following an initial boom, the Early Neolithic Linear Pottery culture (LBK) ended with a major population collapse (*Shennan, Edinborough 2007*). The applied methodology is not convincing. In this specific case study, the CalPal-database used by Stephen Shennan and Kevan Edinborough (*2007*) indeed had a major focus on the LBK-chronology, but its focus was on the LBK in the Rhineland. It contained minimal amounts of ^{14}C-data for other LBK settlement regions, mainly from the Köln-laboratory, and was also incomplete for the subsequent Middle Neolithic period.

The application of the 'dates-as-data' method in paleodemographic studies has been found inadequate for many reasons (*Weninger* at al. *2009b; Crombé, Robinson 2014; Contreras, Meadows 2014, with further references*). In general terms, the problem is the extreme bias of the archaeological ^{14}C-database towards natural research variability such that: (a) large numbers of dates are available for few sites, (b) very few dates are available for other sites, and (c) the majority of sites remains undated. Certain geographic regions have been favoured by researchers to the exclusion of others. Finally, (d) there is a strongly unequal geographic distribution of major radiocarbon laboratories (*e.g.,* GrN in the Netherlands; OxA in Great Britain; many countries have no operating laboratories), and these tended to focus on regional projects. As an example, and certainly not in order to compare the relative importance of any given geographic area (or lab, site, or period) simply by ^{14}C-counting, in the CalPal-database there are more ^{14}C-dated Mesolithic sites (N = 69) from the Netherlands (mainly: GrN-lab) than there are ^{14}C-dated Neolithic sites (N = 37) from the whole of Turkey. When the aim is to achieve higher temporal and modelling sensitivity, in our view, it is advisable to base demographic studies not on ^{14}C-counting (of any variable) but directly on archaeological evidence (artefacts, sites, visibility, taphonomic questions) (see *Çilingiroğlu 2005; Reingruber 2011*).

Nevertheless, an important question at stake is why – having made considerable efforts to correct their large ^{14}C-database for taphonomic bias – Shennan *et al.* (*2013*) found no evidence of the impact of climate variability on Neolithic dispersal. We argue that this is not due to any inherent (size/scope/source) limitations of the database, but rather to the inability of the dates-as-data method to differentiate between statistical-archaeological ^{14}C-noise and the climatic-demographic signal with the required temporal resolution. We illustrate this with an order-of-magnitude estimate. Given that the 8.2ka calBP event extended over a time-span of ~100–150 years (*Thomas* et al. *2007*), that the majority of ^{14}C-ages in the database were processed on charcoal (*i.e.* results have a systematic but uncontrolled age-offset of 0–100 years), and that the majority of archaeological ^{14}C-ages has a precision well beyond 50 ^{14}C-BP (with additional errors following ^{14}C-age calibration), it will be virtually impossible to detect the demographic impact of the 8.2ka calBP (Hudson Bay) event by using only the dates-as-data method. Under controlled conditions (theoretical simulation, random sampling) this *a priori* expectation has been verified by Daniel A. Contreras and John Meadows (*2014*) for the period of the Black Death in Europe, for which a major population decline is historically documented, as well as for the disastrous crash in the Basin of Mexico following the arrival of the Spanish conquerors.

An example from the Neolithic period with relevance for the present study is provided by the recently published ^{14}C-series from Tell Sabi Abyad (Syria). Using N = 69 dates on human bone from six cemeteries, Neeltje Plug *et al.* (*2014*) discuss whether the 8.2ka calBP event is visible in the temporal distribution of these data. All dates from Sabi Abyad were measured by the Groningen-laboratory (GrN) to a precision of 30–50 BP, so one might assume that the precision and accuracy of the ^{14}C-AMS measurements is sufficient to answer the question at hand. Using the method of Bayesian Sequencing, based on the known sequence of cemeteries, the authors attempt to further enhance the dating precision. They conclude that Sabi Abyad was continuously occupied during the 8.2ka calBP interval.

As illustrated in Figure 1, analysis of these data using the method of 'cross-bar' dispersion calibration appears to suggest the existence of two possible gaps in the sequence; one coincides exactly with the 8.2ka calBP (Hudson Bay outflow) event, and the second occurs slightly later, at 6100–6000 calBC. Yet it would be wrong to simply use this to attribute the first gap (for whatever social or climatic reason) to the 8.2ka calBP event, given that the separation of calibrated age clusters before and after the Hudson Bay event can be explained by the strong lateral pull of the median values of the calibrated probability distributions (along the calendric time-scale) by small plateaus in the calibration curve. Hence, the 'gap' is at least partly an artificial construct of the applied analytical method: when ^{14}C-dates are calibrated one-by-one (*i.e.* assumption-free in terms of sequence or grouping) it is typical for their calendric readings to lock into one or the other of the many pre-defined geometric inversions ('quantum states') of the ^{14}C-age calibration curve. Such data clustering as becomes evident from Figure 1 is often seen to occur when analysing ^{14}C-data both with the histogram method (on the ^{14}C-scale) as well as for summed calibrated ^{14}C-ages (on the calendric time-scale). In mathematical terms such effects are due to the (geometric) folding properties of the calibration curve. From a more fundamental (axiomatic) perspective, the data clustering is due to the non-commutative properties of ^{14}C dates (*Weninger* et al. *2011*). Note that similar quantisation effects occur when using the interval method of ^{14}C-age calibration, or Bayesian Sequencing, to some extent even in wiggle matching, although in these approaches the problem is not explicitly visible. We also note in Figure 1 that a *pro-gap* argument could be formulated on the basis of the fact that the cross-bar method seems to successfully reproduce both the known grouping of data according to individual cemeteries, and the known sequence of cemeteries, without any such assumptions having been entered.

Having evaluated the gap-hypothesis, let us now address an alternative: the continuity-hypothesis. A closer look at Figure1 reveals that only one (if any) of the 69 human burials is reliably dated to the time-window of the 8.2ka calBP event. It appears that the continuity hypothesis is an even more artificial construct of the applied analytical method than the gap-hypothesis. The procedure of Plug *et al.* (*2014*) was to apply Bayesian Sequencing using OxCal 4.2 (*Bronk Ramsey 2009*) with boundaries set between the ^{14}C-data pre-grouped according to cemetery. However, in this case study, the Bayesian Sequencing method is not used to further evaluate the continuity model, which is simply applied, but not tested. Of greater interest from a methodological viewpoint is that the incorporation of archaeological information into the calibration procedure apparently does not lead to an enhancement in dating precision in all cases. At Tell Sabi Abyad, the opposite occurs: due to the above-mentioned quantum-effects, and lacking the possibility of applying external numeric (quantitative) dating information, in a real sense 'the simultaneously most precise and accurate results' are achieved when no assumptions are made at all. This effectively negates the main reason for applying the Bayesian Sequencing method, according to which, in general terms, archaeologists may even incorporate ordinal-scaled ('younger-older') archaeological information into the calibration process in order to optimise dating precision. By applying the crossbar-method, despite its acknowledged insensitivity, we at least become aware of the interpretational difficulties that arise from the strong attraction of the calendric-scale readings of all ^{14}C-ages towards pre-established states of quantum chronology.

Before continuing, we note that the second gap in the Tell Sabi Abyad data is curiously coincident with a major sub-structure of the 8.2ka calBP for the period 8030–7960 calBP in the stable oxygen record from Qunf Cave (Oman). In contrast to the first gap, which may or may not be real, this second gap is better described as an interval with non-artificially low data density. At least, it cannot be explained by

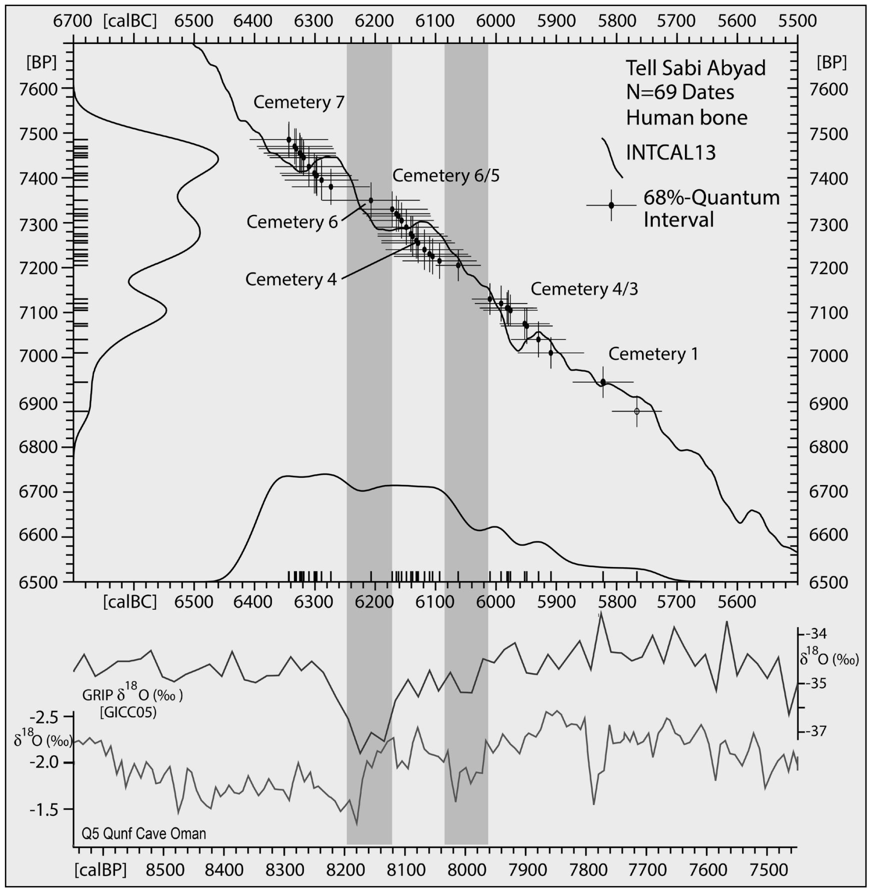


Fig. 1. Tell Sabi Abyad (North Syria). Upper: ^{14}C-scale histogram and calibrated summed probability distribution of N = 69 ^{14}C-dates on human bone from cemeteries 7, 6, 5, 4, 3 and 1 (**Plug *et al.* 2014*****) shown (Lower) in context with Greenland GISP2 δ^{18}O-record (GICC05-age model) as proxy for the Hudson outflow (*****Grootes *et al.* 1993*****), and with Oman Q5 Qunf Cave δ^{18}O-record (*****Fleitmann *et al.* 2007*****) as proxy for shifts in the position of the Intertropical Convergence Zone (*****cf.** ***Fig. 9). Upper: ^{14}C-and calendric scale crossbars (68%-confidence) of the ^{14}C-dates indicate separation of the cemeteries into 4 groups (Cemeteries 7, 6/5, 4/3 and 1). The conclusion of Plug*** **et al.** ***(*****2014*****) that the burial sequence is continuous throughout the 8.2 ka calBP period is not validated (*****cf. text*****). Either there is a real gap, or the apparent gap is artificially caused by the folding properties of the calibration curve). Note the complex internal structure of the '8.2ka calBP event' with sub-events at 8220–8140 calBP and 8030–7960 calBP (indicated by shading) defined according to record comparisons shown in Figure 9.***

the shape of the calibration curve, which is reasonably linear in this interval. Interestingly, it appears to separate the data from cemeteries 6/5 and 4/3 (with the one exception of human bone from cemetery 4, as indicated in Figure 1). The second gap may simply be due to chance effects in ^{14}C-radiometric dating. Nevertheless, given the high quality of the ^{14}C-data, and also since the second gap is equally as long as the first, let us keep its existence in mind for future research. Later, we return to the discussion of the internal structure of the 8.2ka calBP event at a higher temporal resolution (Fig. 9).

In summary, despite the large number of ^{14}C-dates and high sampling quality (single entity bones), we cannot distinguish between the two competing hypotheses. In effect, the burial sequence at Sabi Abyad could be continuous in terms of the sequence of individual burials as well as cemetery level, but there could equally well have been a temporary abandonment of the site during the 8.2ka calBP event.

We infer from this example that the search for climatic impacts on societies is unlikely to be successful when based on single-site analysis. Therefore, and returning to the issue of Neolithic dispersal, we now turn our attention to the study of the signal enhancement that may be expected from a major expansion of the database. Unfortunately, what we see happening in this case is that – in addition to the anticipated problem of limited temporal resolution – a second analytical complication arises. It is related to the spatial distribution of the archaeological ^{14}C-data. We illustrate this spatial, geographic problem in Figure 2 (top left), by comparing a diagram from Ron Pinhasi *et al.* (*2005.Fig. 2*) with a re-interpretation of the same data (Fig. 2, top right).

Both diagrams show the earliest arrival dates of the Neolithic at 735 Near Eastern and European sites, relative to the great-circle distance [km] from Abu Madi (*Pinhasi* et al. *2005; Supplementary Information*). Strongly contrasting with the straight lines used as interpolation method in the original diagram, our reinterpretation (shading) suggests several discrete data clusters. These clusters occur both in the 'horizontal' (along the age-scale) and in the 'vertical' direction (along the distance scale). Closer inspection of the corresponding map (Fig. 2) shows that essentially no data are available for Spain or Western France. The database contains few dates for the Alpine regions, very few dates for Southeast Europe, and is also lacking in Northern Europe. Yet these aspects are not the really critical issues, and it is obvious that the clusters and void regions are largely due to the incomplete character of the database. The critical aspect concerns the absences of dates for Southeast Europe at distances beyond 2000km from Abu Madi, and notably of Early Neolithic ^{14}C-ages prior to *c.* 6600–6000 calBC. Already in general terms, the stepwise character of the age-diagram gives reason to doubt the validity of the 'wave-of-advance' model, regardless of whether a straight line (*Pinhasi* et al. *2005*) or smooth polynom (*Silva, Steele 2014*) is used to trace the dispersal process.

What we observe, formulated in more detail, is (1) an almost complete lack of (^{14}C-dated) Early Neolithic (EN) sites everywhere in Southeast Europe prior to the 8.6–8.0ka calBP RCC-interval; (2) for the same RCC-interval a large number of ^{14}C-dated EN sites on the Greek mainland and in Northern Macedonia; (3) a large number of EN sites in Central Anatolia prior to RCC, but which seem to end at some time within the RCC-interval, and (4), a complete lack of ^{14}C-dated sites (all Neolithic periods) for the West Coast of Turkey. Although we presently remain suspicious as to the validity of observations (1)–(3), which could be out of date, they appear worthy of further consideration (as undertaken below). The last observation (4) is simply wrong, or formulated better, an outdated function of the age of the ^{14}C-database, which was published in 2005 *i.e.* prior to the availability of first Early Neolithic ^{14}C-data from the West Coast of Turkey (*cf.* bibliography in CalPal-database; Weninger (*2014*)). Use of the incomplete Pinhasi *et al.* (*2005*) ^{14}C-database may explain why Carsten Lemmen and Kai Wirtz (*2012*) found no significant impact of climate variability on Neolithic dispersal, despite a dedicated search for such an impact and the application of state-of-the-art geographic modelling procedures (*cf. Lemmen* et al. *2011*).

A less fragmentary compilation of ^{14}C-dates (*Clare, Weninger 2014*) provides further information, (A) concerning the reality (or its chance existence) of the 'EN-RCC-gap' in Southeast Europe, and (B) concerning a potential (regional) refinement of the standard-value of ~1km/yr initially derived by Albert L. Ammermann and Luigi L. Cavalli-Sforza (*1971*) for Neolithic dispersal in all regions of Europe and the Near East. The moment the Neolithic left the Aegean basin, which appears to have occurred not earlier than 6100 calBC, it apparently took little more than 100 years to become established at sites in Serbia, Bulgaria, and Romania, and little more than around 200 years even to have reached the Pannonian Basin. We conclude that it is impossible to further refine the standard speed of 1km/yr for wave dispersal in quantitative terms because, simply, the concept of dispersal at a steady mean speed is flawed. Figure 4 provides support for the recently proposed idea that, following its arrival in Central Anatolia, there was a long (~1000yrs) halt in the Neolithic prior to its further westward spread through the Lakes district into the Aegean (*Düring 2013; Brami 2014*).

Research history of Neolithic dispersal

The rapidity of Neolithic dispersal from the Aegean all the way to regions in the northeast of the Pannonian Basin, if only indicated at low temporal resolution in Figure 4, is not unexpected. Similar ideas were frequently advanced in the past. A first significant step away from slow 'wave-modelling' was provided by Jean Guilaine, who proposed in his so-called 'arrhythmic' model that the expansion of agriculture was neither regular nor uniform across; Europe as a whole, but proceeded in leaps (*Guilaine 2001; 2003; 2013*). Further deviations from 'slow' transmission were demonstrated by João Zilhão for the spread of farming along the Northern Mediterranean coast on the maritime route to the Iberian Peninsula (*Zilhão 2001*). Similar conclusions were arrived at for Neolithic expansion along the Adriatic (*Biagi* et al. *2005; Forenbaher, Miracle 2005; Forenbaher* et al. *2013*). Taking a route that has recently been termed the '*Marine* Epipalaeolithic network' (*Linstädter in press*), the further distribution process along the Mediterranean coasts also appears to have been quite rapid. This is indicated by the arrival of domesticated species in Andalusia and Portugal as early as at 7.5ka calBP (*Aura Tortosa* et al. *2009; Carvalho 2010; Cortés Sánchez* et al. *2012*). Between the Southern Iberian Peninsula and Northwest Africa, within the so-called the Alboran territory (*Linstädter* et al. *2012*), these innovations were further distributed through pre-existing Epipalaeolithic coastal networks representing forager groups focussed on the use of marine resources. Through what has recently been termed '*Continental* epipalaeolithic networks' (*Linstädter in press*), the local foragers from the west-Mediterranean hinterlands adopted Neolithic inventions and integrated them step-by-step into their way of life. The rapidity of

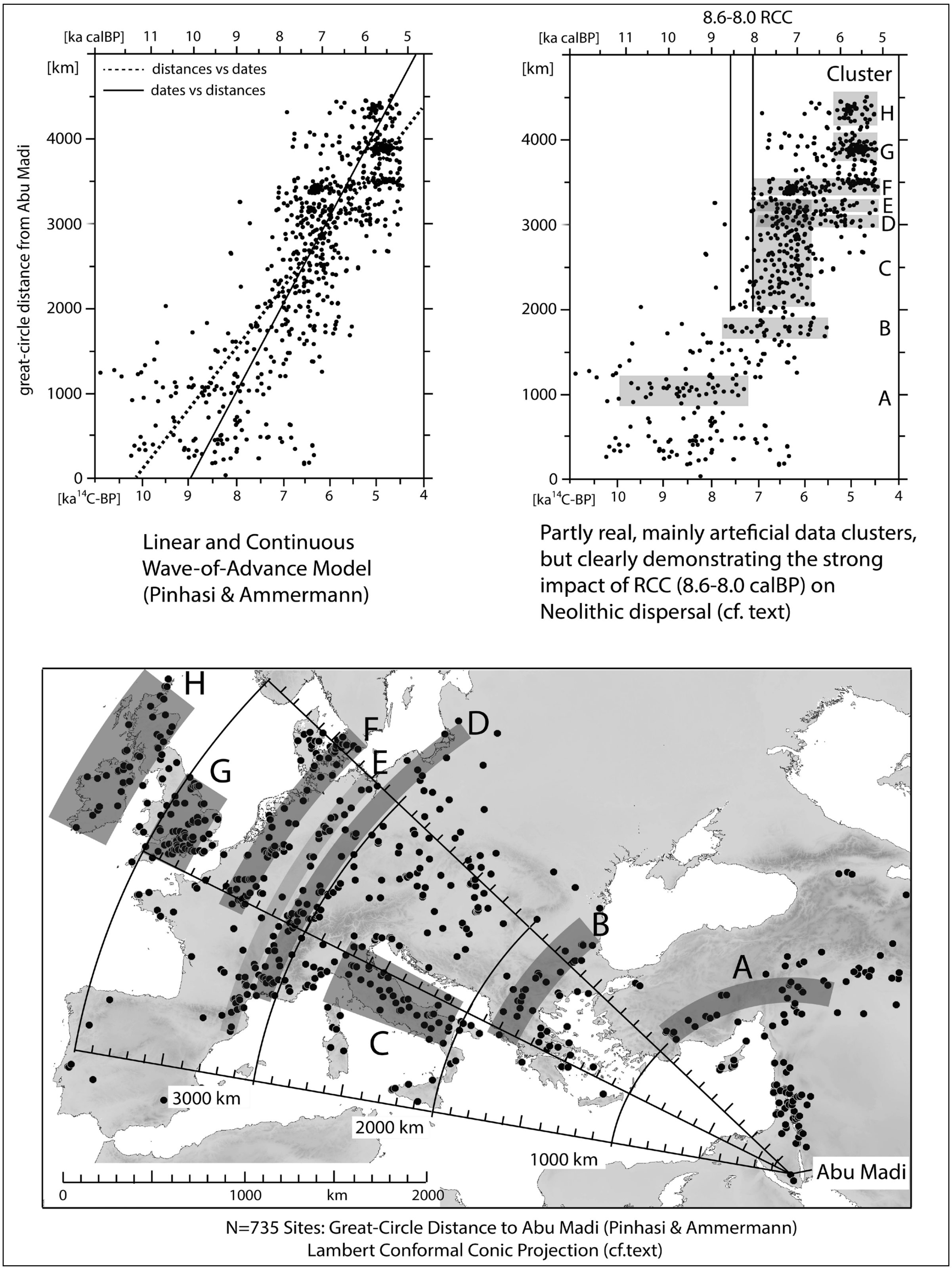


Fig. 2. Map of earliest Neolithic sites according to Pinhasi et al. ***(***2005.Fig. 2***), redrawn with Globalmapper™ using Lambert Conformal Conic (LCC) projection, based on coordinates from ^{14}C-database (***Pinhasi ***et al.*** 2005.Tab. 1***). Top Left: Age-Distance graph redrawn (unchanged) from Pinhasi*** et al. ***(***2005. Fig. 2***). B. Top Right: Age-Distance graph redrawn (with additional shading to show artificial data clusters A-H) from Pinhasi*** et al. ***(***2005.Fig. 2***). When drawn on LCC projection, a straight line approximates a great-circle route between selected start- and end-points. Note: Pilots use LCC-projection for convenient visualization of flight distances.***

these adoptions is indicated by their equally early date of arrival in Morocco, at around 7.6ka calBP (eastern Rif) (*Linstädter, Kehl 2012; Morales* et al. *2013; Zapata* et al. *2013*). However, in comparison to the Eastern Mediterranean, plant cultivation and animal husbandry on the Iberian Peninsula and in North Africa appear to have been only one aspect of subsistence in the sense of a broad-spectrum economy or low-level food production. What is implied by these recent results, and what is important for the present paper, is that there is no evidence in the Western Mediterranean to support an assumption that maritime routes were faster than terrestrial routes of Neolithic dispersal. Although further research is needed, there is wide consensus that the source region for the Neolithic in the Western Mediterranean was somewhere in the Eastern Mediterranean and – most probably – in the Aegean. This again emphasises the importance of precisely dating both the earliest arrival of the Neolithic in the Aegean, and its further pattern of dispersal. As yet, it remains unknown whether such datings fall close together (decadal scale), or far apart (centennial scale).

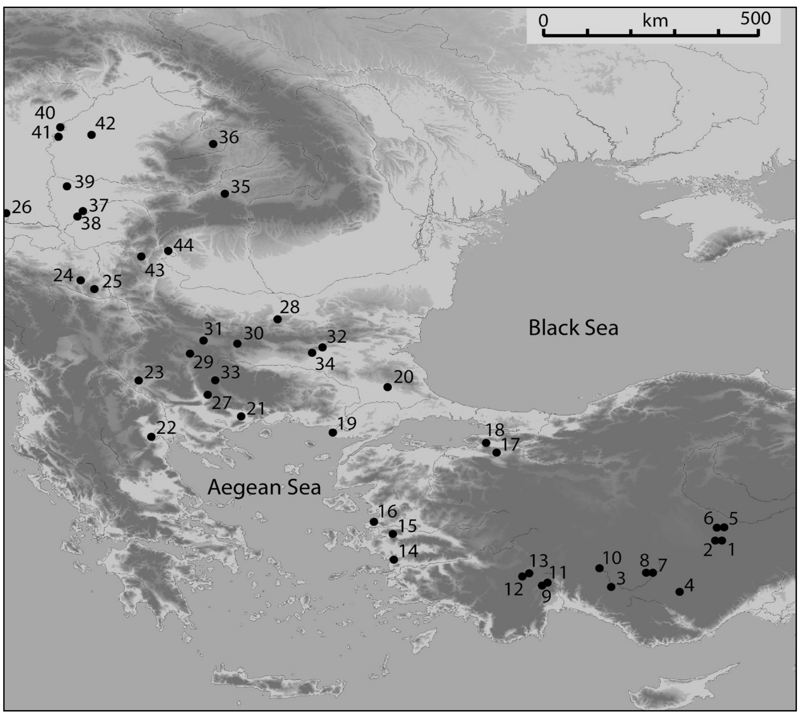


Fig. 3. Distribution of archaeological study sites in Anatolia, Southeast Europe and eastern Central Europe during and after the RCC-interval (6600–5700 calBC). Numbers correspond to site-chronology shown in Figure 4. References for ^{14}C-data: sites 1–20 (**Clare, Weninger 2014*****); site 21 (*****Lespez et al. 2013*****); site 22 (*****Weninger et al. 2006; Linick 1977*****); site 24 (*****Tasić 1988*****); site 25 (*****Bogdanović 2008*****); site 26 (*****Biagi, Spataro 2005; Luca et al. 2008*****); site 27 (*****Lichardus-Itten et al. 2002*****); site 28 (*****Krauß et al. 2014*****); sites 29–34 (*****Görsdorf, Bojadžiev 1966*****); sites 35–39 (*****Biagi, Spataro 2005; Luca et al. 2008*****); sites 40–42 (*****Oross, Siklósi 2012*****); sites 43– 44 (*****Borić 2011*****).***

Rapid Climate Change

It is now well established that a sharp 8.2ka calBP climate event developed in response to the abrupt influx of a large volume of meltwater from the Hudson Bay into the North Atlantic. This meltwater outburst resulted in a brief (<200yrs) disturbance of deep-water formation in the North Atlantic and attendant widespread cooling (Fig. 5). However, the impact of the 8.2ka calBP Hudson Bay outflow was not only the climate perturbation in this period; it is clearly embedded within one of several Holocene 'Rapid Climate Change' (RCC) intervals (*Mayewski* et al. *2004; Rohling, Palike 2005; Marino* et al. *2009*). As shown in Figure 5, the GISP2 non-sea salt (nss) [K+] record best illustrates this sequence of distinct cooling episodes through the Holocene, as an extension of similar (more intense) events during the last glacial cycle (*Mayewski* et al. *1997; 2004; Rohling* et al. *2002; 2003*). Each of these episodes is associated with a more pronounced Siberian High over Asia, which in turn would have led to the increased occurrence and severity of winter outbreaks over Europe and in the Eastern Mediterranean (*Mayewski* et al. *1997; Cohen* et al. *2001; Rohling* et al. *2002; 2003; Casford* et al. *2003*). The existence of recurring cold anomalies during the Holocene is confirmed by a variety of terrestrial and marine records from our study region, the Eastern Mediterranean (*Rohling* et al. *2002; 2009; Mercone* et al. *2001; Meeker, Mayewski 2002; Casford* et al. *2003; Marino* et al. *2009*). Based on the GISP2 nss [K+] record, the strongest RCC-conditions are inferred for the time-intervals ~10.2ka calBP, ~9.2ka calBP, 8.6–8.0ka calBP, 6.0–5.2ka calBP, and ~3.0ka calBP (with varying decadel/centennial-scale age-limits). The most recent RCC-event coincides with an episode that is commonly referred to as the Little Ice Age (LIA; *c.* 1450–1929 AD). Against this RCC background, it appears that the (atmospheric) cold conditions between 8.6 and 8.0ka calBP were amplified between 8.2 and 8.0ka calBP by the impacts of the Hudson Bay event

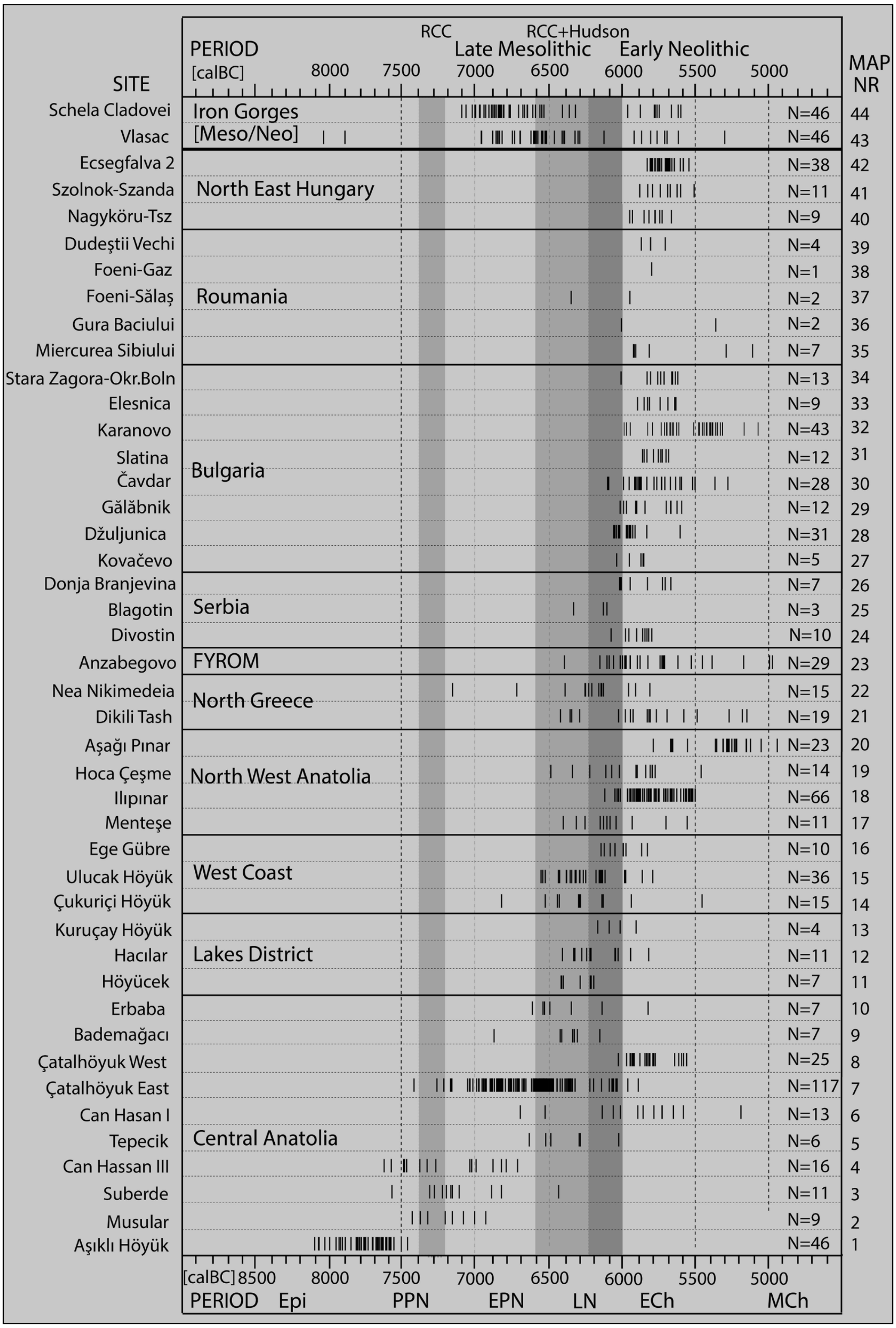


***Fig. 4. Overview of ¹⁴C-ages (total N = 857) for 44 archaeological sites (site numbers refer to the map (Fig. 3), using the Barcode Method of ¹⁴C-age calibration (*cf. *Time-scales and terminology). Each vertical line represents the calibrated median value of one ¹⁴C-age, using CalPal-software (*Weninger, Jöris 2008*) and INTCAL09 calibration data (*Reimer *et al.* 2009*). Shaded areas show Rapid Climate Change (RCC) interval 8.6–8.9 ka calBP according to Rohling* et al. *(*2002*) and Mayewski* et al. *(*2004*), Hudson-Bay outflow interval set schematically to ~6200–6000 calBC. The position of the 9.3 ka calBP RCC-interval according to Fleitmann* et al. *(*2009*) is included for explorative purposes. Abbreviations: Epi = Epipalaeolithic, PPN = Pre-Pottery-Neolithic, EPN = Early-Pottery-Neolithic, LN = Late Neolithic, ECh = Early Chalcolithic, MCh = Middle Chalcolithic, FYROM = Former Yugoslav Republic of Macedonia. From Clare and Weninger (*2014*).*

(*Rohling, Palike 2005; Marino* et al. *2009*). The combined impacts of the RCC and the Hudson Bay event produced one of the most extreme climate anomalies of the entire Holocene. In the following, we consider the nature of the 8.6–8.0ka RCC impacts on our study region.

Seasonality of RCC

Strong and cold north-easterly winds in the Aegean are a regular winter/early spring phenomenon. They are of typically short duration of just a few days at a time. In the Eastern Mediterranean, such outbreaks of polar air masses occur most frequently in December, with fewer occurrences in November and January, still lower frequencies in February and March, with the fewest occurrences in October. No polar outbreaks occur in the summer months (*Saaroni* et al. *1996*). The decrease in the number of outbreaks in January is linked to the end of maximum cooling over Eurasia and the associated drop in anticyclone genesis. Concerning their duration, polar outbreaks tend to fall into two categories. The first and most common category is an outbreak lasting between one and two days. Outbreaks in the second category can persist for more than twice as long (*Saaroni* et al. *1996*). We note that the occurrence of such anomalous winter conditions is well known – and feared – in Mongolia (where cold air outbreaks are referred to as *dzuds*) due to their effects on agriculture and livestock mortality (*Lau, Lau 1984; Begzsuren* et al. *2004; referenced in Tubi, Dayan 2013*).

Palaeoclimate records suggest that there were periods during the Holocene when cold air outbreaks over the Eastern Mediterranean were more frequent and/or intense than today. A key record for understanding Holocene RCC-conditions in the Eastern Mediterranean is provided by ^{14}C-dated marine microfossil assemblage variations in marine sediment core LC21 from south-eastern Aegean Sea (*Rohling* et al. *2002; 2009; Casford* et al. *2003*). This record reveals a series of distinct drops in sea surface temperature (SST) that correlate well (Fig. 5) with periods of enhanced atmospheric dust flux as documented in the Greenland GISP2 glaciochemical record (*Mayewski* et al. *1997*). These SST drops are attributed to the occurrence of north-easterly winds (*Rohling* et al. *2002; Casford* et al. *2003*) that, before reaching the LC21 site, would have blown across the surface of the Aegean Sea for several hundred kilometres. The associated cooling (~1–3°C) of the Mediterranean sea surface (to a depth of ~300m) was sufficiently strong that it contributed to enhanced Mediterranean deep-water formation (*Mercone* et al. *2001; Casford* et al. *2003; Abu-Zied* et al. *2008; Rohling* et al. *2009*).

Rapid Climate Change corridors

There are two main geographic corridors for the outflow of cold masses from the polar regions at times of pronounced 'Siberian High' (SH) (*Tubi, Dayan 2013; with further references*). While the first corridor extends westwards from Central Asia, running north of the Himalayas and crossing the North Pontic steppe, eventually entering Southeast Europe, the second corridor takes an easterly path across China and into the Pacific (*Tubi Dayan 2013*). The westward extension of the SH, on which we focus in the present paper, can lead to continental polar outbreaks over the Aegean, the Adriatic, and the Gulf of Lion (*Rohling* et al. *2002*). These outbreaks are linked to the orographic channelling of polar air masses at the northern Mediterranean margin, more commonly known as the Vardar, Bora and Mistral winds (*Casford* et al. *2003*). Mean annual wind fields over the Mediterranean show a dominance of these northerly outflows (*Pinardi* et al. *2013/14.Fig. 8*), and variations in these systems dominate the spatial pattern of heat loss from the Mediterranean (*Josey* et al. *2011*).

Historical data for RCC in the Eastern Mediterranean and China

As demonstrated by historical data from the recent LIA (*Clare 2013*), severe winter outbreaks are not the only form of perturbation that would have impacted farming communities in RCC-intervals. Based on historical records from the LIA, it is evident that RCC-conditions in the Eastern Mediterranean are also associated with drought and extreme precipitation anomalies. Although apparently paradoxical, this is simply a reflection of inter-annual variability within a context of significantly increased winter extremes (*Clare* et al. *2008; Weninger, Clare 2011*).

What is in itself quite remarkable is that the historically documented LIA-events (Fig. 6) show a clear clustering of drought years, severe winters, famine and plague, especially in the six decades of the interval 1550–1610 AD. However, what we also observe is that this clustering does not correlate well with the strongest events in the GISP2 K^+-record. Notably, the years with highest GISP2 K^+-values (1523 and 1640/1644 AD) actually coincide with the two strongest historical Chinese dust events (*Hui* et al. *2013*). The in-phase character of the Chinese dust storms with the two strongest GISP2 nss K+ peaks, along with the (seemingly) ~20yrs out-of-phase character of Eastern Mediterranean LIA-conditions corresponds well with the existence of the two different RCC-corridors (see above). Notwithstanding these observations, which are at least promising for GISP2 nss K+-based forecasting (at high-resolution) of cold events in China, for the time being we must remain cautious in using the GISP2 nss K+ peaks to forecast individual years with strongest RCC-conditions in the Eastern Mediterranean.

The 8.2ka calBP event: global data (high-resolution records)

Taking a wider geographic perspective, three results of ongoing palaeoclimatological research are of particular relevance to the archaeological 8.2ka discussion:

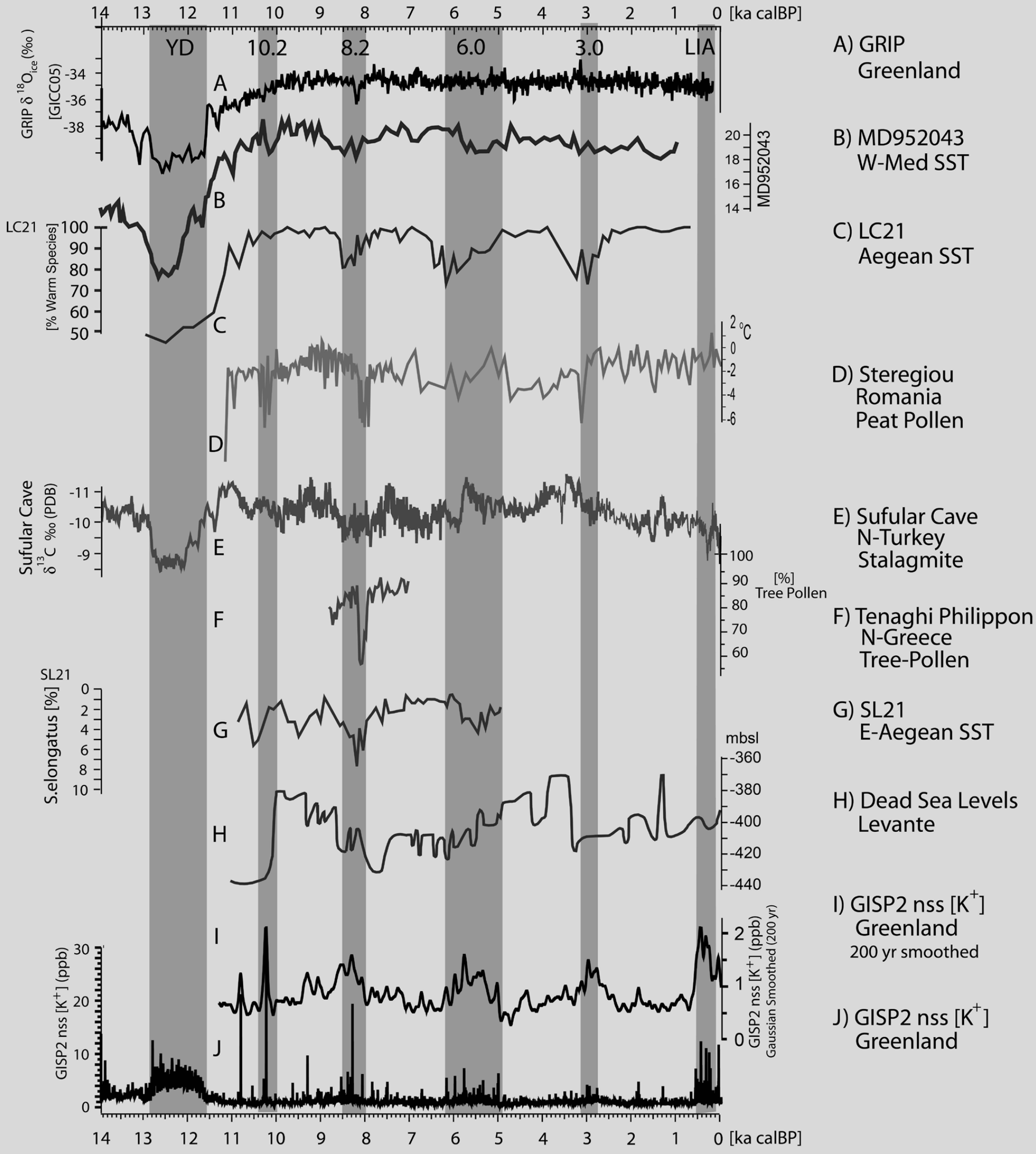


Fig. 5. Northern Hemisphere Palaeoclimate Records showing Holocene Rapid Climate Change (RCC); (A) Greenland GRIP ice-core δ18O (**Grootes *et al.* 1993*****); (B) Western Mediterranean (Iberian Margin) core MD95–2043; C37 alkenones as proxy for sea surface temperature (SST) (*****Cacho *et al.* 2001; Fletcher, Sanchez Goñi 2008*****); (C) Eastern Mediterranean core LC21 (Sea Surface Temperature, SST) fauna (*****Rohling *et al.* 2002*****); (D) Steregiou (*****Feurdean *et al.* 2008*****); (E) Sufular Cave δ13C (*****Fleitmann *et al.* 2009*****); (F) Tenaghi Philippon tree pollen (*****Pross *et al.* 2009*****); (G) Eastern Aegean SL21 (Sea Surface Temperature, SST) fauna (*****Marino *et al.* 2009*****); (H) Dead Sea Levels (*****Migowski *et al.* 2006*****); (I) Gaussian smoothed (200yrs) GISP2 nss [K+] as proxy for the Siberian High (*****Mayewski *et al.* 1997; Meeker, Mayewski 2002*****); (J) High-Resolution GISP2 nss [K+] as proxy for the Siberian High (*****Mayewski *et al.* 1997; Meeker, Mayewski 2002*****).***

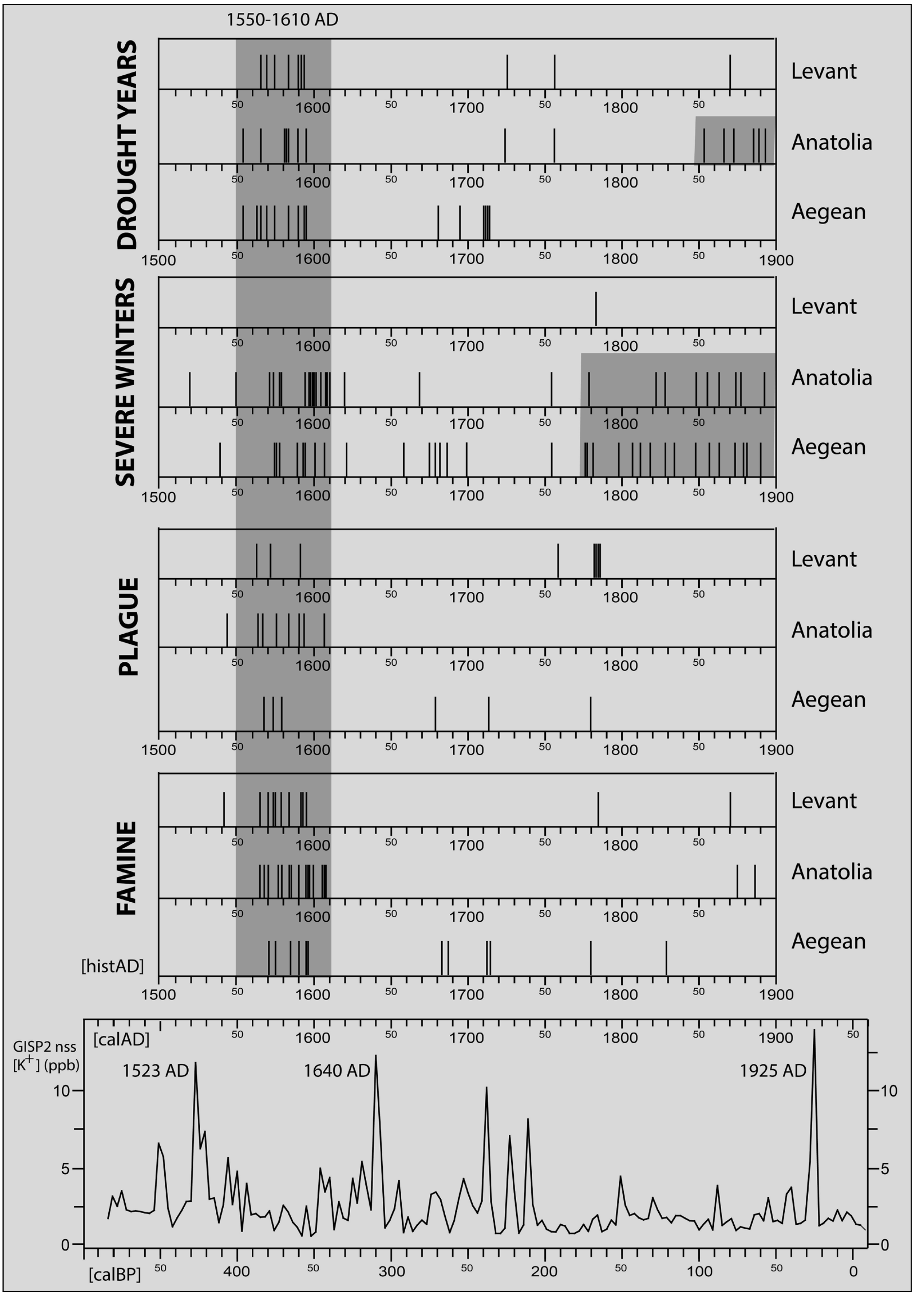


Fig. 6. Compilation of historical records (1500–1900 AD) from different regions of the eastern Mediterranean (Anatolia, Levante, Aegean) with reference of severe winters, drought, plague and famine (data: **Clare 2013*, with further references and discussion), in comparison to GISP2 nss K+ record (*Mayewski *et al.* 1997*). Each historical event is represented by one vertical line. Interpretation: (a) there is clear supra-regional evidence of the strongest impact of LIA-conditions in the time-interval 1550–1610 AD; (b), there is no clear (annual-scale) correlation between historical events in the eastern Mediterranean and strongest Greenland GISP2 nss K+ peaks; (c) the two strongest GISP2 nss K+ peaks (~1523 AD and ~1640 AD) most likely derive from dust storms documented in the N-China plain (*Hui *et al.* 2013*), (*cf. *Fig. 7*).***

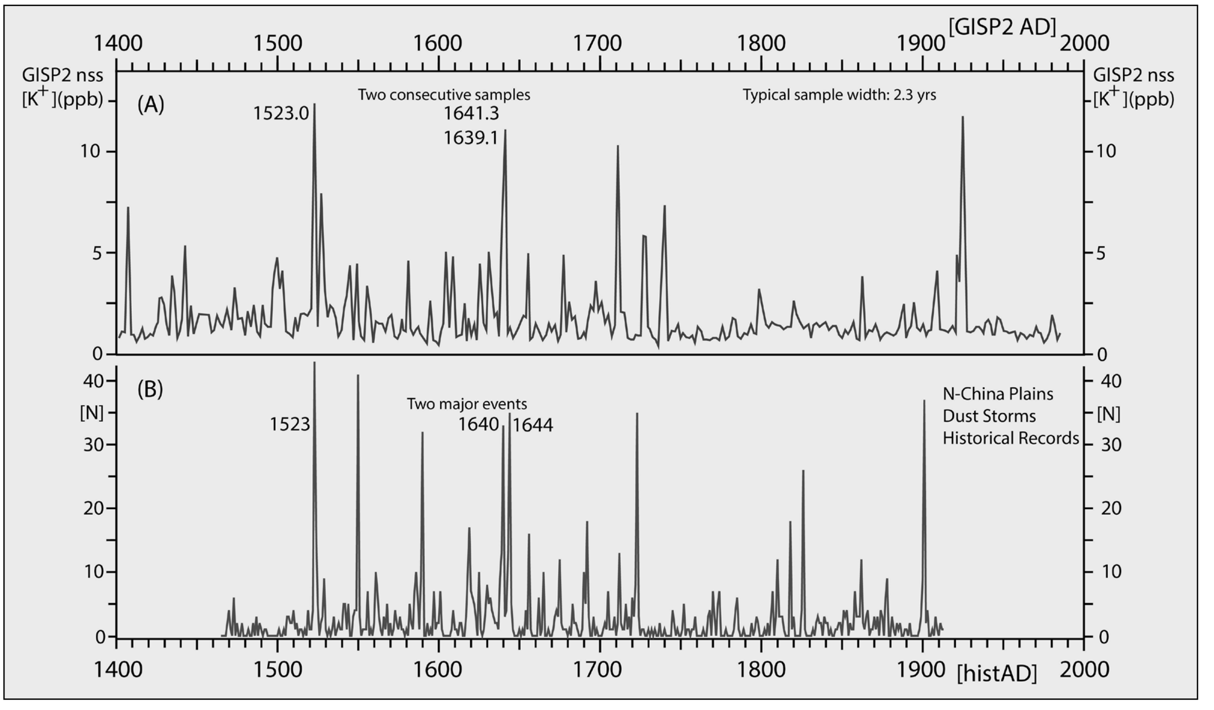


Fig. 7. Dust events in China compared to GISP2 nss K+ climate record. (A) Upper: High-Resolution GISP2 nss [K+] as proxy for the Siberian High (*Mayewski *et al.* 1997; Meeker, Mayewski 2002*); (B) Lower: Summed annual frequency of dust storms North China Plain, AD 1464 to 1913, derived from a total of 1180 historical archives (*Hui *et al.* 2013*). The 1640/1644 AD double-peak represents the highest number of documented dust storms. The 1644 AD dust storm covered the vast region from 32°N to 40°N. The AD1523 peak relates to a dust storm that was documented in six provinces (Shouzhang, Jize, Yifeng, Dingtao, Fanxian, Weixian). Of all identified dust storms, 72.85% occurred in the spring, 16.39% in winter, 8.71% in summer, and 2.05% in the auntumn. Hui* et al. *(*2013*) relate the spatial pattern of dust storms to the movement of cold air systems in North China in winter or spring.

❶ changes in the strength of North Atlantic ocean circulation are in many details (near) synchronous with climatic variations throughout most of the Northern Hemisphere, including the lower-latitude monsoon regimes of Eastern Asia (*e.g.,* China) (*e.g., Rohling* et al. *2003*);
❷ such long-distance synchronicities are understandable only if they are related via the Earth's atmosphere, and not through oceanic circulation with its comparatively slow (millennial and centennial) transfer times;
❸ there are strong indications for a distinctly (almost) anti-phased inter-hemispheric relationship between East Asian and Near Eastern climate regimes on the one hand (*i.e.* north of the Intertropical Convergence Zone [ITCZ]), and South American climate on the other hand (*i.e.* south of the ITCZ).

As such, it is not only the North Atlantic climate regime that requires attentive study, but also the interplay between the different components of the global climate system. This is illustrated in Figure 9 for the time-interval 6700–5900 calBC by a compilation of selected high-resolution records that, on the one hand, have their proximity close to the North Atlantic (Greenland and Germany) and, on the other hand, a geographically much wider dispersal from regions as far apart as China, Oman, and Brazil. We note that some records suggest a more complex internal structure within the '8.2ka calBP event', with two major sub-events *e.g.*, 8220–8140 calBP and 8030–7960 calBP (indicated in Fig. 9 by shading). If the existence of such (very short: decadal-scale) sub-events is confirmed, and they impact the Levant, then this would both complicate future climate-archaeological research in the eastern Mediterranean and provide stimulus for further high-resolution studies. Already above, using the ^{14}C-data from Tell Sabi Abyad (Fig. 1), we have studied the methodological challenge that the identification of complex substructures of the 8.2ka calBP event will impose on high-resolution ^{14}C-dating. Gianluca Marino *et al.* (*2009*) offer a first tentative indication that a double peak may exist in the Aegean cool event that appears to be related to the 8.2ka calBP Hudson Bay event. The relevant climate record (core SL21: E-Aegean SST) is included in Figure 5 (record G).

Cultural history 6600–6000 calBC

On the basis of the aforementioned insights from recent palaeoclimatological research, we posit that archaeological climate-culture analysis for the age-range 6600–6000 calBC should consider that the 8.2ka calBP Hudson Bay event occurred embedded within a wider (RCC) cool interval, so that we may recognise an earlier phase (RCC only: 6600–6200 calBC) and a later phase (RCC amplified by Hudson Bay impact; 6200–6000 calBC). The two climate mechanisms would have resulted in similar environmental impacts with a temporal overlap (*Rohling, Pälike 2005; Marino* et al. *2009*). As an alternative to these climate-based phases, but which have unequal length (400 and 200yrs), we can greatly simplify the archaeological discussion (if only for overview purposes with an acceptable loss of chronological precision) by defining two phases of equal length, Phase A (6600–6300 calBC) and Phase B (6300–6000 calBC).

Phase A: Eastern Mediterranean 6600–6300 calBC

Major developments in the first phase (RCC: 6600–6300 calBC) are summarised in Figure 10 (top). In this phase, there is manifold evidence for population movements not only within Anatolia, but also in coastal and lower-lying locations in the Northern and Southern Levant. In the Southern Levant, the onset of RCC (~8.6ka calBP) coincides with the first appearance of pottery-bearing communities, commonly referred to as the Yarmoukian culture, and increasing intensities of settlement activities in the coastal plain. These trends coincide with the gradual decline of LPPN 'megasites' in the Jordanian Highlands (*Gebel 2004*). As coastal and lower-lying areas would have been less affected by typical RCC-impacts (*e.g.,* summer drought in combination with severe winters), we posit that the widely observed habitat tracking to milder regions, and in particular (1), from the Jordanian highlands to the Levantine coast, and (2), from the Central Anatolian Plateau to the Turkish West Coast, may be attributed to the same climate mechanism (*Clare 2013; with data and references*).

Phase B: Eastern Mediterranean 6300–6000 calBC

Major developments in the second phase (*i.e.* combined RCC and Hudson Bay event: 6300–6000 calBC) are summarised in Figure 10 (bottom). These were centuries of unprecedented social disturbances in the Southern and Northern Levant, Eastern and Central Anatolia. In the Southern Levant, this phase is referred to as the *Late Yarmoukian Crisis* (*Clare 2013*). It sees the widespread abandonment of settlements in the Transjordanian Highlands and the Lower Jordan Valley (south of Lake Galilee), including the major Yarmoukian site of Sha'ar Hagolan. Notably, subsequent Jericho IX culture sites (7900–7600 calBP/ 5900–5600 calBC) are limited to the southern coastal plain, the Jezreel Valley and the Hula Basin. Once again, this trend appears linked to strategies aimed at the mitigation of RCC-impacts.

Eastern Anatolian and Syrian data testify to a similar *period of instability*, with numerous sites providing either substantial, or at least possible, evidence of settlement abandonment. We have discussed this issue above for Tell Sabi Abyad (*Akkermanns* et al. *2006; van der Plicht* et al. *2011; Plug* et al. *2014*). Other examples are 'Ain Ghazal, Basta, and 'Ain Rahub (and other sites in Jordan and Israel covered by rubble layers following RCC-related site desertion, see *Rollefson 2009; Gebel 2009; Zielhofer* et al. *2012*); Shir (*Bartl 2010*), Çayönü (*Özdoğan 1999*), Akarçay Tepe (*Özbaşaran, Duru 2011*), Aşıklı Höyük (*Özbaşaran 2011*) and Mersin-Yumuktepe (*Caneva, Köroğlu 2010*). In the Amuq plain, there is at least a potential hiatus in the ceramic sequence between phases Amuq

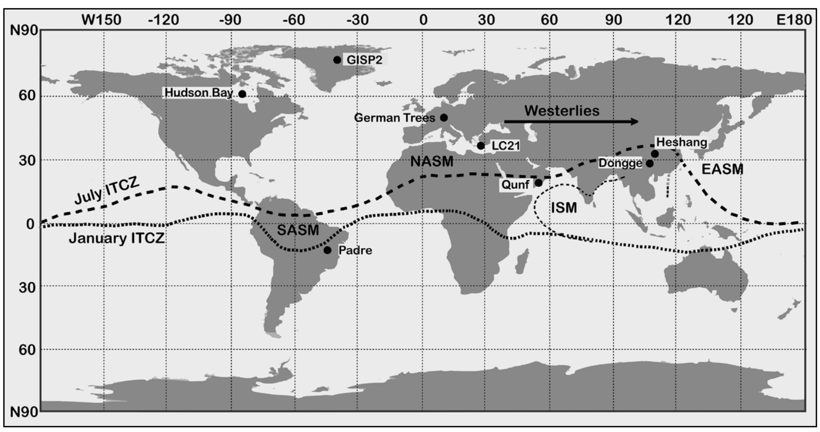


Fig. 8. Modern Position of the Intertropical Convergence Zone (ITCZ) in July and January, redrawn from Cheng* et al. *(*2012.Fig. 1*), with location of key sites for records addressed in the present paper. Abbreviations: GISP2 (Greenland Ice Sheet Project Two); SASM (South American Summer Monsoon); NASM (North African Summer Monsoon); ISM (Indian Summer Monsoon); EASM (East Asian Summer Monsoon).

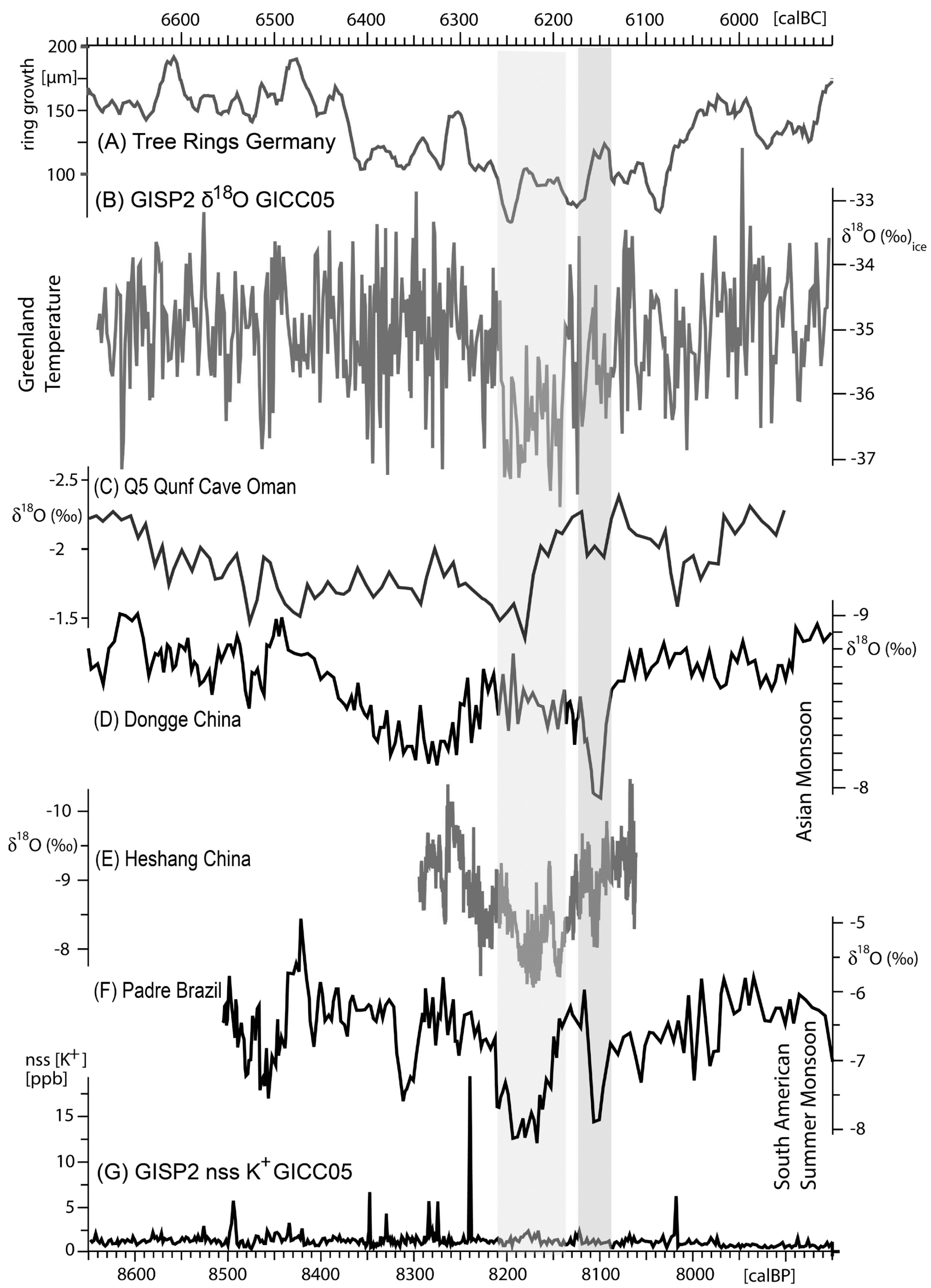


Fig. 9. Timing and structure of the 8.2 ka calBP event on a global scale. Compilation of high-resolution U/Th-dated stalagmite records from China and Brazil (D, E, F) according to Cheng* et al. *(2009), with additional records (A, B, C, G) added. (A) German oak tree-ring growth record (*Klitgaard-Kristensen *et al.* 1998*); (B) Greenland GISP δ18O on Hulu time-scale (*Grootes *et al.* 1993; Weninger, Jöris 2008*); (C) Q5 Qunf Cave (*Fleitmann *et al.* 2007*); (D) Dongge Cave δ18O (*Wang *et al.* 2001; 2005*); (E) Heshang Cave HS4 δ18O (*Liu *et al.* 2013*); (F) Padre Cave Brazil δ18O (*Cheng *et al.* 2009*); (G) Greenland GISP nss K+ on Hulu time-scale (*Mayewski *et al.* 1997; Vinther *et al.* 2006; Weninger, Jöris 2008*). Note the geographic variability and complex internal structure of the '8.2 ka calBP event' with major sub-events* e.g., *8220–8140 calBP and 8120–8090 calBP (indicated by shading).

A and Amuq B (*Balossi 2004*), while in the Rouj Basin (Tell el-Kerkh) there is a shift in burial practices, with the first appearance of a demarcated burial ground (cemetery) and central areas in the settlement used for *public* purposes (*Tsuneki 2010*). Combined, these data suggest geographically widespread and socially significant changes in prevailing social systems at this time. The westward expansion of farming indicated in Figure 10 (bottom) relies on increasing evidence that the introduction of impresso pottery elements in the Aegean could be related to the arrival of groups from the Northern Levant via

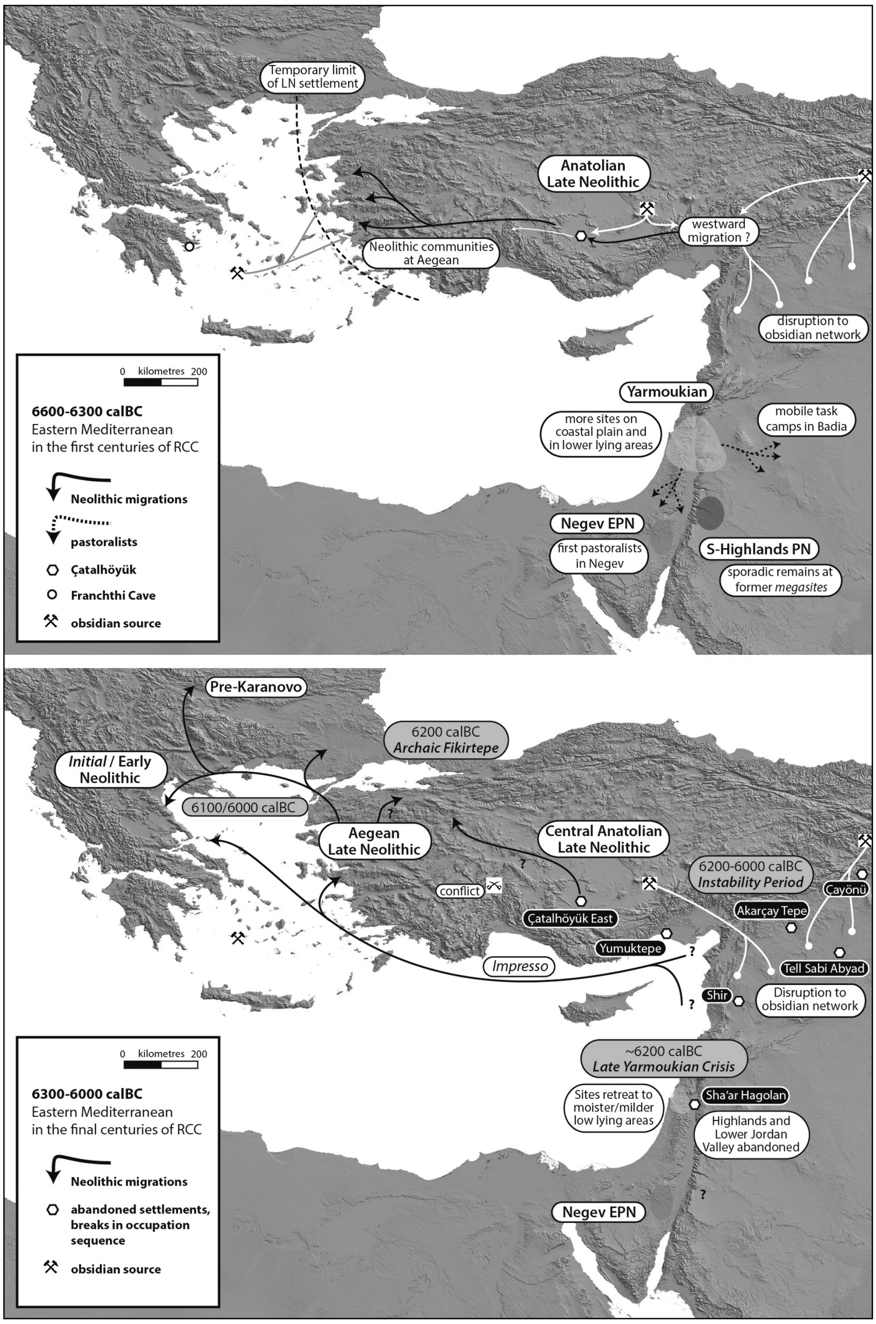


Fig. 10. Top: Summary of events identified in the first phase of RCC (8600–8300 calBP/6600–6300 calBC) in the Southern Levant and Anatolia (after* Clare 2013*). There is evidence of a push/pull to coastal and lower-lying locations in both study areas. In Anatolia, this trend is synonymous with the dispersal of Neolithic communities from their core area as far as the Aegean coast. As coastal and lower-lying areas would have been less affected by typical RCC-impacts (drought and severe winters), it is posited that the colonization of these areas would have reduced the biophysical vulnerability of communities to RCC. The disruption in the flow of Cappadocian obsidian to the Southern Levant is quite remarkable. In Western Anatolia, this same commodity was mainly procured from the Aegean island of Melos. This latter development may even testify to breaks with Central Anatolian traditions, and can be interpreted as an attempt to reduce social vulnerability in the face of climate-induced resource shortfalls.
Bottom: Summary of events identified in the second phase of RCC (8300–8000 calBP/6300–6000 calBC) in the Southern Levant and Anatolia (after* Clare 2013*). In the Southern Levant there is a further retreat of Neolithic sites to moister (less arid) parts. The related abandonment of sites in the Transjordanian Highlands and the lower Jordan Valley is referred to as 'Late Yarmoukian Crisis'. Remarkably, there are similar developments in the Northern Levant and Eastern Anatolia, where many sites bear witness to an interruption in settlement continuity or are deserted (site names on black background). In the Turkish Lakes District there are first indications for internecine warfare. Curiously, all these developments coincide with a further wave of Neolithic expansion into Southeast Europe. Generally speaking, one of the most astounding aspects of the archaeological evidence reviewed in Figure10 is the increase in cultural (and presumably also demic) mobility in many regions of the Near East and Anatolia.

a marine route (*Cilingiroğlu 2010; Brami, Heyd 2011*). In this latter region, this development appears to accompany the widespread appearance of Proto-Halaf culture sites (*e.g., Cruells 2008*).

Before continuing, we note that the traditional assignment of Archaic Fikirtepe (Northwestern Anatolia, Marmara region) to RCC Phase B (Fig. 10, lower) should be treated with caution. This assignment is based on ^{14}C-dates from different levels of Yarımburgaz Cave (near Istanbul), which, however, have an unsatisfactory spread, probably due to stratigraphic disturbance (*cf. Özdoğan* et al. *1991; Clare, Weninger 2014.Tab. 24*). As discussed below, new ^{14}C-dates as well as stratigraphic and ceramic analyses from Barcın indicate an earlier start of the Fikirtepe culture (in RCC Phase A) and even a pre-Fikirtepe farming presence in the region.

Chronological case studies

Above, we commented on the abrupt appearance of Neolithic communities in the Aegean at the beginning of RCC-Phase A. It is, therefore, essential that an exact date be established for the very first arrival of farming communities in this region in order to validate (or falsify) the Rapid Climate Change (RCC) – Neolithisation relationship proposed in this paper. Specifically, if farming had already been introduced to coastal regions of the Aegean *prior* to the onset of RCC-conditions, then this relationship would be difficult to support. In this respect, recent excavation results from the sites of Ulucak, Çukuriçi Höyük, and Barcın Höyük, in each case with a new series of stratified ^{14}C-dates (*cf.* below), provide a welcome test of the Aegean-refugium concept as proposed by Clare (*2013*). Figure 11 shows the geographic location of the archaeological sites under study in the following section.

Ulucak Höyük (Turkish West Coast)

Ulucak Höyük is located in a plain, bordered to the north and south by mountain ranges, 3km east of the Belkahve mountain pass that gives access to the Aegean littoral, some 25km further east at Izmir. Ulucak lies on the path of a natural thoroughfare linking the central Aegean coast with more eastern (inland) areas of western Anatolia. The mound currently rises 6m above the plain with a diameter of some 100m, although drilling in the vicinity of the site has shown that settlement probably extended over a much larger area (4.5ha). Sediment accumulations from slope-wash erosion and alluvial deposition from the Nif Çayı, a small stream adjacent to the site, has detracted substantially from the height of the *höyük*, which is known to extend more than 3 metres below the present surface of the plain. Six architectural levels with numerous sub-phases have been identified at Ulucak (*Çilingiroğlu* et al. *2012*). These are, from top to bottom, Late Roman/Early Byzantine (level I), Early Bronze Age (level II), Late Chalcolithic (level III), Early Chalcolithic/Latest Neolithic (level IV), Late Neolithic (level V), and a possible Pre-Pottery Neolithic (PPN) occupation (level VI) (*Çilingiroğlu 2011. 68–69*).

The stratigraphically derived (age-depth based) results of ^{14}C-wiggle-matching) for Neolithic levels VI–IV (Fig. 12) provide a chronology with ~400yrs later foundation of Ulucak (Level VI: 6630±32 calBC) than estimated by other authors (*e.g., Çakırlar 2012a*; b. ~7000/7040 calBC), but age differences in similar range are not uncommon for Anatolian and Aegean ^{14}C-chronology (*e.g., Rohling* et al. *2003*). While the excavators describe preliminary discoveries in these lowermost Neolithic deposits (level VI) as reminiscent of PPN features in central parts of Anatolia, a recent evaluation of available radiocarbon ages from associated contexts (*cf. Clare, Weninger 2014*) would rather suggest an incipient occupation of Level VI no earlier than the late EPN or early LN.

LN occupations at Ulucak (level V) are further differentiated into six different sub-phases, labelled (Va-f). While the oldest subphases (Vb-f) are associated with free-standing wattle-and-daub houses, with three substantial *representative buildings* in Vb, one of which features a large number of storage facilities (clay bins), the youngest LN sub-phase (Va) is characterised by a change in settlement plan. Houses are no longer free-standing, which is perhaps indicative of an increase in population (*Çilingiroğlu 2011.71*). It is of note that this phase (Va) also marks the introduction of impressed pottery at the site. Impressed wares appear almost contemporaneously around the Aegean at the end of the 7th millennium calBC, a development that may be linked with the arrival of new groups from the Levant and Northern Syria in the region at this time (*Çilingiroğlu 2010*).

Çukuriçi Höyük (Turkish West Coast)

Çukuriçi Höyük (Fig. 11) on the centre of the Western Anatolian coast is located on the Küçük Menderes river delta opposite the island of Samos and is embedded in a sheltered basin that in prehistoric times had direct access to the Aegean. The mound is now visible to a height of 4.50m above the plain and extends over an area of 80 x 100m, originally measuring 160 x 200m and 8m high. In the years following the first small-scale rescue excavations in 1995, which recovered evidence for Chalcolithic and Early Bronze Age occupations, the settlement mound was subjected to severe disturbances by modern agricultural activities.

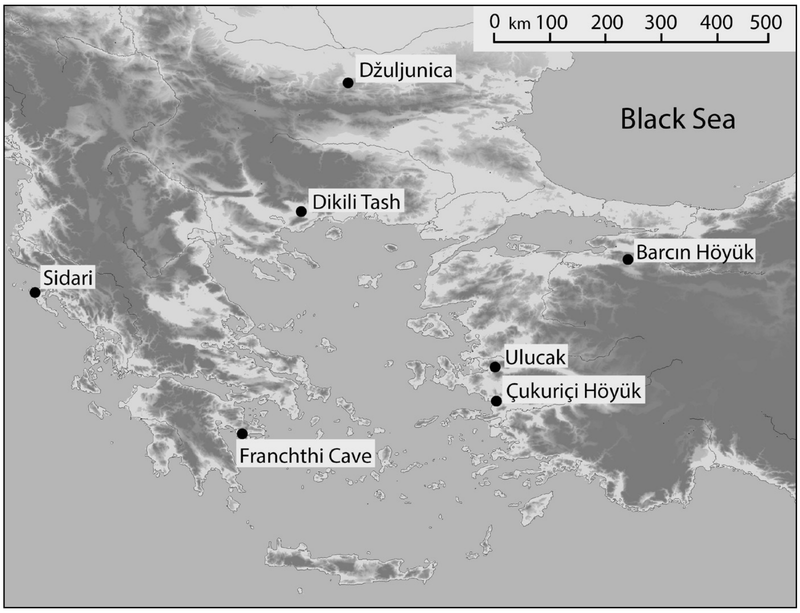


Fig. 11. Geographic distribution of archaeological sites under study in the present paper.

Renewed excavations at the site which commenced in 2006 are now leading to a much clearer picture of the prehistoric settlement sequence at this location (*Horejs 2010; 2012*). The tell was settled during different periods, with six distinct settlement phases excavated so far, including Pottery Neolithic, Early Chalcolithic, Late Chalcolithic and Early Bronze Age periods (*Horejs, Weninger in prep.; Galik, Horejs 2011*). The earliest excavated settlement phase thus far, Çukuriçi Höyük (ÇuHö) X, revealed rectangular houses with stone foundations and a characteristic Pottery Neolithic assemblage that can be dated to ~6630 calBC (Fig. 13). The following occupation level, ÇuHö IX, contains at least one almost complete rectangular building with adjacent open activity zones or courtyards and several other domestic deposits dating between 6400–6200 calBC (*Horejs 2012*). The following settlement ÇuHö VIII also revealed the remains of a rectangular building and various domestic settlement structures dated between 6200–6000 calBC (*Horejs 2012*). The excavated and archaeologically analysed settlement levels are additionally supported by radiocarbon dated drilling cores conducted before the excavation of the Neolithic occupation (Fig. 12).

There are good chances that Çukuriçi Höyük was first settled immediately following the onset of RCC-conditions (Fig. 13), similar to Ulucak (Fig. 12), but this hypothesis remains to be tested by ongoing excavations.

Barcın Höyük (Northwest Anatolia)

Given its potential to elucidate the spread of farming from Anatolia to Southeast Europe and the Balkans, Neolithic research in Northwestern Anatolia has gained tremendous momentum recently, with new projects beginning in the provinces of Bursa, Çanakkale and Istanbul such as Aktopraklık (*Karul, Avcı 2013*), Uğurlu (*Erdoğu 2013*), and Yenikapı (*Kızıltan, Polat 2013*) respectively, adding to the existing projects of Fikirtepe, Pendik, Hocaçeşme, Toptepe and Aşağıpınar (*Özdoğan 2013*). Barcın Höyük, in the Yenişehir Plain south of the İznik Lake and east of Bursa, has contributed to this emerging picture with the earliest evidence of the presence of sedentary farming communities in the region, and new insights into the evolution of regional ceramic technologies (*Gerritsen, Özbal and Thissen 2013b*). Barcın Höyük (Fig. 11) is a small mounded site with Neolithic occupation levels. Excavations at the site began in 2005 (*Gerritsen, Özbal and Thissen 2013a*). The Yenişehir Plain is a basin filled with Quaternary deposits with a minor stream (the Kocasu), which drains the valley to the east. Coring with a hand auger around the site indicates a complex history of sedimentary and hydrological changes, dominated by lacustrine and marsh conditions (*Groenhuijzen* et al. *in prep*). In addition to the Neolithic Phase, the site has yielded Byzantine, Hellenistic/Roman, Iron Age, Bronze Age, and Chalcolithic phases. Most of these are ephemeral traces and represent intermittent and interrupted occupation throughout these periods. The short habitation sequences in these periods are sandwiched by centennial-scale intervals that lack evidence of human activity of any kind.

Excavations have identified five sub-phases (indicated with the letters a-e) with VIe being the earliest and VIa representing the latest Early Neolithic phase (*Gerritsen, Özbal and Thissen 2013a*). Soundings have established that the Phase VIe occupation sits

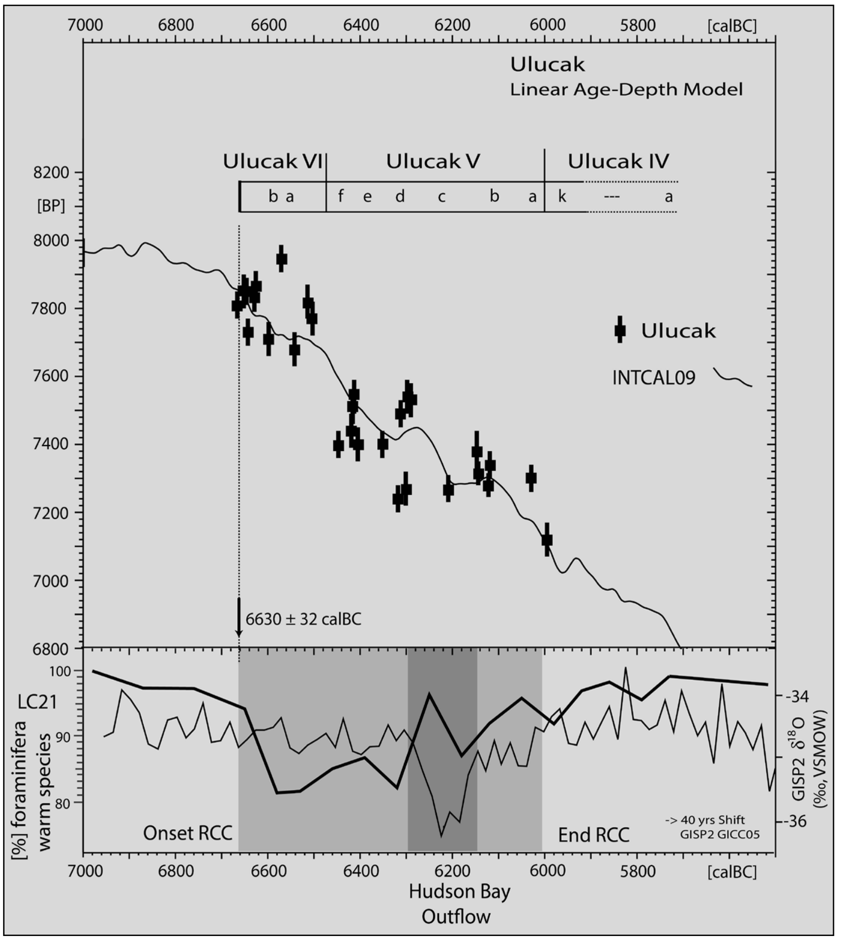


Fig. 12. (Upper) Ulucak (Turkish West Coast, Levels VI–V): Optimised linear stratigraphic ¹⁴C-age model based on stratified charcoal ¹⁴C-ages according to sample depth. Ulucak (Level VI): Monte Carlo Wiggle Matching of short-lived samples based on random Gaussian shuffling of ¹⁴C-ages (N = 10 000 iterations) within an interval 0±20 yrs. The combined Ulucak age-model is shown in comparison to (Lower): Greenland GISP2 ice-core δ¹⁸O record (**Grootes *et al.* 1993*****) as proxy for North Atlantic air temperature and LC21 foraminifera data [percent warm species] as proxy for Sea Surface Temperature in the Aegean (*****Rohling *et al.* 2002*****). Allowing for an (error-prone) 20yrs age difference between initial settlement and dated samples, the settlement was founded at 6650±35 calBC (95%),*** **i.e.** ***synchronous with the onset of RCC-conditions (shaded). Note: LC21 age-model has a dating precision of 100yrs (68%) in this interval. Ulucak ¹⁴C-data assembled from Çilingiroğlu (*****2009; 2010; 2011; 2012*****).***

directly on top of a low natural elevation. During phases VIe and VId, the production and use of ceramics increases from 'practically non-existent' to 'rare' and then to 'common' in phase VId (*Gerritsen, Özbal and Thissen 2013b*). Sharing some very generalised common features with central Anatolian ceramics, the VIe and VId pottery types are best seen as the genesis of a regional northwest Anatolian ceramic tradition that culminates in phases VIc and VIb in the Fikirtepe tradition also known from other sites in the eastern Marmara region. The best preserved architectural deposits come from Phases VIc and VId, which yielded a sequence of row houses surrounded by courtyards. Walls of rectangular houses were constructed from wooden posts set closely together in foundation ditches, providing a skeleton for the mud-covered walls. Adult burials were usually placed within the courtyards, while infant burials, relatively more frequent, have been found in houses, within walls and around oven complexes. Zoo-archaeological analyses show that the subsistence economy was based from the first occupation level onwards on herding and cultivation.

Current evidence provided by the stratigraphy, pottery development and ¹⁴C-dates for the Neolithic Period (Level VI) suggests a period of about 600 years of habitation between 6600 calBC and around 6000 calBC (*Gerritsen, Özbal and Thissen 2013b*). This is confirmed in Figure 14 by application of Gaussian Monte Carlo Wiggle Matching based on an explorative equi-length phase model, which was applied independently to the data of the different sub-phases. The validity of this model remains to be established. The existence of a gap (or hiatus) between sub-phases VIc and IVb at the time of the 8.2ka calBP event cannot yet be excluded, but is not evident in the ceramic sequence or stratigraphy. An intriguing idea – although impossible to substantiate – is that the abandonment of Barcın Höyük and the foundation of Ilıpınar, some 40km distant at Lake Iznik, may have been related events. What can be stated with confidence is that the settlement was founded in sub-phase IVe around 6600 calBC, or a few decades later if due allowance is made for the dating of potentially long-lived charcoal samples.

Dikili Tash (North Greece)

At the Dikili Tash (Fig. 11) site in North Greece, the first detailed on-site geomorphological evidence has been reported for an environmental impact at the time of the 8.2ka calBP event at high dating resolution (*Lespez* et al. *2013*), as outlined in the following. Dikili Tash is one of the largest tells in northern Greece, covering an area of ~4.5ha (250 x 180m² at its base) and with a total height of ~22m, of which 17m are above and 5m are below the modern surface. Ongoing excavations, which commenced in 1961, have provided a good insight into the long stratigraphic sequence of this settlement, which spans from the Neolithic to the Bronze Age (*Treuil R. 1992; Koukoulli-Chryssanthaki* et al. *2008; Darcque* et al. *2009*). In the immediate vicinity of the tell there is a freshwater spring; this fills a pond, which then drains via a streamlet running adjacent to the eastern side of the tell (*Lespez* et al. *2013. Fig. 1*). Of interest for the present paper is the observation that the 8.2ka calBP event is marked at Dikili Tash by an abrupt rise in ground-water level in this hydrological system, which ultimately led to the relocation of the early Neolithic settlement (*Lespez* et al. *2013*). Given their importance for our RCC-related studies, we briefly review these inferences. The rise in water level is documented in two cores (core C2 and core C3), but we focus here only on C3 from the northern part of the tell, for which a series of stratified ^{14}C-ages is also available (*Lespez* et al. *2013. Tab. 2*). Core C3 shows an approximately 10m long sedimentary sequence that extends from the Pleistocene, through the Early and Middle Neolithic, up to the Late Neolithic I and II periods (*Lespez* et al. *2013.Fig. 3*). We concentrate on the earliest Neolithic layers. Starting with Pleistocene clay at its lower end, the core shows a sequence of archaeological layers with Early Neolithic artefacts (*e.g.,* bone fragments, small flakes, one red-brown burnished sherd, and a semi-circular end-scraper). Some of the layers appear to be disturbed, whereas others seem to be *in situ*. The EN-sequence is interrupted at ~53–54m asl by a series of palustrine silts and oncolithic sands (schematically illustrated in Fig. 15, top). Having established by Gaussian Monte Carlo Age-Depth Wiggle-Matching (Fig. 15, top) that the sediment accumulation in C3 is linear (with average growth rate of 2.55yrs/cm) for the study-interval 6400–5600 calBC, it is possible to analyse the corresponding sedimentary sequence (Fig. 15, top) in relation to the GISP2 ^{18}O record (Fig. 15, bottom).

The timing of the Hudson Bay outflow relative to the sedimentary sequence of core C3 (Fig. 14) supports the concept of Laurent Lespez *et al.* (*2013*) concerning an abrupt rise of the ground-water level at the time of the 8.2ka calBP event. With the age-depth model shown in Figure 14, we note two important details, namely (1) that the rise of ground water level coincides very closely (within error limits <

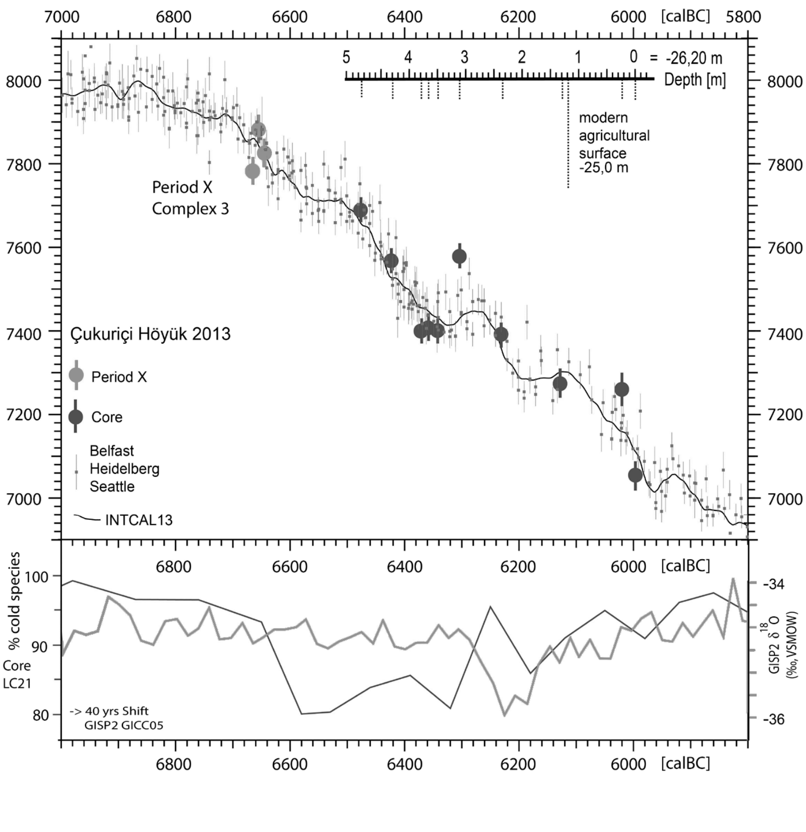


Fig. 13. (Upper): Çukuriçi Höyük (Turkish W-coast). Stratigraphic age-depth model based on geomorphological coring by Helmut Brückner (University Cologne, Department of Geography) at the west edge of the tell. The deepest ^{14}C-age (charcoal: UGAMS–6043; **Horejs, Weninger in prep.*****) is from lowermost cored archaeological deposits. Period X ^{14}C-Data: Monte Carlo Wiggle Matching of short-lived samples based on random Gaussian shuffling of ^{14}C-ages (N = 10 000 iterations) within an interval 0±20yrs. (Lower): Greenland GISP2 ice-core δ^{18}O record (*****Grootes et al. 1993*****) as proxy for North Atlantic air temperature and and LC21 foraminifera data [percent warm species] as proxy for Sea Surface Temperature in the Aegean (*****Rohling et al. 2002*****). ^{14}C-Data:*** **Horejs, Weninger in prep.*****; CalPal-database (*****Weninger 2014*****).***

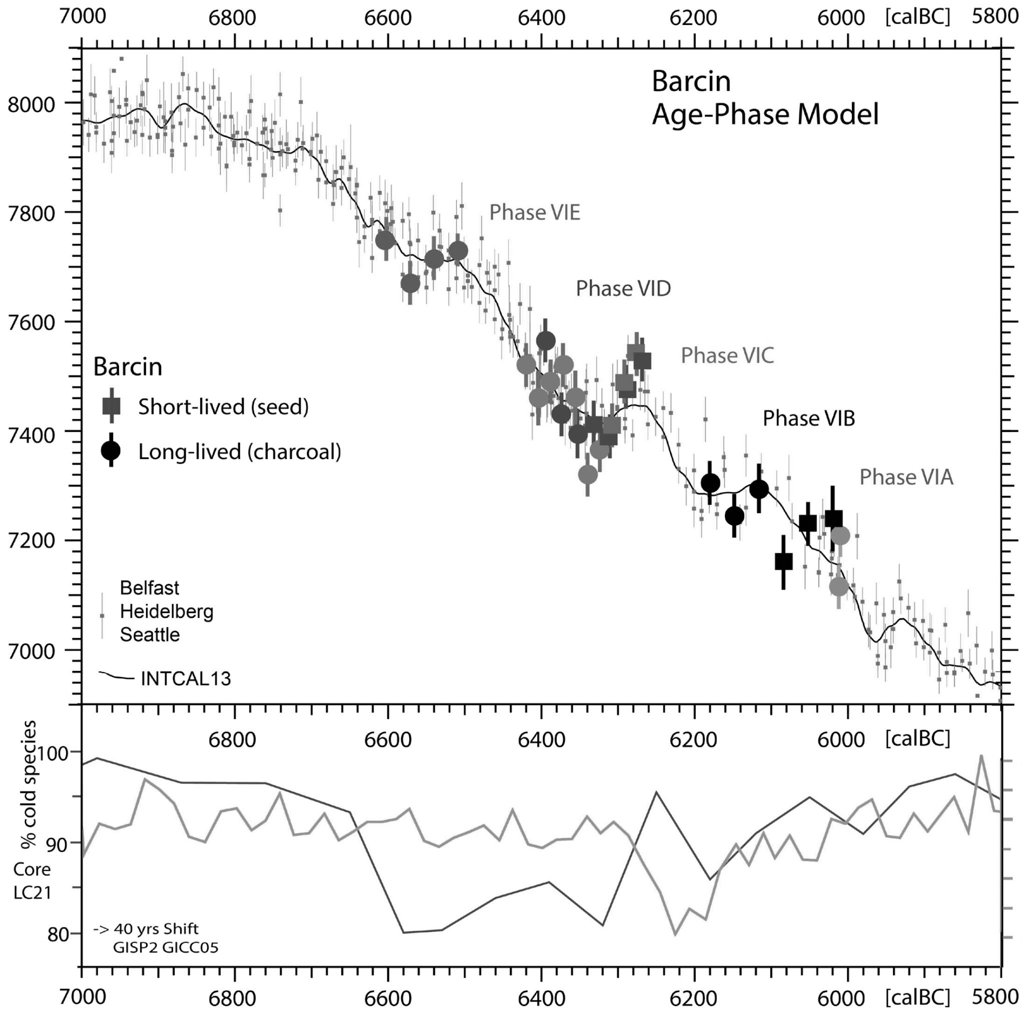


Fig. 14. Barcın Höyük (Northwest Anatolia). (Upper): Explorative equi-length phase-model, established by independent analysis of the ¹⁴C-dates from sub-phases IVa–VIe, shown in context (Lower) with GISP2 δ¹⁸O-record (GICC05-age model) as proxy for the Hudson outflow and with marine core LC21 (% cold species) as proxy for RCC-conditions in the Aegean. The existence of a gap (or hiatus) between sub-phases VIc and IVb in parallel to the 8.2ka calBP event cannot yet be excluded, but is not evident in the ceramic sequence or stratigraphy. Hence the temporal overlap of ¹⁴C-dates from sub-phases VId and VIc is likely to be the artificial outcome of applied modelling procedures. ¹⁴C-Data: **Gerritsen, Özbal and Thissen 2013b*****; CalPal-database (*****Weninger 2014*****); with (outlier) Beta–340889 removed.***

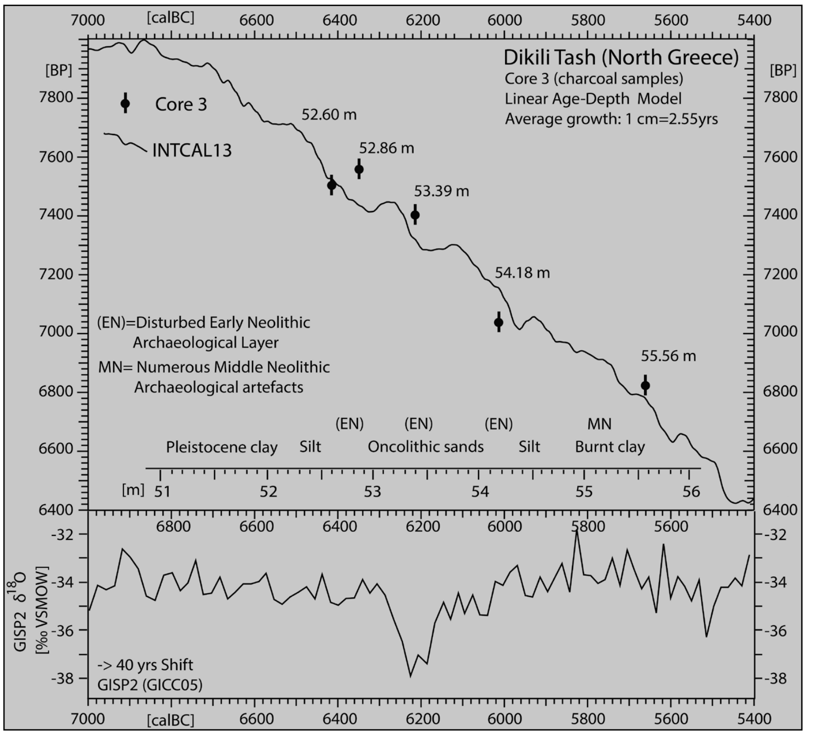
100yrs) with the onset of the 8.2ka calBP event, and (2) that the site was already occupied (if perhaps only by a few decades) *prior* to the onset of the 8.2ka calBP event. The necessity for settlement relocation due to the rising ground water level is also confirmed by ^{14}C-ages from Core 2 from a location closer to the site's pond and water courses (*Lespez* et al. *2013.Tab. 2*).

Lespez *et al.* (*2013*) further address the question as to why RCC-conditions at Dikili Tash are accompanied with a rise in ground-water level. Based on temperature and precipitation values from pollen transfer functions at the nearby (former) swamp at Tenaghi Philippon (*Peyron* et al. *2011*), Lespez *et al.* (*2013*) argue that a reduction in evapotranspiration during the 8.2ka calBP interval due to a large estimated decrease in winter (~4°C) and summer (~2°C) temperatures coincided with a rise of 75mm in summer rainfall. This combination would have sufficed to generate high ground-water levels. The interpretation that the 8.2ka calBP interval experienced colder than normal winters and wetter than normal summers (*Peyron* et al. *2011*) seems to be supported by an increase in *Gramineae* (grasses) and *Cyperaceae* (sedges) at the Tenaghi Philippon swamp (*Pross* et al. *2009*).

Sidari (Corfu)

Another hydro-climatic phenomenon for the 8.2ka calBP interval was recently observed at Sidari on the island of Corfu (Fig. 11), where flooding and deep

Fig. 15. Dikili Tash (North Greece). Linear Age-Depth Model for ^{14}***C-dates from Core 3 (*****Lespez *et al.* 2013. Tab. 2; Fig. 3*****) shown in context with GISP2 δ*** ^{18}***O-record (GICC05-age model) as proxy for the Hudson outflow. Due to the occurrence of oncolithic sands in Core 3 at depths 53–54m asl the authors identify a rise in groundwater level of a site-adjacent pond. This appears to be a local response to the 8.2ka calBP event, causing a settlement relocation to dryer parts of the tell (*****Lespez *et al.* 2013*****). Note that the uppermost*** ^{14}***C-age SacA-22588: 6210±35 BP from core 3 at depth 56.33–56.15m (*****Lespez *et al.* 2013.Tab. 2*****) is removed from analysis as outlier (in respect to the assumed linearity).***



fluvial flows are documented *on-site* during the transition from an Initial to an Early Neolithic settlement phase (*Berger, Guilaine 2009; Berger* et al. *2014*). At this site, a lower Mesolithic level (layer D) is covered by deposits attributed to an 'Initial Neolithic' (layer C, basis: badly fired pottery, little decorated, indications of the breeding of small ruminants), which is followed by a sterile deposit (hiatus) that, in turn, is overlain by 'Early Neolithic' deposits (layer C, upper part) with characteristic Impressed Ware of Adriatic type. As indicated by the ^{14}C-dates (*Berger* et al. *2014.Fig. 6*), all these layers are chronologically so close together that they cannot yet be clearly separated using the available ^{14}C-ages (values range between 8000–7670 BP for the Mesolithic-Neolithic transition, and 7500–7170 BP for the transition between the two Neolithic layers). Importantly, but in need of further validation, Sidari is similar to Dikili Tash in that it records a switch to moister conditions with distinct hydro-sedimentary impacts for the 8.2ka calBP interval. Combined, the studies of Laurent Lespez *et al.* (*2013*), Jean-François Berger *et al.* (*2014*), Jorg Pross *et al.* (*2009*) and Odile Peyron *et al.* (*2011*) define an important milestone for understanding the interplay between (global) climatic change and local hydrological conditions during the 8.2ka calBP interval.

Franchthi Cave (Argolid, Greece)

We conclude the Aegean section of this paper by noting that essentially identical results (*i.e.* ~6600 calBC) for the arrival of early farming on the Turkish West Coast have recently been obtained by Catherine Perlès *et al.* (*2013*), using direct ^{14}C-AMS dating of domestic seeds at Franchthi Cave (Argolid, Greece) (Fig. 11). The relevant ^{14}C-dates are GifA-1106: 7805±40 BP and GifA-11455: 7740±50 BP for sample FAN163, and GifA-11017: 7780±40 BP and GifA-11456: 7645±50 BP for sample FAN162 (*Perlès 2013.Tab. 1*). Since all four measurements are statistically identical (Chi-square test: 7.6%) on the ^{14}C-scale, it is not possible to define an age difference for the two samples on the calendric timescale. Although it is strictly speaking pointless to base any kind of inference on the weighted average for the given (non-commutative) ^{14}C-ages, for convenience (in talking about these dates), we nevertheless calculate an average age of 6580±40 calBC (*i.e.* ~6600 calBC) for these samples. What is important is that there is no measurable age-difference between the earliest (known) date of arrival of the Neolithic at Franchthi and for the Turkish West Coast.

Džuljunica (North-Central Bulgaria)

Regarding the further dispersal of Neolithic lifestyles into Southeast Europe, key information may be obtained from north-central Bulgaria and the Early Neolithic settlement of Džuljunica (Fig. 11). The location contains natural springs that flow from the base of the prominence upon which the site is located. Even today, there are four active springs at the foot of the site. The prominence itself is a slightly elevated ri-

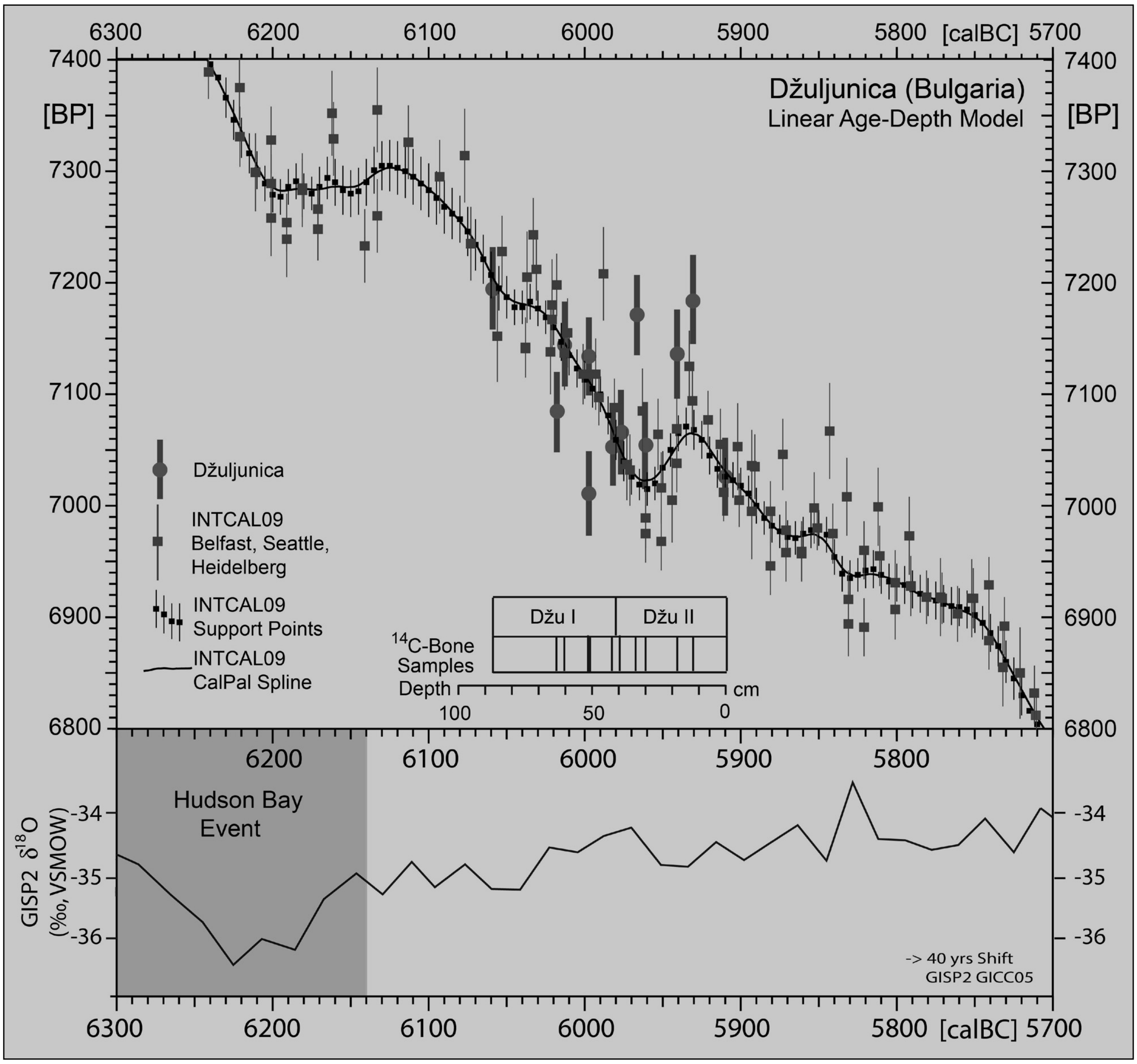


Fig. 16. (Upper): Džuljunica (NE-Bulgaria). Optimized Linear Stratigraphic Age model for Phases Dž I–II for average Growth-rate of 1.70yrs/cm, in comparison to INTCAL09 curve (*Reimer *et al.* 2009*), INTCAL09 high-precision calibration raw-data (Seattle/Heidelberg); (Lower): GISP2 $\delta^{18}O$-record (*Grootes *et al.* 1993*) as proxy for North Atlantic ocean/atmosphere temperature with GISP2-ages shifted 40yrs younger according to Weninger and Jöris (*2008*) in agreement with GICC05-age model (*Vinther *et al.* 2006*). ^{14}C-Data: see Krauß* et al. *(*2014*).

ver terrace above the Džuljunica River, which – together with other tributaries – flows into the Yantra River today at about 6.5km north of the settlement.

Finds from the oldest settlement layer at Džuljunica (Dž–I) attest to clear similarities with material of the West Anatolian Late Neolithic. As such, pottery from this level is coeval with the very beginning of its usage in the Southeast European Neolithic cultural sequence. Furthermore, this earliest pottery (Dž–I) is comparable with assemblages from the near vicinity, including the oldest material from Koprivec and Pomoštica, as well as with vessels from Orlovec and Poljanica-Platoto. Similar vessel forms have also been recovered from Hotnica-Pešterata, but this material most probably represents a transition from Dž–I to Dž–II. Convincing parallels are attested in assemblages from West Anatolia, especially in the Izmir region, specifically Ulucak Va and early IV, Çukuriçi Höyük, and Yeşilova. Further details and references, in particular for the construction and interpretation of the ^{14}C-age-depth model for Džuljunica phases I and II (Fig. 16), are presented by Raiko Krauß *et al.* (*2014*).

What is important is that, (1) the ^{14}C-dates based on stratigraphic ^{14}C-age modelling for the different sites are consistent with the respective pottery synchronisms in each case at phase level, and (2) the date of 6050 calBC achieved for the incipient occupation at Džuljunica (Dž–I) represents, to the present state-of-knowledge, the very earliest Neolithic known from anywhere in Southeast Europe outside the Aegean. New radiocarbon dates from the old excavations in Koprivec measured on cattle bones confirm that Neolithic settlement in that particular region does not begin before Džuljunica (*Scheu* et al. *forthcoming*).

Conclusions

Beginning with the Pre-Pottery-Neolithic (~7500 calBC: Anatolian nomenclature. Fig. 4), the long-distance dispersal of Neolithic lifestyles from the Near East to Southeast Europe appears to have been established in a stepwise manner. Here we have focussed on achieving high-resolution dates for the introduction of farming in the circum-Aegean regions and its further dispersal into Southeast Europe. For arrival and dispersal, we distinguish two major chronological steps. The first comprises a land-based dispersal of the Neolithic from Central Anatolia to the Aegean and southern Marmara region, and – probably – also by the sea-based coastal route from the Near East. This first step, which dates (abbreviated) to ~6600 calBC (*i.e.* the onset of RCC-conditions) appears to have been consolidated within a few decades, although this remains to be validated. The second step took Neolithic lifestyles away from the Aegean littoral all the way to north-eastern Hungary, Starting at ~6050 calBC (*i.e.* towards the end of RCC-conditions); this step was completed within 200 years. We infer that these processes can partly be explained by a mitigation of climate-induced biophysical and social hazards.

Time-scales and terminology

The age-models and chronologies discussed in this paper are based on tree-ring calibrated ^{14}C-ages. Numeric ages are given on the calendric time scale using [calBP or calBC/AD] units, with AD1950 = 0 calBP as a reference year, using CalPal software (*Weninger* et al. *2008*) and the INTCAL09 data set (*Reimer* et al. *2009*). All GISP2-ages are shifted 40yrs younger than published (*Grootes* et al. *1993*), according to Bernhard Weninger and Olaf Jöris (*2008*). By this procedure, annual agreement with the recounted Greenland ice-core GICC05 age model (*Vinther* et al. *2006*) is achieved. Calibrated numeric ^{14}C-age values are based on optimised (shortest) 95% cal-scale intervals [a,b], as calculated from the calibrated age-distributions, then re-scaled to provide a calibrated *median* [defined as (a+b)/2] and a *calibrated* '±' *value* (approx. 68%) [defined as (a–b)/2]. This notation (applied in Figs. 1 and 4) is convenient for the purposes of numeric abbreviation (for tabulated calibrated ^{14}C-ages), as well as providing room for further graphic contextualisation (*e.g.,* representation of large amounts of site data and/or reference to climate records). The method is derived from probabilistic Dispersion-Calibration (*Weninger 1986*), simply, by showing only the calibrated median values and leaving out the envelope curve. To minimise age-distortion due to the non-commutative properties of the calibration operator, this so-called 'bar-code' method is based on quantum-theoretical Bayesian procedures that utilise non-normalised probabilities (*Weninger* et al. *2011*). The modelling results shown in Figure 12 (Ulucak), Figure 13 (Çukuriçi Höyük), Figure 14 (Barcin Höyük), Figure 15 (Dikili Tash), and Figure 16 (Džuljunica) were achieved by applying an automated version of the method called 'Optimizing Gaussian Monte Carlo Wiggle Matching' (oGMCWM) described in Benz *et al.* (*2012*). CalPal-internally all numeric calculations have annual precision. With the exception of oGMCWM, this reduces to decadal precision for program-external comparisons (*e.g.,* with OxCal or CALIB).

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All ^{14}C-dates used in this paper are available from: https://uni-koeln.academia.edu/BernhardWeninger/CalPal

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A new look at the introduction of the Neolithic way of life in Southeastern Europe. Changing paradigms of the expansion of the Neolithic way of life

Mehmet Özdoğan
İstanbul University, İstanbul, TR
c.mozdo@gmail.com

ABSTRACT – *Questioning when, how and even why the Neolithic way of life appeared in Europe has been one of the most debated problems of European prehistory, leading to the formulation of various explanatory models, each providing evidence to support its point of view, but without convincing others. Conventional standpoints, one-tract thinking and considering the emergence of the Neolithic way of life as a short-term event have hampered consensus, bringing discussions almost to a deadlock. Recent evidence has made it clear that the Neolithisation process in Europe was a multifarious event that went on for more than a millennium; thus, all previous hypotheses were correct with regard to their specific cases. Analytic or synthetic explicative models such as migration, colonisation, segregated infiltration, the transfer of commodities and of know-how, acculturation, assimilation, and maritime expansion that are seemingly mutually contradictory actually took place simultaneously as distinct modalities.*

IZVLEČEK – *Vprašanja kot so kdaj, kako in celo zakaj se je neolitski način življenja pojavil v Evropi predstavljajo temelje razprav o Evropski prazgodovini, ki so vodila k oblikovanju različnih razlagalnih modelov, ki so vsak zase podprti z dokazi, ki jih prinašajo, a so hkrati nezdružljivi z drugimi modeli. Tradicionalna stališča, enoumno razmišljanje) in razumevanja pojava neolitskega načina življenja kot kratkočasnega dogodka ovirajo konsenz ter so pripeljali razpravo skoraj na mrtvo točko. Nedavni dokazi kažejo, da je bil proces neolitizacije v Evropi raznolik, več kot tisočletje trajajoč pojav, tako da so prejšnje hipoteze, vsaka zase, pravilne. Analitski ali sintetski razlagalni modeli kot so migracija, kolonizacija, segregirana infiltracija, izmenjava izdelkov in znanja, akulturacija, asimilacija in pomorska ekspanzija, ki so si navidezno medsebojno nasprotujoči, so se dejansko lahko odvijali sočasno kot različne modalitete.*

KEY WORDS – *Neolithic dispersal; Neolithic package; segregated migration; Marmara region; Anatolia*

Prelude to the problem

Discussions on when and how the Neolithic way of life was introduced to Europe have a century-long history, a trajectory of thinking and arguments swaying from one extreme to the other (*Budja 1993; 2004; Özdoğan 1995; Sherratt 1997; Tringham 2000*). Initially, almost up to the late 1970s, there was not much to discuss; endemic diffusion – almost in colonisation mode – was considered the indubitable explanation for the emergence of the Neolithic way of life in regions outside the Near East; thus, debates mostly targeted its subsequent stages. Here, it should be noted that in the decades following World War II, there was a growing tendency in social sciences to unscramble conventional approaches; as is often the case, it took some time for the quest to break away from the traditional frameworks to influence European prehistoric archaeologists (*Barford 2002; Bentley 2006*). It mainly took the form of a total denial of cultural diffusion; thus, expansionist models propagating the Near East or Anatolia as the origin of European Neolithic were met with considerable reaction, at the same time triggering a fierce debate between defenders of conventional models and defenders of the autonomy of the Eu-

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ropean Neolithic. Inevitably, through the final quarter of the last century, the question 'How?' became the central focus of discussions; a number of controversial models were formulated and debated. For some years there has been a shift back to what might be termed 'neo-diffusionism'; nevertheless, it is far removed from the over-simplistic narratives of previous decades.

At the time when we presented a paper to *Documenta Prehistorica* almost 20 years ago (*Özdoğan 1995*), very little was known from the Northwestern parts of Turkey on the early stages of Neolithisation, so most of what we had noted was based on intuitions rather than on concrete data. In that paper, we stressed the fact that biases in the quest for the beginning of Neolithic life in Europe had their roots in the unbalanced distribution of evidence between Southeastern Europe and Anatolia: while the former was known through hundreds of excavations, the work on Anatolia was minimal. Nevertheless, in spite of the paucity of evidence, certain indicators hinted at connections between the Neolithic assemblages of the Balkans and Central Anatolia, making it possible to surmise an endemic movement out of the Anatolian Plateau in the direction of Southeastern Europe. However, at that time, no data were available from the interim zone, *i.e.* the region around the Sea of Marmara, so we left our view as a suggestion. Rather paradoxically, over-documentation or the excessive number of studies in the Balkans had paved the way for other biases, the overall picture being blurred by being lost in details. Throughout Southeastern Europe there has been an apparent over-emphasis of the stylistic features of pottery assemblages, overriding other components of the material evidence, with cultures occasionally being defined by scrupulous categorisations of decorative elements – in a way, 'Balkanising' cultures that are more or less similar to the level of the smallest geographic unit. Nevertheless, with the inflow of new evidence from the Western and Northwestern parts of Turkey, it became possible to elaborate the picture we had drawn 20 years ago. Although there are still considerable gaps in our knowledge and various pitfalls in assessing the evidence, it is now at least plausible to develop a comprehensible view with a supra-regional perspective based on subtle evidence. In this respect, one more point needs to be defined: the archaeologies in Southeastern Europe and in Anatolia-Near East developed as distinct fields of specialisation, with little or no contact between them for decades, thus hampering the flow of knowledge, modalities and terminologies as well; the significant difference between the Anatolian and Balkan archaeologies in, for example, what is meant by terms such as 'culture' or 'material assemblage' had considerable implications for developing a mutual understanding between the two sides (*Özdoğan 2004*). In the tradition of Anatolian archaeology, as in most Near Eastern archaeology, proxies other then stylistic variants are taken into consideration to define cultures in time and in space. What is denominated as the 'Halaf' culture best exemplifies the conceptual approach of Near Eastern archaeology. Halaf culture extends from western Iran to Cilicia, in an area comparable in size to the Balkan Peninsula, with numerous stylistic variants that are much more apparent then those between Sesklo – Starčevo – Kremikovci – Gradesnitsa – Karanovo I – Körös and Çris, although it is still called Halaf Culture.

One significant novelty of the last two decades has been the shift in research priorities, both in Anatolia and in the Balkans, which regretfully has not helped to answer the ultimate questions as much as it could have. While Neolithic sites began to be excavated in previously unexplored regions of Western Anatolia, the number of Neolithic excavations in the Balkans, where the focus of interest was diverted to the later periods of the Neolithic, declined sharply. Having large-scale exposures is one of the principle excavation strategies in Turkey, whereas most of the recent work in Southeastern Europe, with the exception of rescue operations, are carried out as restricted soundings and even as core-drillings. Evidently, this also makes it more difficult to make secure comparisons between the two regions.

Archaeology in Anatolia developed from 'Mesopotamia-centric' roots, almost totally overlooking what had taken place in the west, or more specifically, in the prehistory of the Balkans. Although this has been somewhat ameliorated in the last decade or so, the aftermath of Mesopotamia-centric thinking still prevails (*Özdoğan 1997*). Thus, collating the archaeological evidence of Anatolia with the Balkans has its particular problems, which are apparent even in border regions that are separated only by present-day political borders. In spite of all the drawbacks, some progress has been made to improve the development of mutual understanding between the archaeologies of Anatolia and the Balkans by at least being aware of what is happening on the other side.

Within the framework of this paper, it is not possible to present even a conspectus on the newly emerging picture; instead, we shall be concerned with new ways of looking at this century-old problem from the standpoint of changing paradigms. The term 'Neolithic package' seems to have taken a central place in current debates on the origin and dispersal of the Neolithic way of life; however, it is also clear that what is implied by the term 'Neolithic package' is not always the same. Accordingly, for the sake of clarity, we first have considered looking into the coverage and implications of this term.

The 'Neolithic package'

The concept of Neolithic grew with what had been defined as the 'primaries', consisting of constructed spaces indicating permanent habitation, domestic animals, cultivated cereals and legumes indicating food production, pottery vessels indicating storage and cooking, ground stone objects indicating food processing, celts indicating a new technology of finishing stone tools by polishing. Until recently, the presence of 'primaries' sufficed to denominate a site as Neolithic, as the Neolithic period was viewed as a period of simple farming communities striving to survive and gain dominance over their habitats. Thus, detecting the absence or presence of the primaries was, more or less, the prime objective of research for a long time. While most components of the package such as architecture, pottery and ground stone are easy to detect, determining agricultural practices and domestication of animals necessitated work by special experts; thus working on floral and faunal remains soon became the main objective of Neolithic excavations. Through the meticulous work of natural scientists, the much needed data leading to summarizing the stages towards food production became available; however, at the same time, the Neolithic came to be conceptualised in terms of subsistence, overlooking the structure of cultural and social entities. Moreover, the prominence given to subsistence patterns has hampered the search for answers to other questions, including 'origins' or 'identity', that are essential to understanding the modalities of Neolithic dispersal.

The recent picture of the Neolithic of the Near East is far more sophisticated and multifarious than what could have been imagined in the previous decades, necessitating other sets of questions that would enable us to follow origins, sequences of developments, trajectories of dispersal, spheres of interaction *etc*. It also became evident that in the early, pristine stages of Neolithisation, what was being consumed as food was not as important for Neolithic communities as we have hypothesised. It is apparent that Neolithic communities did not identify themselves with how they procured food, while some remained hunters for long periods, others were utilising various cereals or legumes, or managing sheep, goat or cattle. Regardless of their subsistence pattern, they interacted, sharing knowledge, which clearly indicates that their socio-cultural identity was the prime marker that differentiated them from other groups. Thus, the course of our thinking on Neolithic communities fixed on the efficiency of food production has to be revised to enable new paradigms to be developed for holistic approaches (*Özdoğan 2002*).

With the increase in our knowledge of the Neolithic Period defining what is implied by the term, the Neolithic became far more difficult than before; now, the definition varies according to the types of question being asked. However, any hypothesis based on conventional 'primary' elements would fail to answer even the simplest questions. Although the term 'Neolithic package' has emerged to mark the multifarious outlines of Neolithic cultures, considering it as a single, homogenous package is as misleading as the earlier assumptions. The Neolithic package has to be defined and specified both in time and space as distinct packages.

Following this idea, we have devised a tentative list of proxies to specify and diagnose Neolithic packages and tested them to construe various clusters, spheres of interaction, and trajectories of dispersal. As our approach and methodology have been described elsewhere in detail (*Özdoğan 2010b; 2011a*), this paper is limited to presenting some of the basic issues that are relevant to the discussions here. As the first step, we began by defining 52 components of the Neolithic assemblages that we considered as indicative of tracing cultural clusters (*Özdoğan 2010b.Tables*). These ranged from settlement layout to architectural designs to symbolic or prestige objects to utilitarian tools that reflected either certain technologies or traditions. During the later stages of our work, we extended the list to 94 by adding new components. The results are by no means conclusive, and are apt to be expanded and elaborated by time; however, at least they provide a subtle basis for investigating certain problems. The list should be considered as a database intended to cover various Early Neolithic assemblages in an extensive geography, as a guide to what to look for. Methodologically, our approach is basically the same as what was devised to trace the distribution patterns of the 'crop package' of founder crops (*Colledge, Conolly 2007*).

The next stage of our work has been to define spatial and chronological zones that would be the final basis for sorting the list, enabling us to trace the distribution patterns of the components of the Neolithic package. With a supra-regional view, trying to avoid local variations, we defined seven geographic zones, each of which has more or less similar traits during the initial stage of Neolithisation (*Özdoğan 2012.Fig. 1*); the annotated geographic units used to plot entities of the Neolithic package will be described briefly.

Designating geographic zones

Seven geographic zones that could potentially contribute to tracing the spatial distribution patterns of the Neolithic package have been defined (Fig. 1); these are:

Zone A: The main core area of Neolithisation, covering the Central Anatolian plateau, the Levant, northern Syro-Mesopotamia, Southeastern Turkey and Western Iran. The Neolithic way of life emerged within this zone as early as the 11th millennium calBC and continued to develop for some 3000 years without expanding its boundaries or having a detectable impact on other regions. The vast territory that has been denominated as the core or the formative zone of primary Neolithisation is not a uniform entity, but consists of at least three sub-divisions: the Central Anatolian plateau, Southern Levant, and the region conveniently named Greater Mesopotamia; each featured its own particular settlement pattern, architectural design, material assemblage, burial customs, symbolic indicators and technologies. However, in spite of the apparent differences, there was still an intensive interaction and, more significantly, sharing of knowledge throughout the entire area of Zone A, regardless of the diversity of their cultural systems.

Zone B: The immediate periphery of Zone A, where the components of the Neolithic package began to appear by the turn of the 8th to the 7th millennium BC, although rather sporadically. The boundaries of this zone are not well defined, seemingly changing through time. The Western parts of the Anatolian peninsula and, possibly, the littoral areas of the Aegean comprise Zone B. Most of the terrain covered by Zone B comprises small intermountain plains, some – like those in the Lakes district – occupied by lakes and alluvial valleys extending along tectonic fault-lines. The picture along the littoral areas of the Mediterranean coast is not that clear. The maritime route following the coastline of the Neolithic era seems to have been as effective as that of the land route (*Özdoğan 2011b*).

The appearance of Neolithic elements in the region at the initial stage seems to have been rather sporadic and random. The initial stage seems to continue until about 6500–6400 BC, being followed by more intensive and organised waves of intrusion, each following different trajectories and bringing together distinct Neolithic packages, with the final and more intensive wave dating to a time around 5600 BC. Maritime routes, whether following the coast or not, must have been as important as those of the land-routes through Anatolia in the expansion of Neolithic communities (*Perlès 2005; Özdoğan 2011b*). It is also of interest to note that the communities established in the new areas mentally and physically were not totally detached from their land of origin. Through the initial stages of Neolithisation up to the end of the Early Chalcolithic Period, communities living in these areas were evidently aware of the changes taking place in the core area. David Anthony (*1997*) calls sustained relations with the old homeland by constant back-and-forth movements between the core and periphery as "*chain migration*" (*Anthony 1997.24*); the same generalisation holds for Zones C and D.

Zone C: This covers the north-south oriented corridor in inner-west Anatolia and the eastern parts of the Sea of Marmara. At its southern end, Zone C touches the Lakes District of Zone B. It seems highly probable that the initial wave out of Central Anatolia, after reaching the Lakes District, diverged into two branches, one going westward into Zone B along the valley of the Menderes River and the other northwards along the Sakarya River, reaching eastern Marmara by 6500–6400 BC, taking with them the Neolithic package characterised by the so-called 'monochrome' assemblage, which in time will emerge as the Fikirtepe group. In an overview, this process of Neolithisation differs from the others. Firstly, the coastal regions of eastern Marmara were densely occupied by the Mesolithic communities known as the Ağaçlı group. There, as evidenced at sites such as Yenikapı, Fikirtepe and Pendik, both groups peacefully merge, developing a coastal variant of the Fikirtepe culture that differs from those of inland sites such as Demirci Höyük, Barçın and Kanlıtaş Höyük. The migration of Neolithic farmers after integrating with the local communities ends in the region around the Istanbul area, with no attempt to move further into Thrace. Secondly, this zone was totally avoided by the second and more massive movement

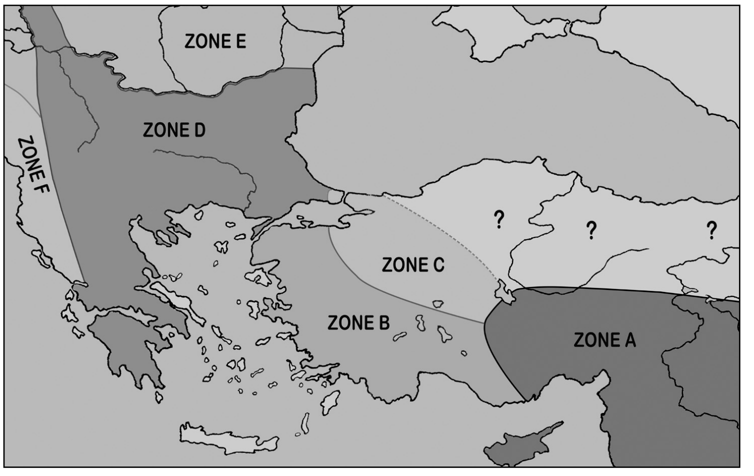


Fig. 1. Geographic Zones designed to follow Neolithic packages.

which brought with it the Neolithic package characterised by the red-slipped pottery assemblage. We were rather startled by the different compositions of the Neolithic packages of Yenikapı-Fikirtepe-Yarımburgaz group and that of Aşağı Pınar in Eastern Thrace, only 100km away; this will be further detailed below

Zone D: This covers most of the Aegean and the Balkans, with the exception of the Adriatic littoral. Evidently, this vast territory could also have been broken into several smaller units, the most apparent being the southern parts of the Greek peninsula that feature rather distinct from most of the Balkans. As noted for Zone B, the maritime routes seem to have been more effective in bringing in Neolithic elements. Perlès (*2005*) has explicitly noted that there must have been some direct connections between the northern Levant and mainland Greece that bypassed the Anatolian peninsula.

The initial wave of Neolithic expansion reached some parts of Zone D by 6500– 6400 BC, though extremely sparsely and even indistinctly in most areas. As in Zones B and C, this initial stage is characterised by the Neolithic package of monochrome pottery. Although infiltration into the region seems to have been sustained for some centuries, at around 6100–5900 BC there is a considerably massive and organised migration, as evidenced by the rapid foundation of hundreds of new settlement sites in almost every alluvial plain and valley throughout Greece and the Balkans, bringing with them the package of the red-slipped horizon. Throughout the region, the material assemblages present an apparent uniformity, and almost every component of the Neolithic package appears in a fully developed stage. The sudden appearance of similar or even identical elements throughout the vast geographical area extending from the Aegean to the Danube indicates that the occupation by Neolithic migrants was very rapid.

In parts of Southeastern Europe where there was a strong presence of Mesolithic communities, the process of Neolithisation took place in different modalities that varied from region to region, either as gradual acculturation or adaptation, as in the Iron Gates and Western Balkans (*Bonsall 2007; Borić 1999; 2011*) or as in the case of Eastern Marmara, the peaceful merging of two communities. It is of interest to note that Zone D, after following the trends in Zones A and B in the initial stages, later became detached to develop as a new core for the Neolithisation of areas further in Central Europe.

Zone E: This covers those parts of Central and Western Europe where the Linear Band Ceramic assemblages appear as a uniform entity. In spite of the discrepancy regarding its origins, during its later stages it developed as an independent identity, being totally detached from events that took place at the core area of primary Neolithisation (*Bánffy, Sümegi 2011; Oross, Bánffy 2009*).

Zone F: This is the Central and Western Mediterranean, the region of so-called Impresso and of Cardium-Impresso groups. This zone can also be broken into numerous regional variants, partly due to distinct environmental features, partly because of the strong presence of Mesolithic groups preceding the arrival of Neolithic elements. Although the appearance of Neolithic package happened as early as the mid-6th millennium BC, indicating the effective implementation of maritime connections through out the Mediterranean basin, it is also clear that the dispersal of Neolithic elements was not due to endemic movements, but resulted from the transfer of commodities and/or know-how.

Zone G: This covers the northeastern parts of Turkey and most of Caucasia, where the appearance of Neolithic elements appear as late as the 6th millennium BC, seemingly not due to an endemic movement, but to the transfer of commodities and know-how.

The geographic zones noted above, with the exception of Zone A, should not be considered as definite entities, but more as starting points for testing working hypotheses. Firstly, none of them has clear boundaries; moreover, their areas and position in the process of Neolithisation changes through time. Likewise, any of them could be further segregated into different units or merged with each other. Nevertheless, the template suggested here enables us to trace the distribution patterns of various Neolithic packages and demonstrate regions of origin. Even a preliminary assessment has revealed that the spread of Neolithic culture in Zones B, C and D was due to multiple waves of very rapid endemic movements covering large territories relatively quickly. We are aware that what has been noted above covers a wide and diversified geographical area, inevitably leading to questions about the pace at which communities and or commodities could move.

Pace of Neolithic dispersal

It has often been argued that the movement of communities that lack pack animals must be very slow, so seeking analogies to present-day nomadic tribes would be erroneous. Accordingly, various models have been suggested for the spread of Neolithic communities, such as leap-frog and wave of advance; almost all of them consider a very slow pace of expansion, almost in the range of one kilometre per year. In calculating the pace of migration, demographic built-up, the time needed for demographic pressure to built up to a level that would trigger people to move in search of new areas to settle has been one of the main concerns. Most of these models have been explicitly described and discussed in a number of works, so we refrain even from presenting a review of these (*Bellwood, Renfrew 2002; Bocquet-Appel* et al. *2009; Harris 2003; Pinhasi 2003; Price 2000; Richards 2003; Zvelebil 2002; 2005*). Before going into problems related to demography, which we deal with below, some facts concerning the pace of the movements need to be discussed.

In estimating the pace of Neolithic expansion, the available radiometric dates are not of much help in specifying the time of the initial stages of the movement because, firstly, the margins of absolute dates are wide, and secondly, those from the basal layers of occupation are very few in number and rather random. Nevertheless, they help to place cultural assemblages in the main stages of Neolithic dispersal, such as the 7200–6400, 6400–5900, 5900–5600 BC general slots.

Accordingly, until more precise absolute dates are available, other agents have to be looked at to view the pace of dispersal. In this respect, the level of uniformity and similarities in the stylistic details of material assemblages within Zones B, C and D is remarkable. For example, what we have been recovering in Layer 7 of Aşağı Pınar in Eastern Thrace is identical to contemporary material not only from Bulgaria, but also Macedonia and the Danubian basin, as if the same craftsmen had made them (Fig. 2). In our view, this could only have occurred if the expansion was very rapid, giving no time for stylistic changes or the introduction of new components to the assemblage. So the problem is: how rapid can the movement of Neolithic communities that are in search of new areas of habitation have been? Although – as mentioned above – estimates deduced from the pace of migration of present-day nomadic groups is considered to be misleading; it should also be considered that, even if they possess pack animals, the speed of their movement depends on the distance a flock of sheep or goats can walk in a day. In their annual migration from wintering grounds to summer pastures, modern sheep-herding Turcoman tribes move an average of 8 to 15km per day, and within two to three weeks they travel 150 to 250km to cross over the Taurus Mountains. In alluvial plains or steppes, the distance covered in a day can be even greater (*Bates 1973; Danışmaz 2012; Hütteroth 1959*). Even if this is considered an exaggerated estimate for movement through hostile environments, from Aşağı Pınar in Eastern Thrace to the basin of the Danube, which is only 250km as the crow flies, can easily be covered during a season. Accordingly, once people have a motive to migrate, the distances that we conceptualise as unfeasible are actually achievable within reasonable periods. We

Fig. 2. Clay figurines of Aşağı Pınar 7; finds identical to these are extensively distributed throughout almost the entire Balkan Peninsula.

thus surmise that the regions of the Karanovo I and related groups, for example, could be occupied by immigrating farmers within a year or two, providing their numbers were sufficient to fill this area. This leads to the question of how to differentiate between settlements founded by immigrant groups and local communities that were Neolithicised either by acculturation or adaptation.

Identifying endemic movements: 'village life' as an indicator

To what extent migrant farmers were the actual founders of the Early Neolithic sites of Southeastern Europe and how these can be differentiated from those due to cultural interaction is a critical question in understanding the process of Neolithisation; no matter how simple it looks, the answer is not easy. The presence or absence of certain components of the Neolithic package and, in particular, types of artefacts, are not dependable criteria for answering this question, as commodities and technologies can easily be transferred and adopted. Likewise, certain utilitarian or prestige items that require skill and experienced know-how to manufacture could have been distributed by wandering craftsmen; thus, by following this line of thought, a consensus is difficult to reach. On the other hand, 'village life' is a more dependable criterion if what is implied by the term can be properly defined.

Settlements in the core area of primary Neolithisation, Zone A, had become 'villages' as early as the beginning of the Pre-Pottery Neolithic stage, developing life-styles markedly different from those of 'other' communities. Alhough discerning criteria for village life is not easy, regardless of the artefactual assemblages, even by looking to the plan of a settlement anywhere in Zone A, be it in the Southern Levant or in Central Anatolia, they clearly reveal a picture of a village in the true sense of the term, where the presence of complex social order is apparent (Fig. 3). Thus, Neolithic farmers on the move had behind them the social memory of a tradition established several millennia previously, which can be clearly viewed in the newly founded settlements in Zones B, C and D. It seems evident that the immigrant groups could not give up the modalities of life to which they were accustomed when settling down. The social modalities of village life are not easy to adapt for an outsider. It requires long experience and a tradition to be comfortable with; thus, it cannot be imitated in a short period. It is for this reason that we included way of village life as one of the major components on our list. Even the earliest settlements in Zones B, C and in nuclear sectors of D are villages in the sense of Anatolian and/or Near Eastern ones, regardless of their size, layout or construction techniques. However, none of those on the fringes of Zone D, and almost none that are in Zone F are habitation sites in the tradition of the eastern Neolithic. Accordingly, as a working hypothesis, the type of habitation is apt to be an indicator in defining the area covered by endemic movements.

Social meaning attached to the living space is consequential to the development of village life; it is bound tightly to the concept of a 'new way of life' and is another criteria with which to identify settlements established by immigrant farmers. In the Zone A tradition, buildings are not mere shelters, but homes, structures ascribed to new values; likewise, compared with conventional dwellings, Neolithic houses are multifunctional, closely reflecting modalities of the new way of life (*Özdoğan 2010a; Watkins 1990; 1996; 2012*). The transition from simple huts to houses, the consolidation of the living space to comply with the expectations of the Neolithic way of life, took place in Zone A at a very early stage. Even during the Pre-Pottery Neolithic A period, when

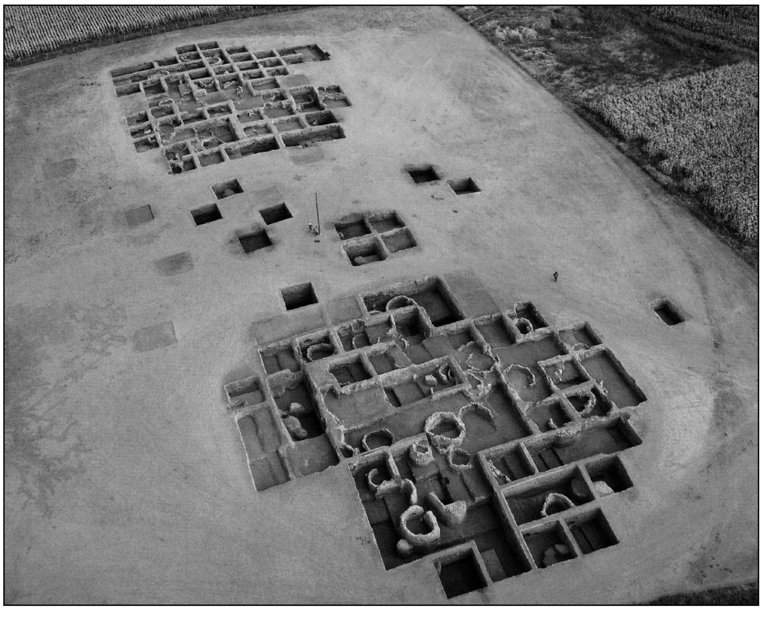


Fig. 3. Aerial view of Körtiktepe, a Pre-Pottery Neolithic A site in Southeastern Turkey (from* Özkaya *et al.* 2013*).

the building plans were circular, they were already houses, not simple huts (Figs. 3–4). The development of building techniques that required structural innovations was a long process; through trial and error; stable rectangular-plan buildings had already appeared in Zone A by the transition from Pre-Pottery Neolithic A to B (*Özdoğan 2010a*). Accordingly, by the last quarter of the 9th millennium BC, buildings throughout Zone A were rectangular in plan and multifunctional, representing well-developed structural practices designed to leave open spaces in between for other activities. On the other hand, the dwellings of contemporary Mesolithic communities were exclusively light, hut-like structures, round or oval in plan. Immigrant farmers coming from Central Anatolia were accustomed to solid houses. After entering the temperate forest zone, possibly in Zone B, they began practicing with wood as a building material and rather quickly became acquainted with using wooden posts and timber to build rectangular, solid and multifunctional houses. Although some round plan buildings occur at newly established coastal sites such as Hoca Çeşme or Ege Gübre, they are also solid structures with stone foundations incomparable to the hut-like dwellings as in the peripheral areas of Zone D.

Accordingly, we also consider the presence of huts or homes as an indicator to set settlements founded by immigrants apart from others. In this respect, the difference between the settlements of coastal and inland sites of the Fikirtepe culture presents a fine example (*Özdoğan 2013a*). Sites located distant from the coastal areas without a Mesolithic substratum are villages in the true sense of Neolithic settlements of the core area. However, at coastal sites where local Mesolithic groups merged to live together with the newcomers, the picture is notably different. Recent excavations at Pendik revealed a rectangular mud-slab building (Fig. 5) in the same layer, with numerous round or ovoid wattle-and-daub hut-like dwellings (*Kızıltan 2013*). Likewise, Starcevo, Körös and Cris settlements in the marginal areas of Zone D also differ from those in the central sections as they consist of huts, and the settlement habitation areas lack the indicators of ‘village life’. Accordingly, it is possible to surmise that the endemic movement covered only parts of the Balkan Peninsula, mainly northern Greece, Eastern Thrace, Bulgaria, Macedonia and only parts of Serbia.

Demography

In seeking modalities that might have triggered communities to leave their homeland, increases in population that exceeded the carrying capacity of the terrain have always been on the agenda as being among the most probable options. It has been generally argued that deterritorialisation of habitat either by intensive consumption or climatic fluctuations, or by the overpopulation due to the optimal living conditions brought by the Neolithic way of life, were the main agents leading to the momentum to migrate (*Bocquet-Appel, Bar-Yosef 2008; Bar-Yosef 2009; Clare* et al. *2008; Goring-Morris, Belfer-Cohen 2008; Rollefson, Köhler-Rollefson 1989; Weninger* et al. *2009; Sherratt 2004*). Some sort of social unrest or turbulence has also been considered as a reason for massive movements from the core area to other regions (*Clare 2010; Özdoğan 2013a*). Although what may have led populations to migrate is beyond the

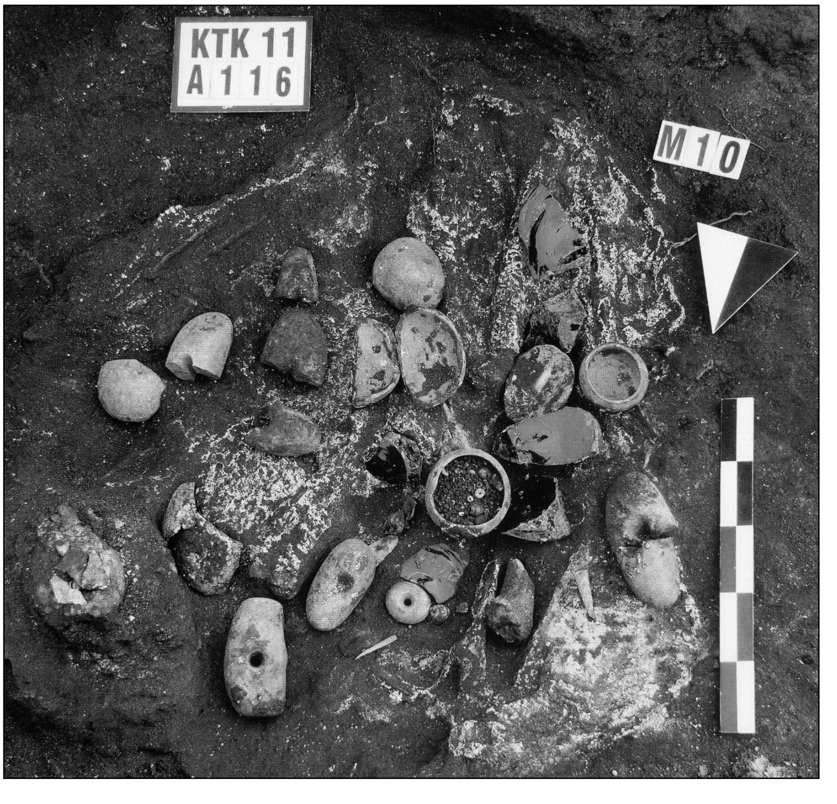


Fig. 4. Burial gifts of a sub-floor burial from a round building of the Pre-Pottery Neolithic A at Körtiktepe (from* Özkaya *et al.* 2013*).

concern of this paper, there is clear evidence of population displacements both in the southern Levant and in Southeastern Anatolia, some sites being abandoned, others diminishing in size, eventually leading to what has been termed the 'Neolithic Collapse' by the last quarter of the 8th millennium BC; this is also a period when previously unattested elements of the Levantine and Southeastern Anatolian Neolithic cultures begin appearing on the Central Plateau (*Özdoğan 2013a; 2014*). It is thus possible to surmise that some groups, mainly farmers and herders with the now fully domesticated animals, had left the eastern parts of Zone A, moved into Central Anatolia and merged with the local communities, with which they had long-standing connections. It is of interest that no component of the dominant clerical system of the east was transferred to the west; seemingly the movement was by ordinary people, while the ruling elite or the clergy remained, which is highly suggestive of some sort of social turmoil (*Özdoğan 2008. 141*). It also seems plausible that after entering Central Anatolia, some people kept moving west, firstly as stray bands and then in a massive and more organized fashion. However, whether prior to the mass movement of around 6000 BC, the level of population growth had reached a level that would cover Zone D is a question that still needs to be answered.

Related to the demography question, it should also be taken into account that the westward expansion of Neolithic farmers was not a singular event, but took place in multiple installments extending through a millennium, each wave bringing together certain components of the Neolithic package and having its distinct trajectory. The evidence from Neolithic excavations in Western Turkey indicates that in deciding locations to settle, migrating groups omitted places that had been occupied by the previous newcomers. Accordingly, the content of the Neolithic package differs not only in time, but also locality. For example, in a relatively small area around İzmir, five Neolithic sites have recently been excavated, Çukuriçi, Latmos Beşparmak, Ege Gübre, Ulucak and Yeşilova, and there are apparent differences among the material assemblages of layers that are even contemporaneous.

A case study: comparing the Neolithic packages of two neighboring regions

With the onset of numerous Neolithic excavations now mounting to 13 altogether, the region around the Sea of Marmara provides the means to exemplify some of the issues mentioned in this paper. As the details of the sites with extensive bibliography have been published elsewhere, they will not be repeated here (*Özdoğan* et al. *2013*). Among them, Gürpınar, Çoşkuntepe, Uğurlu and Hoca Çeşme, are located in the western sector of the region, almost along the coastal strip of the Aegean; Yarımburgaz, Yenikapı, Fikirtepe, Pendik, Ilıpınar, Menteşe, Barçın in the eastern sector; and Aktopraklık and Aşağı Pınar in the interim zones by geographic location (Fig. 6). Among these sites, Fikirtepe was the first to be excavated (1952–54) followed by Pendik, Yarımburgaz, all located in the eastern part of the region. When we began working on the Neolithic assemblages of these sites in the 1980s, even at the initial stage of our assessment, it was possible to detect numerous finds that are similar to the Neolithic assemblages of both the Lakes District in Turkey and the so-called Karanovo horizon in the Balkans. Similarities in tool types such as the bone spoons, belthooks *etc*. were too specific to be explained by parallel developments. This led us to conclude that the Fikirtepe culture of Eastern Marmara derived from the Neolithic sub-stratum of the Lakes District, at that time known mainly from Hacılar, Kuruçay, Erbaba and Süberde, and that it was ancestral to the

Fig. 5. The rectangular mud-slab building at Pendik excavated in 2013 (courtesy of the Istanbul Archaeological Museums).

Neolithic cultures of Bulgaria (*Özdoğan 1995; 1997*). With that view in mind, through our early work in Thrace, we tried to detect elements specific to the Fikirtepe culture in Thrace and were somewhat misled by the presence of certain dark-coloured wares. The absence of certain elements of the Karanovo assemblage at Fikirtepe, such as red-slipped painted wares, tubular lugs, pedestalled bases was rather startling, but we considered that the second wave that brought red-slipped painted pottery to the Balkans had bypassed Eastern Marmara. Excavations at Hoca Çeşme were in a way an indicator of the difference in the Neolithic assemblages between the eastern and western parts of the Marmara region, but not conclusive, as the excavations were on a rather limited scale. Excavations at Aşağı Pınar provided ample evidence to draw a clear picture; firstly, because there was a clear uninterrupted cultural deposition covering the entire sequence of the Early Neolithic period and the large extent of the exposures; it is now evident that the basal layers of Aşağı Pınar, layer 8, pre-dates Karanovo I and is contemporary with early Fikirtepe, while Aşağı Pınar 7 is contemporary with Karanovo I and Yarımburgaz 4 (*Özdoğan 2013b*). In an overview, neither Aşağı Pınar 7 or 8 have elements typical of Fikirtepe-Yarımburgaz group with the exception of elements that are common to all of Zone A and B; on the other hand, the basal layers of Aşağı Pınar have the characteristic features of pre-Karanovo and Karanovo I cultures, also sharing the same assemblages as sites such as Hoca Çeşme, Uğurlu *etc.* in western Marmara. Some of the most characteristic features will be discussed in some detail below.

One of the most striking differences between the east and west Marmara assemblages is apparent in the lithic industries (*Gatsov 2001; 2003*); the sites of the Fikirtepe culture, both the coastal sites such as Yenikapı, Fikirtepe, Pendik and the inland sites such as Ilıpınar, Barçın, Menteşe, Aktopraklı have a very distinctive micro-blade industry, notably featured by pressure flaking and bullet cores (Fig. 7). Round curricular scrapers, keeled scrapers, end scrapers and backed blades are among the most common tool types. There is also some obsidian in the assemblages, mostly in the form of bladelets. However, as in the case of the Karanovo I sites, at all sites of the western group, including Aşağı Pınar, there is a general deficiency of lithic tools. The featured Karanovo I blade is the only clear-cut made tool (Fig. 8), others being mostly ad hoc pieces. There is some obsidian at coastal sites, but it is completely absent from Aşağı Pınar. The absence of developed lithic tools in the Thracian sites is rather astounding, as pressure-flaked bullet core technology with micro-blades occurs throughout Zone B.

Another striking difference is in the burial customs. As evidenced at Çatal Höyük in Central Anatolia, primary, secondary or collective intramural burials was a common practice in Zone A, but seldom in Zone B and almost absent from Zone D. On the other hand every site in Zone C has revealed large numbers of burials comparable to those of Zone A, the most abundant being at Ilıpınar, Pendik, Yenikapı and Aktopraklık (Figs. 9–10). With the exception of a few rather random scatters of bones, no burials have been recovered at any of the Thracian sites.

Clay figurines found in hundreds at almost every site in Zone B and D, including west Thracian ones, hardly exist at sites in Zone C. The recovery of a wooden figurine at Yenikapı (Fig. 11) suggests that wood might have been preferred to clay in eastern Marmara, but this does not exclude that wooden figurines might have been present in other regions and have not been recovered, as none had the conditions of preservation found at Yenikapı.

The scarcity of polished stone tools in eastern Marmara sites is interesting; well-finished celts or adzes occur, but in minimal numbers. Considering the wooded environment in which they lived, this also is strange. West Thracian sites, and particularly Aşağı

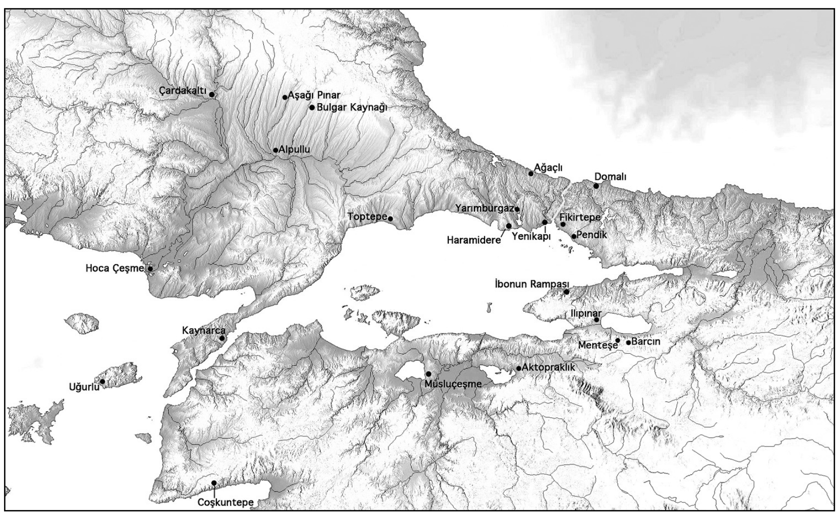


Fig. 6. Excavated Neolithic sites in the Marmara region.

Pınar, have yielded vast amounts of polished stone tools of all sizes and shapes. Other particulars in comparing the two assemblages and, especially those related to pottery, can easily be seen in Figure 12; we will not go into details. Considering both the similarities, as well as the differences among the assemblages, simple explanations such as necessity or environmental concerns would not suffice to answer the question why. Nevertheless, knowing that at this stage a clear answer is not possible, we still find it worth contemplating.

Fig. 7. Aktopraklık; bullet cores typical of the eastern Marmara Neolithic.

As we have already noted, the presence or absence of certain commodities, whether utilitarian or prestige, can be the result of a number of reasons. On the other hand, ritual and symbolic practices, as in the lifestyle, are more resistant to change. In the case of Zone C, the presence of burials and the absence of clay figurines are suggestive of identities distinct from those that occupied Zone B and D, necessitating an examination of the assemblages of Zone A for similar traits. During the Pre-Pottery Neolithic stage, particularly in Southeastern Anatolia and the Levant, clay female figurines do not stand out among the most significant symbolic indicators. They are incomparably crude compared to those in stone, and in many cases are indistinct in form, occurring together with male and animal figurines in domestic areas; the prominent appearance of clay female figurines in the Neolithic assemblages happens in the transition to the Pottery Neolithic period. On the other hand, intramural burial, primary, secondary or collective, was a widespread practice through the Pre-Pottery Neolithic period, but by the transitional period to the Pottery Neolithic intramural burials disappeared from the eastern parts of Zone A. Seemingly, burials occur in cemeteries that are not in the immediate vicinities of the settlements. In this respect, Central Anatolia stands out as an exceptional area, as evidenced at Çatal Höyük, where the tradition of intramural burials was sustained. What is of interest is that while communities moving westward to Zone B did not bring with them the tradition of burying the dead within or nearby the settlement, those in Zone C do maintain the tradition. While the number of human burials that have been recovered at over 300 sites excavated in Zones B and D is less than a few dozen, the number of excavated skeletons is over 300 only at Pendik, Ilıpınar and Aktopraklık (Figs. 9–10). It thus seems plausible to surmise that groups of diverse origin, each having their particular social habits, were on the move. As we have already noted, we use this case to exemplify our trajectory in looking at Neolithic dispersal, being fully aware that much more data has still to be procured to draw a conclusive picture.

Concluding remarks

There has been an almost sudden inflow of new data coming from all over the Near East, Anatolia and Southeastern Europe, shaking the foundations of what we had taken to be the Neolithic. The picture emerging now is so different from the conventional one that some more time is still needed for it to settle in and de-contextualise in order to become part

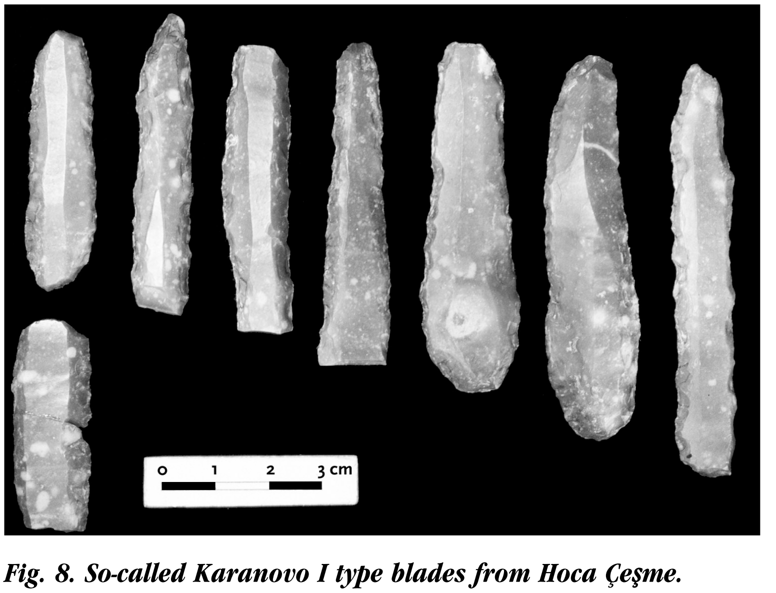


Fig. 8. So-called Karanovo I type blades from Hoca Çeşme.

of new conceptual approaches. Only then will it be possible to adjust our perception of Neolithic identity. It is evidently not easy to avoid clichéd definitions that are so deeply rooted, and as already noted, more time is needed to develop a new way of looking at old problems. What we have presented in this paper is by no means conclusive and should be considered as a quest to develop new trajectories for approaching the problem. We tried to stress the primal difference between the core and periphery. Any discussion of problems related to the dispersal of the Neolithic way of life inevitably involves looking at a vast territory through a supra-regional perspective. In this respect, narrowed over-specialisations are an obstruction, since to most of the archaeologists working in the core area, events that took place on the exterior at later dates are simply uninteresting. On the other hand, most colleagues working on regions of secondary or late Neolithisation, such as Europe or Central Asia, lack even a basic knowledge of the core area, as they are so much involved with the problems of their own regions. The contact zones on the borders of major cultural entities are generally overlooked, as their material evidence is atypical of neighboring regions, making it difficult to establish 'mental' bridges between the two areas. What is important is to maintain a delicate balance between over-simplistic generalisations and becoming lost in the details of the narrow confines of selective artefact typology; the latter obscures the overall picture by distracting the focus from the primary evidence to subsidiary issues. With these in mind, we conclude by noting certain traits that may help to develop supra-regional perspectives when examining the dispersal of the Neolithic way of life.

Fig. 9. Neolithic burials from the 2013 excavations at Pendik (courtesy of the İstanbul Archaeological Museums).

All of the components of the Neolithic package that are present in Zones B to E have antecedents in Zone A, but in different ratios. An item that might be very rare in Zone A may turn out to be a common item or continue as a prestige object in any of the other zones. For example, 'bone spoons', 'festooned bone objects' and 'pintaderas' (Figs. 13–15) occur at random in some of the Pre-Pottery Neolithic assembla-

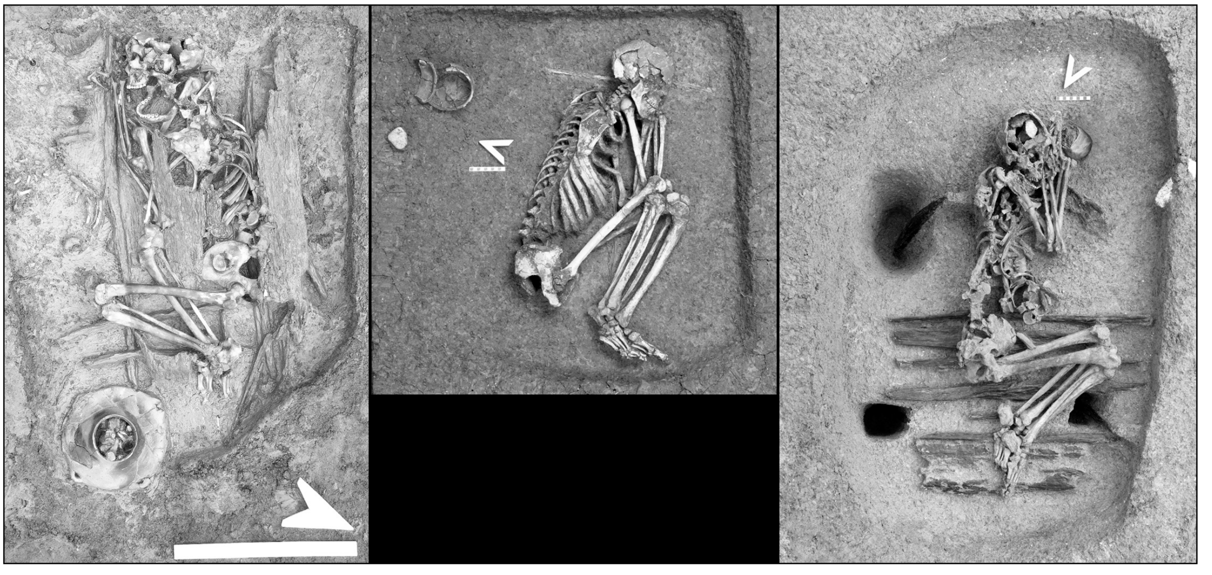


Fig. 10. A Neolithic burials from Yenikapı (courtesy of the İstanbul Archaeological Museums).

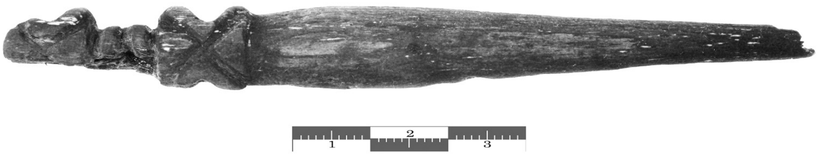
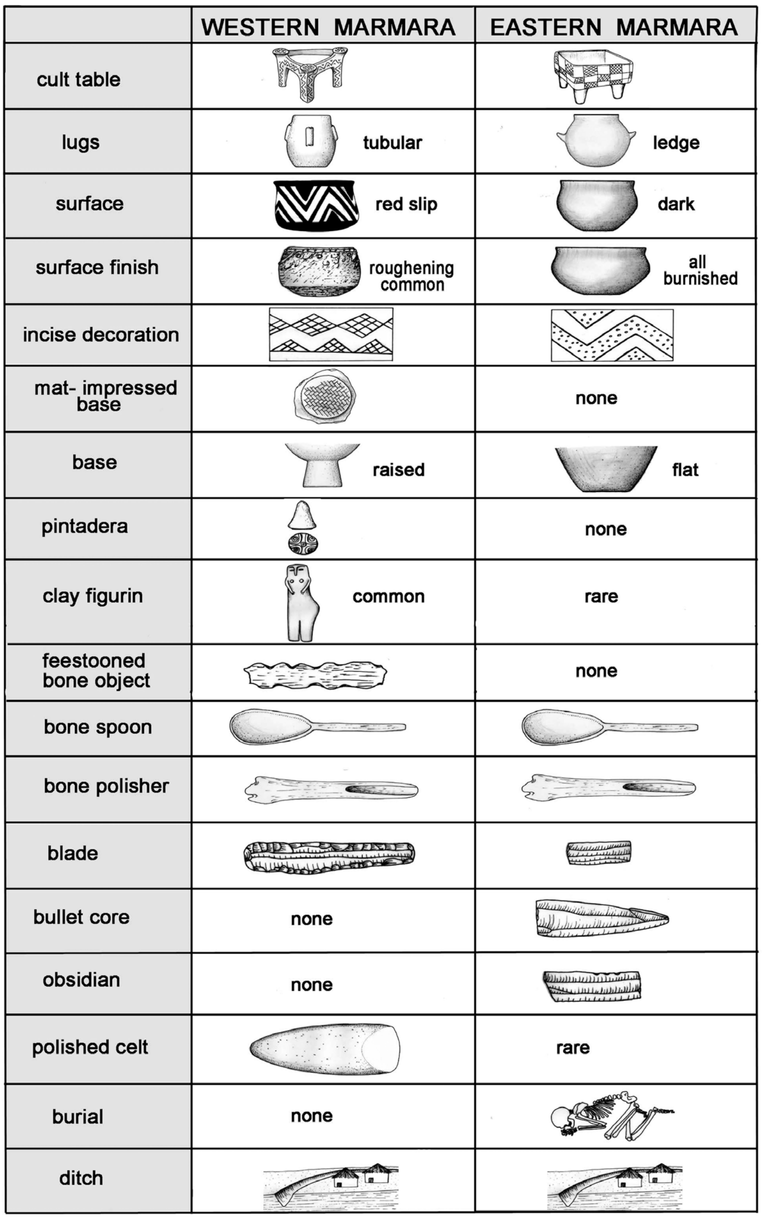


Fig. 11. Wooden Neolithic figurine from Yenikapı (courtesy of the İstanbul Archaeological Museums).

ges of Zone A, with no indication of being ranked as status objects. Bone spoons become a common commodity in Zones B, C and D, at the same time attaining a symbolic value as, at least in Zone C, most are found among grave goods. On the other hand, 'pintaderas', which were so rare and insignificant during the Pre-Pottery stage, become exceedingly common with the onset of the Pottery Neolithic even in western parts of Zone A, then moved into Zones B and D, but not Zone C. 'Festooned bone objects', which are of insignificant occurrence in Zone B, are more common and varied in Zone D.

Items from Zone A that require an extremely high level of craftsmanship to manufacture occasionally occur in the earliest horizons of Zones B, C or D, but as poorly made imitations, possibly reflections of social memory. The so-called 'terrazzo' floor of the Pre-Pottery Neolithic, for example, occurs at some sites in Zone B as red-coated lime floorings. Terrazzo floors at Pre-Pottery Neolithic A and B sites such as Çayönü, Nevali Çori or Göbeklitepe located in the eastern wing of the core area were made by burning lime, which requires high technology, know-how and organised labor (*Hauptmann, Yalçın 2000*). Moving west, red-colored lime floorings become simpler, although in some cases such as Aşıklı, lime was being processed; the westernmost examples, those from Hacılar, Ulucak, Hoca Çeşme III and Aşağı Pınar 8, were made simply by setting pebbles in lime mortar and finishing with a red ochre coating. A similar case are stone bracelets: those of the Pre-Pottery period are highly sophisticated, decorated by grooves, ridges *etc.*, while those in Zones B and C are still made of stone, but shaped as simple rings. In Zone D, however, they are even simpler, being mostly made of clay (Fig. 16). Likewise, so-called altars or cult tables that are insignificant components of the Zone A and B pottery assemblages are the most common objects in Zones C and D, being rectangular in the former and triangular in the latter (Fig. 17).

As noted above, the ancestral forms of all of the types that are present in Zones B to E are to be found in Zone A. However, the composition of the assemblages varies considerably from region to re-



	WESTERN MARMARA	EASTERN MARMARA
cult table		
lugs	tubular	ledge
surface	red slip	dark
surface finish	roughening common	all burnished
incise decoration		
mat- impressed base		none
base	raised	flat
pintadera		none
clay figurin	common	rare
feestooned bone object		none
bone spoon		
bone polisher		
blade		
bullet core	none	
obsidian	none	
polished celt		rare
burial	none	
ditch		

Fig. 12. Comparative table of east and west Marmara Neolithic assemblages.

Fig. 13. Bone spoons from Fikirtepe and Pendik.

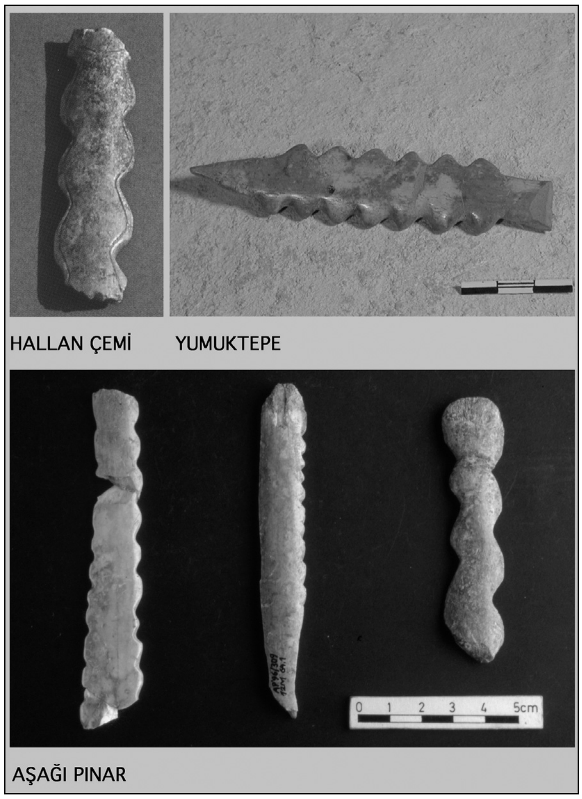


Fig. 14. Festooned bone objects.

gion or even from site to site. In sorting out our list, we were able to find analogies to every item of Zones B to D somewhere in Zone A, but unevenly distributed. Thus, for example, analysing the material assemblage of a site in Thrace in search of similarities with Zone A, one item points to the Levant, another to Southeast Anatolia and still others to east Central Anatolia. The apparent mixed pattern of origins leads us to deduce the following.

It seems evident that the initial dispersal of the Neolithic way of life was due to a considerable demic movement beginning in the core area. The assessment of the Neolithic package in the new areas of Neolithisation clearly indicates that the antecedents of most objects that were transferred are in the eastern parts of the core area, in Northern Syria, the Levant and Southeastern Turkey, but not in Central Anatolia. Accordingly, the initial 'push' for migration must have originated from the eastern parts. What happened when this passed through Central Anatolia, where there was already a Pre-Pottery Neolithic sub-stratum, is not yet clear, but again, the Neolithic package that is found in the immediate contact zone in the western parts of Turkey suggests that they somehow merged. The various amalgamations of the Neolithic package imply that the movement to the west, at least in its earlier stages, was not an organised migration. On the contrary, the mixed or merged composition of the assemblages is highly suggestive of what we described elsewhere as the "*segregated migration model*" (*Özdoğan 2008*).

As we have noted before, the dispersal of the Neolithic way of life from the core to other regions was a multifarious event that lasted for more than a thousand years. In any time segment during this process, different modes of dispersal were taking place simultaneously. That is to say, while the most apparent

Fig. 15. Pintaderas.

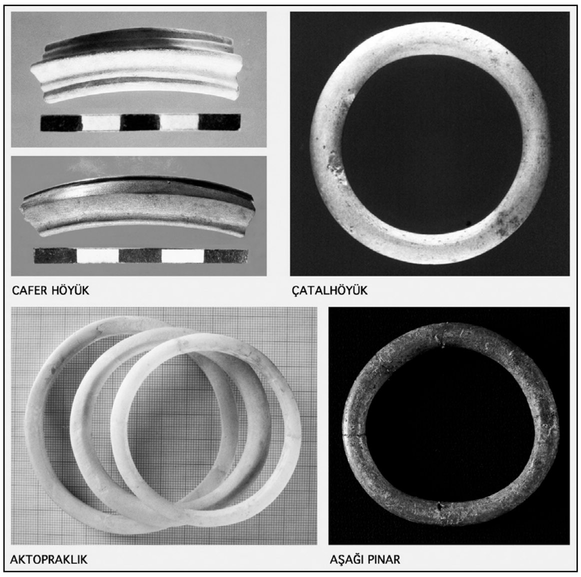


Fig. 16. Marble bracelets from Cafer Höyük in Southeast Anatolia, Çatalhöyük in Central Anatolia, Aktopraklık in southern Marmara, and a clay bracelet from Aşağı Pınar-Eastern Thrace.

model was the segregated migration type, at the same time, direct migration, acculturation and/or transfer of know-how and technologies were also

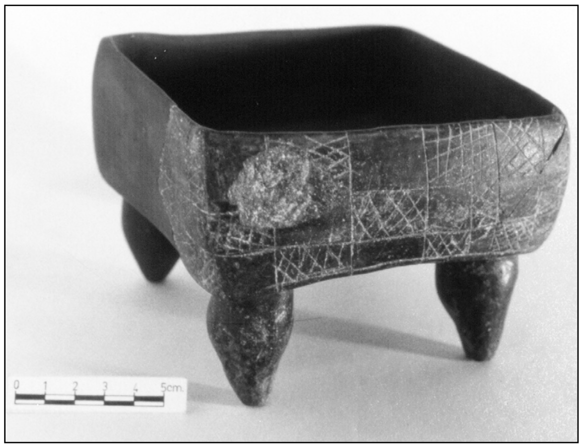


Fig. 17. A rectangular cult table from Fikirtepe.

taking place both by land and sea. It is also evident that further away from the core area, Neolithisation due to interaction or cultural contacts was more pronounced than any of the migratory models. The fact that all of the previous hypotheses on Neolithic dispersal – from migratory to autochthonous models were correct for each individual case, offers no way to finish the discussion at the present stage of our knowledge.

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Beginnings of the Neolithic in Southeast Europe: the Early Neolithic sequence and absolute dates from Džuljunica-Smărdeš (Bulgaria)

Raiko Krauß [1], Nedko Elenski [2], Bernhard Weninger [3], Lee Clare [4], Canan Çakırlar [5] and Petăr Zidarov [6]

1 Institut für Ur- und Frühgeschichte und Archäologie des Mittelalters, Eberhard Karls Universität Tübingen, DE
raiko.krauss@uni-tuebingen.de
2 Regional Museum of History, Veliko Tărnovo, BG
3 Institut für Ur- und Frühgeschichte, Universität zu Köln, DE
4 German Archaeological Institute, Orient Department, Berlin, DE
5 Groningen Institute of Archaeology, Groningen, NL
6 New Bulgarian University, Sofia, BG

ABSTRACT – *Investigations of a balk in the centre of the prehistoric settlement of Džuljunica-Smărdeš comprised a sequence of archaeological deposits from the very onset of Neolithisation in Southeastern Europe throughout the end of the Early Neolithic. The arrival of Neolithic lifeways in the region coincides with the end of a period for which palaeoclimate proxies attest to considerable climate fluctuation. In connection with these investigations, the zoological finds were examined, which provide insight into the economy of this key settlement for the entire Balkan region.*

IZVLEČEK – *Raziskave ozkega pasu sedimenta med dvema izkopnima jarkoma v središču prazgodovinske naselbine Džuljunica-Smărdeš predstavljajo zaporedje arheoloških depozitov od samega začetka neolitizacije v Jugovzhodni Evropi do konca zgodnjega neolitika. Prihod neolitskega načina življenja v regiji sovpada s koncem obdobja, za katerega paleoklimatski kazalci pričajo o znatnih klimatskih nihanjih. V povezavi s temi raziskavami smo preučili zoološke najdbe, ki omogočajo vpogled v gospodarstvo te za celoten Balkan ključne naselbine.*

KEY WORDS – *Neolithisation; Bulgaria; painted pottery; 'Rapid Climate Change'*

Introduction

The dispersal of the Neolithic from the Near East to Europe is a long-standing focus of scientific research. In this context, Southeast Europe is of particular relevance to these investigations due to its status as a transit connecting Anatolia with Central Europe. Accordingly, this land mass is situated between the source area of Neolithisation and the European heartlands. The vast river valleys that transect this mountainous terrain provided natural thoroughfares along which agriculture, animal husbandry and ceramic-producing technologies disseminated. Significantly, new discoveries made since the 1980s have demonstrated that the onset of Neolithisation actually predates the better known tell occupations otherwise considered characteristic of the Neolithic in this region. In this context, the earliest settlements in Greece are now dated to the second half of the 7th millennium calBC, and although the Neolithic reached areas north of the Aegean only slightly later, it soon became evident that these occupations predated the formation of tell settlements in this region as well. Meanwhile, several sites recorded in North Bulgaria and Thrace are also known to predate the lowest occupation level at the prominent Neolithic site of Karanovo, most notably at Koprivec, Poljanica-Platoto (*Todorova 2003*), Pomoštica (*Elen-*

ski 2008b), Orlovec (*Stanev 2008*) and Tabaška Cave (Survey *Elenski, unpublished*) (Fig. 1). However, intensive studies have shown that these assemblages should not be considered 'monochrome', in the Anatolian sense of the term (*Stefanova 1996; Krauß 2006.161–162; 2008.119–121*). For example, several of the earliest (Pre-Karanovo I) Neolithic sites known in the Balkans produced both monochrome and painted pottery. This fact alone refutes the hypothesis that there existed a 'Monochrome Neolithic' as an earliest phase of the Balkan Early Neolithic sequence (*Lichardus-Itten* et al. *2002*).

Discussions of the character of the earliest Neolithic pottery in Southeast Europe have so far lacked any reliable absolute-chronological basis. In fact, the absence of a 'Monochrome Neolithic' is still indicated only by typological comparisons of material from the few relevant sites from which a small number or uncertain ^{14}C-ages have been published (*cf. Görsdorf, Bojadžiev 1996*). Similarly to the Southwest Anatolian Lakes District, *e.g.,* at Hacılar (*Mellaart 1970*), 'Monochrome' pottery is the predominant ceramic ware in the developed Southeast European Early Neolithic, while painted pottery occurs in only small amounts (*Krauß 2011*). The Early Neolithic settlement of Džuljunica-Smărdeš is currently proving a key site for determining the characteristics of the earliest Neolithic on the Balkans. Meanwhile, numerous survey trenches excavated in the substantial settlement area have produced an extensive array of finds, and there are now good reasons to assume that the occupation of this site commenced at the very onset of Neolithisation in the East Balkans. In addition, this site remained occupied throughout the entire Early Neolithic sequence, thus providing us with a unique insight into cultural-historical developments at the dawn of agriculture and animal husbandry in this region.

Geographical location and settlement topography

The catchment of the Yantra, one of the largest tributaries of the lower Danube, drains the central Balkan massif to the north. Geographically, the point where the Yantra enters the Danube corresponds almost exactly with the southernmost extremity in the course of the Danube between its sources in the southern Black Forest to its mouth at the Black Sea. The excellent geographical location of the Yantra is self-evident and has proved particularly important for the region throughout its history. The country between the main ridge of the Balkan Mountains and the Danube can be divided into three larger regions that include a still densely wooded mountainous area in the south, the northerly adjacent mountain foothills, and the Danube lowlands, with their characteristic undulating loess deposits. This is reflected in the highly contoured shoreline on the Bulgarian side of the Danube compared to the very level banks on the northern (Romanian) side.

The Early Neolithic settlement of Džuljunica is situated 3km north of the eponymous village, approx. 500m west of the local railway station, in a field known as Smărdeš (Fig. 2). The location was probably chosen due to the occurrence of natural springs which flow from the base of a natural prominence upon which the site is located. Even today, four springs at the foot of the site are active. The prominence itself is a slightly elevated river terrace above the Džuljunica River, which, together with other tributaries, flows into the Yantra some 6.5km north of the settlement. The geographical situation of the site in the prehistoric period has not yet been determined, including its relation to the Yantra and its tributaries, which today flow just 2km from the settlement. The previously meandering water courses of these rivers have

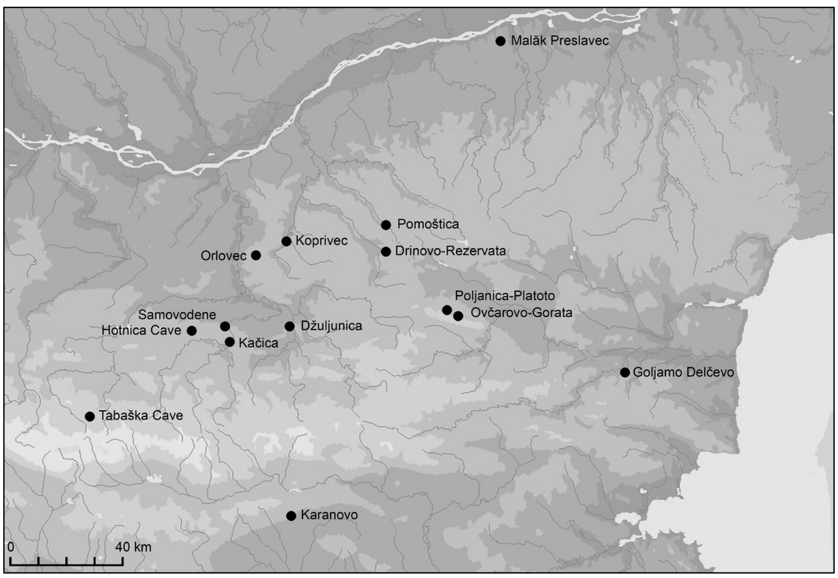

Fig. 1. Location of the Early Neolithic sites in NE-Bulgaria mentioned in the text.

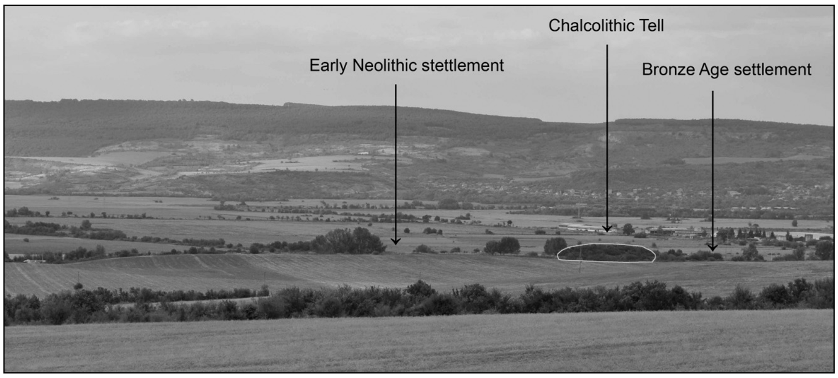

Fig. 2. Džuljunica-Smărdeš from the hilltop south of the site with approximate location of Neolithic (red), Chalcolithic (blue) and Bronze Age (green) sites.

since been artificially regulated and corrected. However, old water courses, some of which reach up to one kilometre from the site, have been identified in satellite images and antique maps. The water discharged from the modern springs flows in a westerly direction, directly towards the Yantra. Pronounced erosion channels in the northeast and southwest have significantly altered the shape of the prominence, with slope gradients of 16° in the northeast and 22° in the southwest. The site lies at between 70 and 77m above sea level. The highest elevations are at the west of the terrace, decreasing slightly to the southeast. To the north, the site gives way to the old floodplain, conferring a plateau-like appearance upon the settlement area.

On the basis of results from surface surveys, it is estimated that Neolithic occupations extended over some 4ha, and that there were noticeable shifts in settlement activity within this area in the course of its long occupation, ultimately leading to the development of a pronounced horizontal stratigraphy. The spatial extent of the settlement towards the close of the Early Neolithic (Phase Dž–IV) has been determined more precisely. In this period, the settlement area covered approx. 0.2–0.3ha. In the eastern most part of the site there is a small spur on which a Copper Age settlement mound developed. Sporadic finds found on the tell and attributed to the Early and Middle Bronze Age suggest that the accumulation of deposits did not come to a complete end at the close of the Copper Age, but continued into these later phases. A substantial concentration of Bronze Age finds has been detected in an area southeast of the mound, where the centre of the Bronze Age settlement is expected.

History of research

The first mention of a settlement mound at Džuljunica dates to the late 19th century. In a report by the Škorpil brothers (*Škorpil, Škorpil 1898.99*), Czech antiquarians, reference was made to the clearly visible Copper Age tell, which was later included in the register of archaeological sites compiled by Vasil Mikov (*1933.58*). The first archaeological investigations were undertaken in 1983–84, when salvage excavations became necessary in the course of road construction. The focus of this small-scale examination was a section through the Copper Age tell in the northeast caused by these intrusions and now braced by a concrete wall. The succession of deposits revealed in this section span the entire duration of the Bulgarian Copper Age (5th millennium calBC) with sporadic finds from the Early Bronze Age on the surface of the mound (*Stanev 1984.28–29; 1985.35*). A later analysis of the excavated ma-

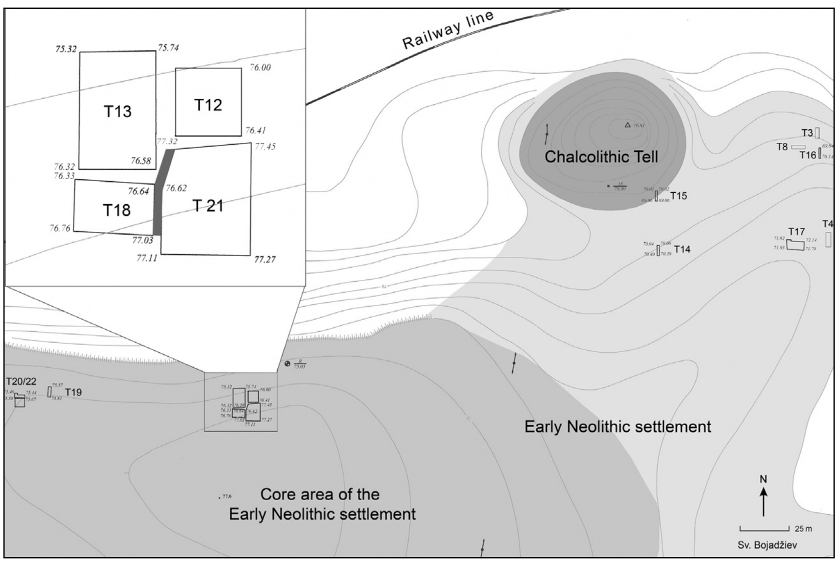

Fig. 3. Džuljunica-Smărdeš. Extension of the Early Neolithic site and Chalcolithic tell (grey shading) with location of trenches excavated since 2001 by N. Elenski (T). Trenches 12, 13, 18 and 21, and the location of the balk investigated in 2010 (red) are shown in detail.

terials showed that among finds from the Copper Age recovered from a depth of 4.10 to 6.10m below the modern surface there was also material attributed to the Early Neolithic which was interpreted by the excavator as indicating an Early Neolithic settlement lying beneath the tell (*Stanev 1995.93*).

Several test trenches to the southwest, south, and east of the Copper Age tell that were excavated between 2001 and 2005 by Nedko Elenski, and renewed work commencing in 2008 (*Elenski 2006; 2008a*), have been dedicated primarily to the investigation of the Early Neolithic settlement (Fig. 3). The general development of this earliest occupation can now be presented. The oldest two phases at Džuljunica (Dž-I and Dž-II) extend from the northern edge of the terrace, covering its entire width from the southwest to the northeast; in fact, the various test trenches confirm the presence of these oldest two levels over the entire terrace. The third occupation level (Dž-III) was detected only in the centre and on the eastern side of the terrace, where it takes the form of a thin sediment accumulation almost entirely lacking in architectural features and with only few fragmented finds. By the end of the Early Neolithic, the settled area had decreased in size and was restricted to a small area in the centre of the terrace (Dž-IV), leading to what might be described as initial tell-development.

The earliest investigations in 2005 revealed a high concentration of earliest Neolithic pottery along the eastern edge of the terrace, while finds from the end of this period were found concentrated on its western side. So far, a total of 22 test trenches have been excavated. Initially, the positioning of trenches was oriented to finds of Early Neolithic pottery discovered below the Copper Age tell. For this reason, the first test trenches (1–8 and 16–17) were excavated in the east of the settlement. Only in the course of excavations was a further series of connected trenches (10–13) opened up in the west. Remarkably, these excavations revealed accumulations from the entire Early Neolithic sequence of the Eastern Balkans. As no continuous cultural deposits from later occupation phases were encountered in this area, the focus of attention could be placed firmly on the Early Neolithic. Post-Neolithic disturbances in this area were seldom, and barely affected the structure of the earlier settlement levels. Two additional trenches (14 and 15) opened to the south of the Copper Age tell revealed no further Early Neolithic accumulations.

The end of Early Neolithic settlement was also documented in excavations on the eastern side of the terrace. This evidence took the form of disturbed and redeposited material that was later cut by an Early Bronze Age ditch; no coherent features and structures were discovered (*Elenski 2002.27–28; 2003.17–18*). Test trenches 4 and 17 represent approx. the southern limit of the Early Neolithic settlement layer in the east. Significant settlement accumulations in this area are assigned to the Copper Age and Early Bronze Age. In contrast, the underlying 20cm thick Early Neolithic layer produced only sporadic fragments of pottery (*Elenski 2002.27–28; Elenski, Leštakov 2006.36–39*).

The only trench on the east of the terrace to reveal any significant deposits from the Early Neolithic was test trench 8, which was excavated 60m east of the

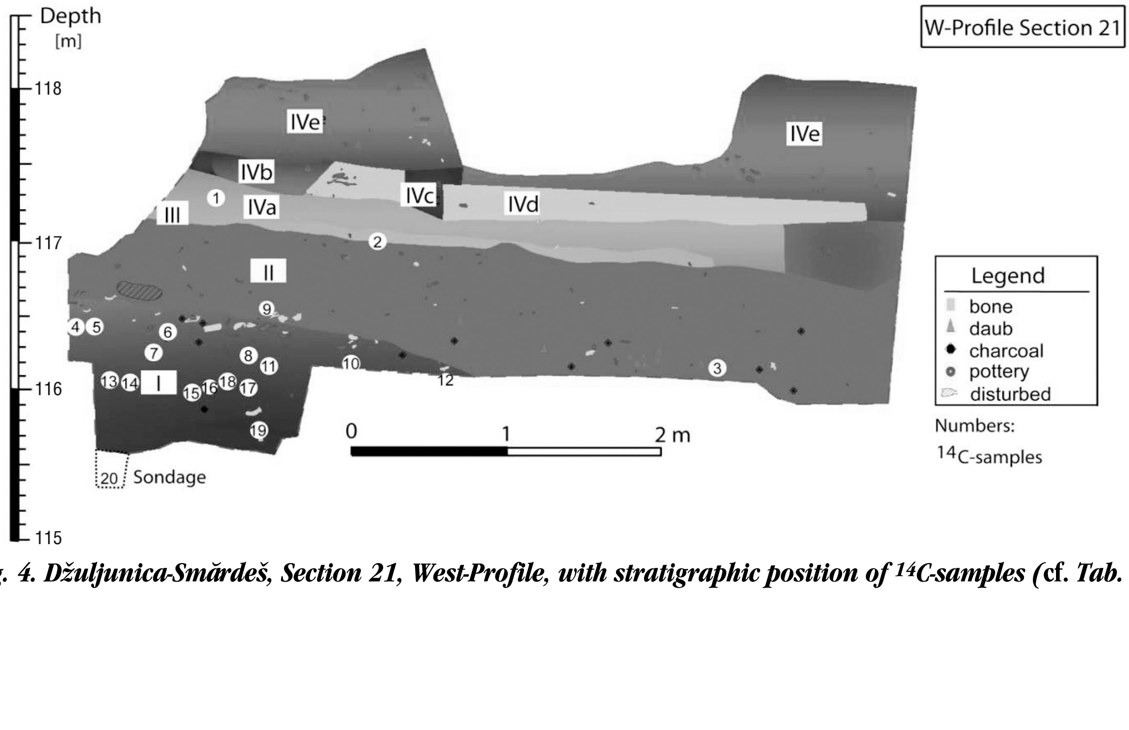

Fig. 4. Džuljunica-Smărdeš, Section 21, West-Profile, with stratigraphic position of ¹⁴C-samples (*cf. *Tab. 1).

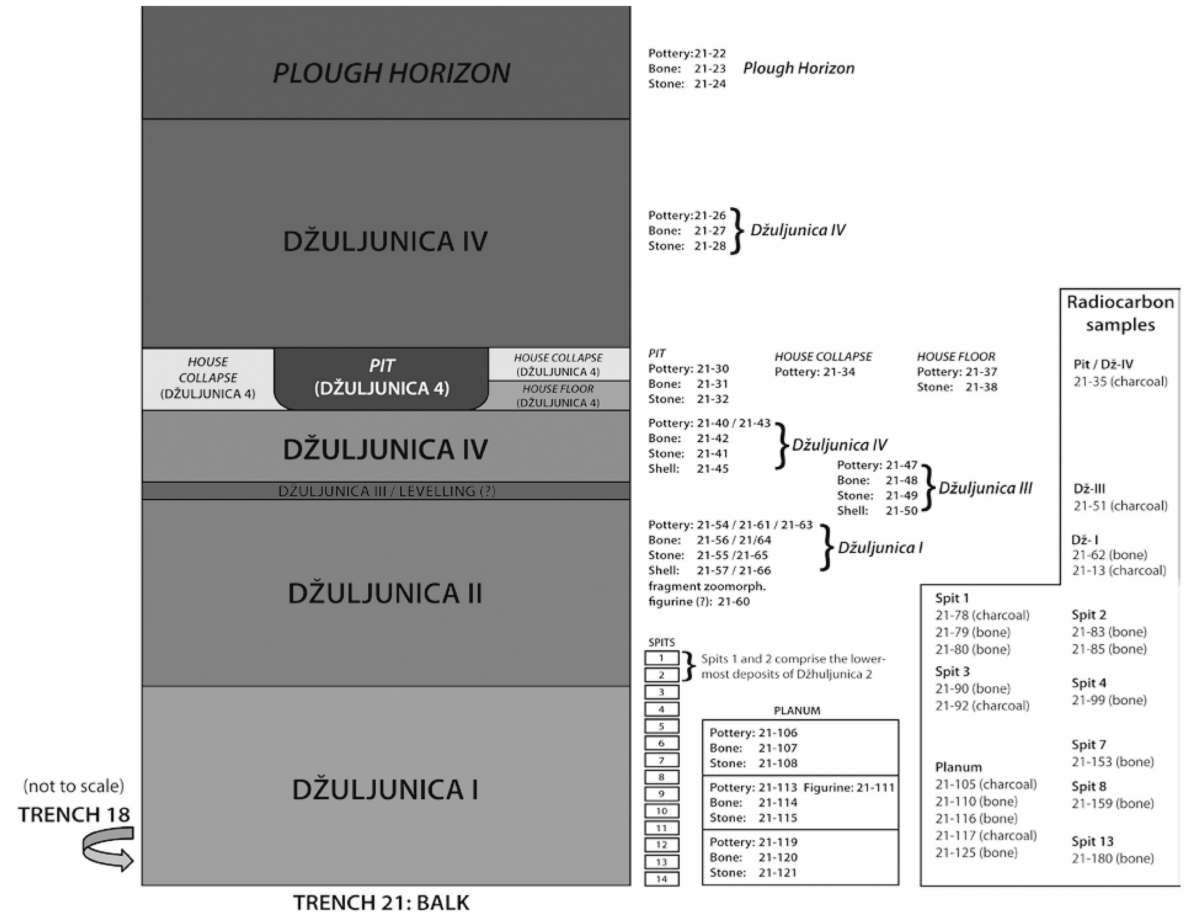

Fig. 5. Schematic representation of stratigraphic units and associated finds and radiocarbon samples excavated at Džuljunica-Smărdeš, 20th–28th September 2010.

tell. These remains were covered by a 1.3 to 2.0m thick layer of Early and Late Copper Age strata. Early Neolithic accumulations were shown to comprise three superimposed layers with a total thickness of 1.0 to 2.2m. Insights into changes in the size of the settlement are therefore based primarily on observations made in trenches 12, 13, 18 and 21, which were opened in close proximity to one another on the central part of the terrace

Description of settlement layers

The oldest layer (Dž–I) lies directly on loess and is on average 0.2 to 0.3m thick, although in some pits it reaches depths of up to 1.0m. In the central part of the terrace (in test trenches 12, 13, 18 and 21), a house sunk into the native loess was excavated. In all probability, structures from this early period were without exception pit houses, between which further features were discovered that were probably not directly associated with the houses. Signs of further structures which might belong to the houses from this layer were located in trenches 8 and 22. It is possible that we are dealing here with a line of houses which follows the course of the northern edge of the terrace. The extension of the excavation should clarify the layout of the settlement in its earliest phase, providing far better insights than are presently possible based on observations from the very central part of the settlement, which allows for only very general conclusions.

The second settlement layer (Dž–II) is 0.45 to 0.90m thick in the central trenches 12, 13, 18 and 21. Clearly defined buildings or prehistoric surfaces have so far not been discovered for this phase, although three extensive concentrations comprising the remnants of clay ovens and three large ashy deposits with numerous finds, primarily painted pottery fragments, were recorded. In the course of extensive horizontal excavation, it was observed that some pits from this second layer cut into deposits of the underlying first settlement layer. In trench 22, in the far west of the settlement, a pit from the second settlement layer was recorded which contained human and faunal skeletal remains. In comparison to the earliest settlement level (Dž–I) this second layer is characterised by considerably thicker deposits and especially by the occurrence of a greater number of finds. Once again, in spite of the limited extent of observations that can be made in this layer due to the use of test trenches, clear characteristics of this settlement phase can be discerned. However, any interpretation is rendered especially difficult owing to the nature of the excavated structures, *i.e.* houses which were not destroyed by fire and therefore are poorly preserved. Therefore, a more extensive horizontal excavation is essential if we are to better understand the delimitations of these structures.

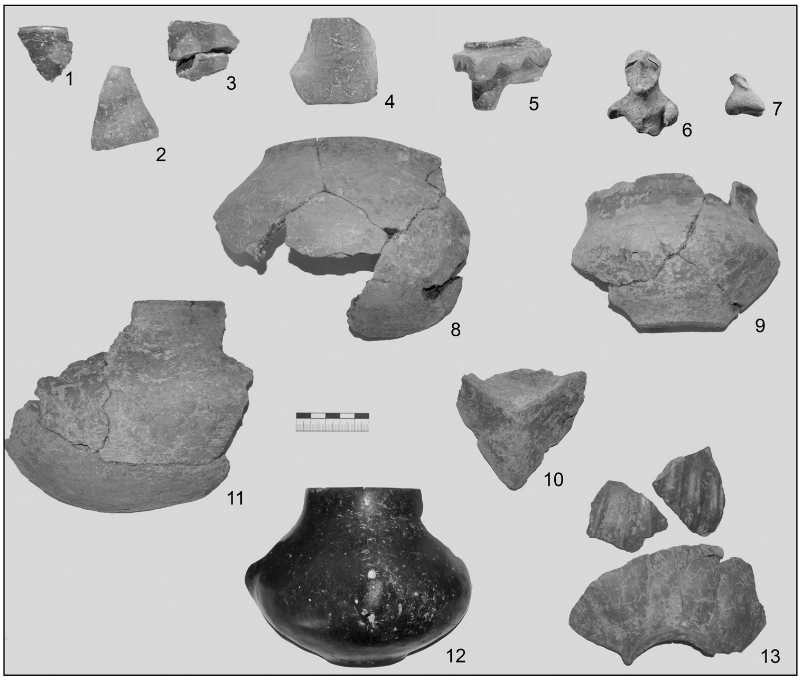

Fig. 6. Džuljunica I. 1–3 dark painted pottery; 8–9, 11–13 pottery from excavations by N. Elenski; 10 corner of a four-legged vessel; 6–7 Early Neolithic figurines from the planum adjacent to the section documented in 2010 (**cf.** ***Figs. 23–24).***

The third level (Dž–III) has been documented only sporadically over the entire area, being at most just 0.10m thick. In comparison to all the other layers, this particular layer is not only significantly thinner but also of a much firmer texture, and not ubiquitously present even in the centre of the settlement. While this third layer can be observed throughout trenches 13 and 18, in trenches 12 and 21 it is only visible in two thirds of the excavated area. This layer contains a large number of stone artefacts and highly fragmented pottery and bone finds. It is extremely likely that we are dealing here with a levelling layer. There are absolutely no signs of house floors in this level and no remains of loam daub. This suggests that it may have been a structure-free area within the settlement and with any associated structures so far poorly known due to the small extent of excavation work. Nevertheless, the platform of an oven has been attributed to this settlement phase.

The fourth settlement level (Dž–IV), which has so far only been detected in the central part of the settlement, is 0.90m thick and is divided into three different sub-phases:

● The lowermost sub-phase of the uppermost Early Neolithic settlement (Dž–IVa) is a 0.40m thick deposit of loose, dark grey sediment. In the southern central part of the settlement (trench 13) a row of six postholes was observed. Additionally, three subterranean structures were recorded in trench 21; these were originally accessed via platforms, beams or steps. It is probable that these structures served as workshops, for flint knapping, for example.

● In the second sub-phase (Dž–IVb) a ground-level house structure, and two thirds of a second such structure (both untouched by fire) were investigated. These buildings were built directly adjacent to one another, *i.e.* sharing a common wall. The first structure displays a rectangular plan; floors comprised a 0.10m thick layer of trodden earth. The wall foundations rested on a single or double row of stones; there were no signs of postholes; the house walls were constructed using loam. An oval-plan oven was excavated in the north-western corner of the room. The second building also featured a rectangular plan, with a 0.05m thick trodden earth floor. Stone foundations in this structure were lacking, except beneath the common wall separating it from the adjacent building. In the north-eastern corner of the house, a massive rectangular-plan oven was discovered. The remains of this structure suggest that it measured approx. 2.20 x 2.00m, with a 0.30m thick wall.

● In the third (uppermost) sub-phase of the fourth settlement level (Dž–IVc) a small part of an unburned structure was investigated. This house partially superimposed one of the buildings from the underlying sub-phase. The higher-lying northern part of this house had already been damaged by modern ploughing, as had a part of a hearth construction, fragments of which were collected from the surface of the field in the immediate vicinity. The plan of the house appears to have been rectangular, and its trodden earth floor was some 0.10–0.05m thick. An oval oven-platform was located in the western part of the house.

In the eastern part of the settlement, younger occupation levels assigned to the Early and Late Chalcolithic are observed overlying the Early Neolithic deposits. Two Late Copper Age burials were discovered in this area (*Elenski 2002.27–28; 2003.17–18; 2006*). Additionally, in the east the remains of a Bronze Age ring ditch were excavated. This ditch enclosed an area with concentrations of pits and circular loam platforms (*Elenski 2002.27–28; 2003.17–18; 2006*). In the slightly raised central part of the settlement, where all four Early Neolithic levels were documented, several pits from the Early and Late Iron Age and Late Antiquity were uncovered (*Elenski 2006; 2009; 2010; 2011*). Finally, this part of the site also yielded remains of a domestic structure from the Early Middle Ages (9th–10th century AD) with accompanying pits (*Elenski 2005; 2006; 2010; 2011*).

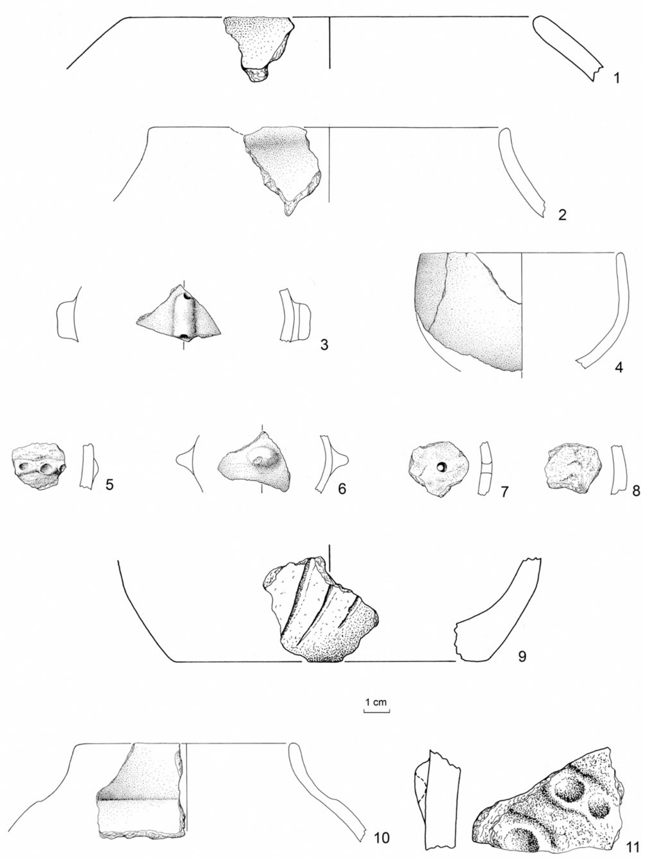

Fig. 7. Džuljunica I. Ceramic finds from the balk: 1–9 spit 3 (n. 21–88); 10–11 spit 4 (n. 21–94).

Location of the balk and methodology of the 2010 investigations

In summer 2010, supplementary investigations were undertaken in the course of continuing work at Džuljunica-Smărdeš by a joint team from the University of Cologne (Collaborative Research Centre 806 – Our way to Europe, Project F1), financed by the German Research Foundation (DFG), and the University of Tübingen. The focus of these activities was the excavation and documentation of a stratigraphically significant section in an unexcavated balk separating test trenches 18 and 21 (Fig. 4). The stratigraphic excavation of this balk promised to provide important information relating to the occupation sequence for the Early Neolithic; all documented Early Neolithic phases at the site were attested in this section, and no significant disturbances from younger occupation phases were expected. The Early Neolithic occupation deposits in this area had been disturbed only by the aforementioned shallow pits from the Iron Age and by a house feature from the Early Middle Ages in trench 21.

The balk was excavated according to stratigraphic layers and all sediment was sieved. On the reverse side of the balk, *i.e.* in trench 18, a narrow trench was excavated to assess the maximum depth of earliest Neolithic (Dž–I) deposits. These revealed that they extended some 30–40cm below the current planum of trench 21. Subsequently, these deposits were the focus of particularly meticulous documentation. Accumulations assigned to this initial phase were excavated in artificial spits of 10–15cm. In trench 21, the planum directly adjacent to the section was also extended downwards, *i.e.* parallel to the excavation of the balk. All finds were documented and samples for radiocarbon dating (bone and charcoal) extracted from all stratigraphic relevant units.

All steps of our excavation were documented numerically, and each is referred to by a two-part number separated by a hyphen. While the first (*prefix*) number refers to the location of the balk in *trench 21*, the second number identifies the particular step (or *position*). For example, 21–10 is the tenth recorded step of our excavation of the balk. In this way, finds and samples were assigned a unique *position-number* at the exact moment of their recovery. In this paper, we again refer to these numbers in illustration captions and in the radiocarbon table. Figure 5 provides an overview of the allocated *position-numbers* of finds and radiocarbon samples, and their stratigraphic provenance.

Finds from individual settlement layers and their cultural-historical position in the Balkan Neolithic

Finds from the oldest settlement layer at Džuljunica (Dž-I) (Figs. 6–9) show clear similarities with material of the West Anatolian Late Neolithic. As such, pottery from this level is coeval with the very beginning of its usage in the Southeast European cultural sequence. Bulbous vessel forms with flattened bases or slightly pronounced foot are particularly characteristic. The vessel form repertoire also includes spherical pots with a narrowing or slightly conical inclining neck, bowls with an S-shaped profile, and open bowls with straight walls.

The elaborate surface treatment of vessels while in their unfired and leather-hard state is quite remarkable and has resulted in a consolidated and shiny, in some cases enamel-like, appearance. This is all the more exceptional considering the coarse matrix of the pottery, with its numerous coarse organic inclusions. The only exceptions are the smaller, thin-walled vessels; no organic inclusions are visible with the naked eye in the fractures of these pots. These vessels appear in no way inferior to modern porcelain in their strength, hardness and gloss. Handles are limited to vertical cord lugs at the widest part of the vessel. Even among the oldest pottery, impressed decoration and plastic applications are attested, *e.g., warts* or wide, well-smoothed incisions. In their fractures, coarse wares are mostly deep black, and the fine ceramics varying from grey to brown. Surface colours range from dark hues of ochre to brown, orange and red. Some fragments feature smoke marks and are discoloured dark brown to black. A few sherds also carry a simple painted decoration in a dark colour (Figs. 6.1–4; 8.1). This painted decoration takes the form of plain wavy and wide comb motifs which extend over large areas of the vessel surface. However, painted pottery constitutes less than 1% of the excavated material.

The pottery from Dž-I is comparable with assemblages from the near vicinity, including the oldest material from Koprivec (*Krauß 2006. Taf. 1.3.5*) and Pomoštica (*Elenski 2008b.Abb. 1–9*), as well as with vessels from Orlovec (*Stanev 2008. Abb. 98–101*) and Poljanica-Platoto (*Todorova 2003. Abb. 1*). Similar vessel forms were recovered from Hotnica-Pešterata (*Ilčeva 2002.Taf. 1–4*), but this material most probably already represents a transition from Dž-I to Dž-II. Convincing parallels are attested in assemblages from West Anatolia, especially from the Izmir region, specifically Ulucak Va and early IV (*Çilingiroğlu* et al. *2004; Çilingiroğlu 2009.Abb. 4.1, 4.2; 2011.Abb. 3, 5*), Çukuriçi Höyük (*Galik, Horejs 2011.Abb. 5*) and Yeşilova (*Derin 2011.Abb. 5–7*). In the geographically nearer Marmara region, Dž-1 material can be parallelised with Classical Fikirtepe, although vessel forms from Ilıpınar IX–VIII (*Thissen 2001.Abb. 21–29*) or the eponymous site at Fikirtepe (*Özdoğan 1999.Abb. 33*) only allow the identification of more general consistencies with our typological spectrum.

Generally speaking, vessel forms from the second settlement phase Dž-II (Figs. 10–15) do not differ substantially from those of the first phase. However,

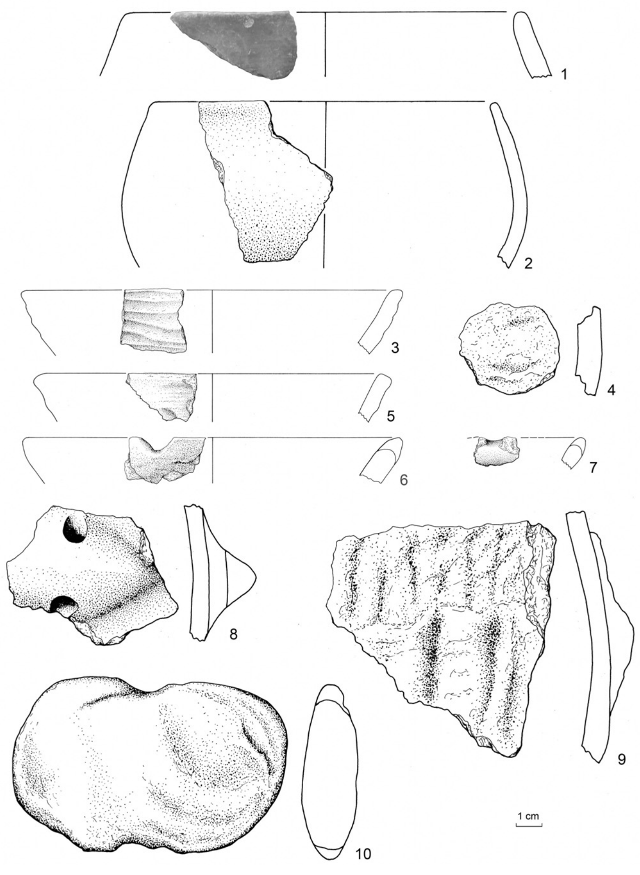

Fig. 8. Džuljunica I. Ceramic and stone finds from the planum (trench 21) adjacent to the balk: 1–4, 8–9 n. 21-88; 5,7 n. 21-113; 6 n. 21-120; 10 grooved mallet? –n. 21-109; 1 fragment of a dark-on-light painted vessel.

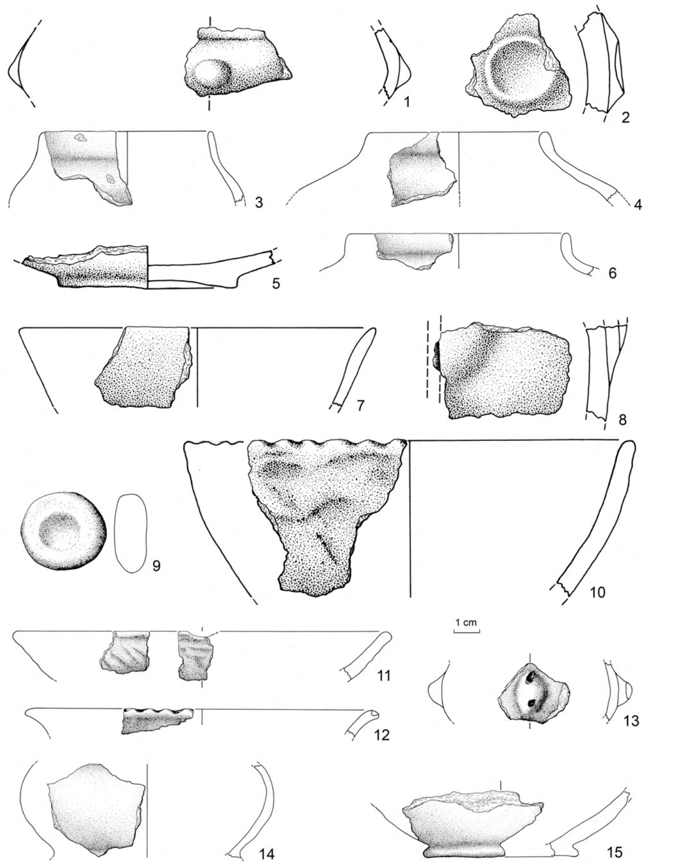

Fig. 9. Džuljunica I. Ceramic and stone finds from the balk: 1–5 spit 5 (n. 21–141); 6 spit 6 (n. 21–145); 7–8, 10 spit 8 (n. 21–155); 11–12 spit 10 (n. 21–167); 9, 13–15 spit 11 (n. 21–171); 9 stone support for a mortar.

as finds from this phase are more numerous, a few of the forms appear in slightly greater variation; nevertheless, there are no new vessel forms associated with this settlement phase. Most vessels feature a surface treatment which is of an equally high standard as noted for the previous settlement layer. A new development is the occurrence of white painted decorations on a red slip (Figs. 12.1–10; 14.3,7; 15.8); the dark painted decoration from Dž–I continues to be documented (Figs. 10.4; 11; 14.1). In addition, two fragments feature a creamy or ivory painted decoration (Fig. 12.14–15) and three sherds were painted entirely white (Fig. 12.11–13). White-painted motifs include dabbed spots arranged into triangle shapes, latticed and stepped bands, parallel W-motifs arranged one above the other, and patterns reminiscent of textiles. The ratio of painted pottery in this layer reaches just 1–2% of the entire assemblage. One tenth of painted sherds are of the dark-painted variety. Significantly, in the upper part of Dž–II deposits, dark-painted wares vanish and only white-painted decoration occurs. The white-on-red decoration connects Dž–II with the Karanovo I horizon in Thrace. Finds of pottery with white-painted decoration in combination with dark-painted vessels have recently been reported from Turkish Thrace, from the site Aşağı Pınar 7 (*M. Özdoğan 2011.Abb. 10–11*). On the other hand, extensive decorations using beige paint are documented from the Izmir region; these may indicate parallels between Dž–II material and Ulucak IV h–l (*Çilingiroğlu 2009.Abb. 4.19, 4.21*).

For the central part of the site, the third settlement layer Dž–III has already been described as a very thin deposit with relatively few finds. Due to the high state of fragmentation, pottery from this layer does not allow for a reliable reconstruction of vessel forms (Figs. 16–17). Especially notable, however, is the lack of highly burnished sherds with a dense surface. Only a few fragments carry a white-painted decoration on a red slip (Fig. 16), while dark-painted pottery is now absent for the first time. The stratigraphic position of this layer suggests that it may run parallel to developed Karanovo I, which would certainly not be contradicted by the material recovered from this deposit. Particularly crucial for this conclusion is the presence of white-painted, and the absence of dark-painted, decoration. A more precise chronological delimitation is not possible due to the small number of finds.

Pottery recovered from the fourth settlement layer Dž–IV includes vessel shapes characteristic for the developed Early Neolithic in the region (Figs. 18–20), especially as known from the settlement of Ovčarovo-Gorata (*Krauß 2011.Abb. 6–7; 2014.Taf. 1–59*). Vessels are characterised by bases with a solid foot or a pronounced foot rim. Common vessel shapes are tall beakers, also with lateral strap handles, and diverse bowl and pot forms. There also occur occasional cylindrical lids which belong to bulbous vessels with elongated cylindrical necks. Generally, pottery from this phase is coarser than in the earlier phases, albeit that the occurrence of fragments of fine ware still attests to efforts to produce highly burnished and lustrous surfaces. Vessel decoration is now dominated by plastic types of surface treatment. In contrast, painted decoration is no longer discerned. Particularly characteristic is an extensive canellated/fluted relief decoration found especially on beakers (Figs. 18.1–3; 19.3; 20.2, 6–7, 12–13), and various plastic applications, such as spirals, small blossom patterns, as well as knobs or warts. The entire surface of coarse vessels is frequently covered, with the exception of the rim and foot zones, either with prick marks or with parallel or diamond-shaped incised motifs.

Fig. 10. Džuljunica II. Ceramic vessels and a four legged vessel (4) with zoomorphic head and traces of dark colour from excavations by N. Elenski.

From a larger scale perspective, we are dealing here with a horizon that correlates with Karanovo II in Thrace, which on the European side of Turkey is attested at Aşağı Pınar, layer 6 (*Parzinger 2005.Taf. 116–117; E. Özdoğan 2011.Abb. 10*). Coeval with this phase, but typologically different, is material from known sites in Anatolia. On the basis of radiocarbon ages, it is assumed that Dž–IV is roughly contemporaneous with Ilipinar V and the uppermost Chalcolithic layer of Ulucak IV.

Turning now to the ceramic small finds, for the lowermost levels Dž–I and Dž–II so-called labrets, small idols in the shape of highly stylised cattle heads, are particularly characteristic (Fig. 21). Two fundamental types are differentiated: more compact specimens with a wide body rounded at the bottom (Fig. 21.1–7), and elongated rod-shaped pieces (Fig. 21.8–9). A broken idol carries a decoration comprising deeply incised lines (Fig. 21. 4).

A massive baton made of grey stone with a wide and perforated end might also be attributed to this group of objects (Fig. 22.1). The pointed end of this piece in particular is strongly reminiscent of ceramic rod-shaped labret types. This sceptre-like artefact was discovered in test trench 12 in 2004 and is attributed to level Dž–II.

Fragments of a similar stone with a fine crystalline structure and a highly smoothed inner surface may be the remains of flat bowls or palettes. Only one specimen was recovered from trench 21 and can be attributed to level Dž–I (Fig. 22.3). Two further pieces, including one with a cantilevered edge, were discovered in trench 22 (Fig. 22.2, 4). While large numbers of these palettes are already known from Anatolia, the fragments from D–D are, as far as we are aware, the first ever discovered in Southeast Europe.

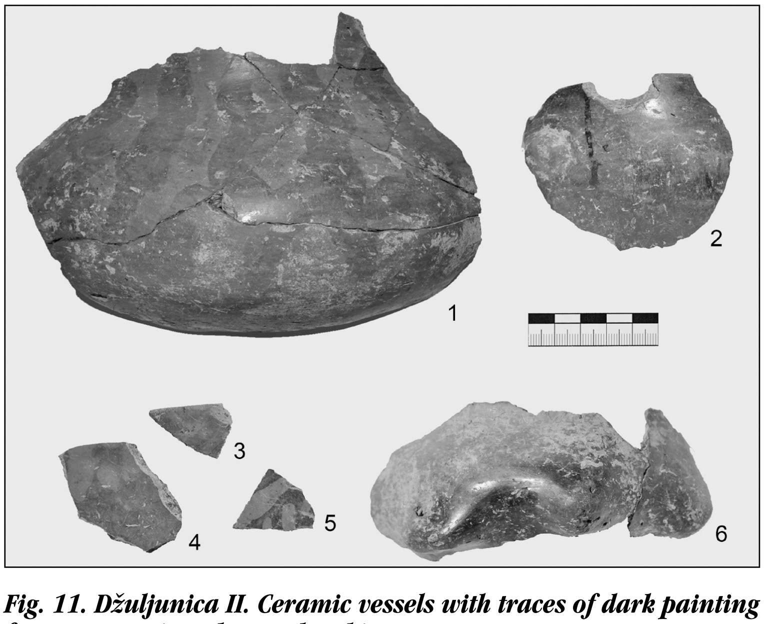

Fig. 11. Džuljunica II. Ceramic vessels with traces of dark painting from excavations by N. Elenski.

A special ceramic form identified at the site is the four-footed vessel (Figs. 6.5, 10; 10.4) which is attested only in the oldest settlement layers Dž–I and Dž–II. These vessels are either void of all decoration or they are trays with a relief-type adornment of their sides; normally this decoration takes the form of hanging triangles or protuberances pinched out of the vessel surface.

Among the most remarkable finds from Džuljunica are two anthropomorphic figurines discovered in 2010 during our excavation of the balk se-

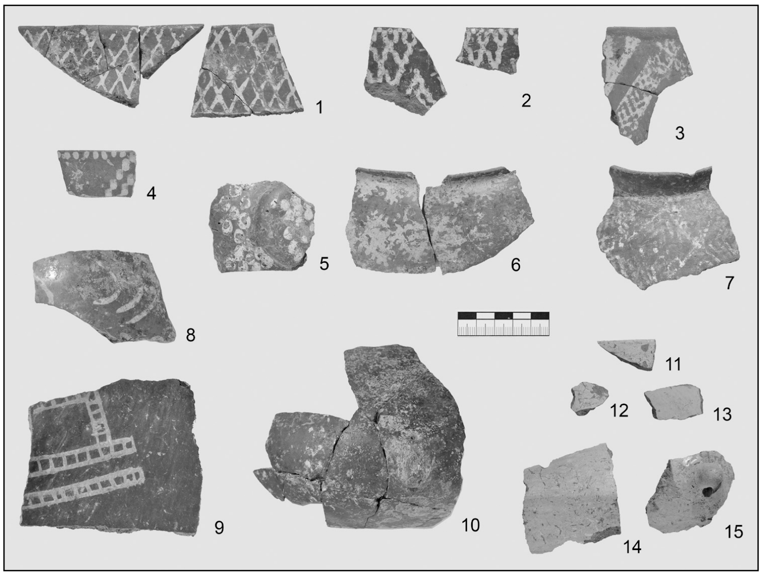

Fig. 12. Džuljunica II. Ceramic vessels with white and cream painting from excavations by N. Elenski: 1–10 white-on-red painted sherds; 11–13 sherds with white slipped surface; 14–15 sherds with crème slipped surface.

parating trenches 18 and 21. The first figurine, the gender of which cannot be determined, comprises a human torso and head, with what appears to be a masked face and coffee-bean eyes (Fig. 23; see also Fig. 6.6). The edge of the head is scuffed. The forearms and the lower part of the body are missing. A small breakage point on the front of the figurine suggests that the arms of the figure were originally folded across the belly. Exceptional from a typological perspective is the masked appearance of the face, a considerably younger feature that is more commonly associated with figurines of the Vinča culture. Typologically, the piece can be lined up alongside previously discovered Early Neolithic figurines from Southeast Europe, first and foremost due to the characteristic coffee-bean eyes. The assignment of this figurine from Džuljunica to the Early Neolithic is further substantiated by its securely documented embedding in lowermost Dž–1 settlement layer deposits, just 0.50m in front of the investigated section. Radiocarbon ages were determined on a charcoal (OxA–25044: 7095±40 ^{14}C-BP) and on a bone sample (OxA–24979: 7145±38 ^{14}C-BP) in the direct proximity of the find. Accordingly, the figurine was deposited at this location around 6000 calBC. The surface and breakage points are heavily rubbed, indicating that this piece was in circulation for an extended period.

A second smaller figurine was found at the same level, approximately 1.5m south of the first figurine (Fig. 24; see also Fig. 5.7). This second figurine is of an extremely compact type. It is seated and features a greatly enlarged rump, and shortened legs. The arms, which are only suggested, also appear to be crossed across the breasts. Large parts of the head have been chipped away. In spite of its small size, this piece can be attributed to a known format: the representation of a seated, presumably female individual that is comparable, for example, with a figure vessel from Ulucak IV b2 (*Cilingiroğlu* et al. *2004.Fig. 25. 32, 58*). Parallels from Ulucak also show quite clearly how the position of the arms of the Džuljunica figure should be reconstructed. The figure is holding her hands below the breasts, presenting them in this way to the viewer. This gesture is a commonly encountered characteristic of Neolithic figurines in the Near East and Anatolia, but only observed in very few examples from Southeast Europe (*cf. Hansen 2007.350, Tab. 9*). It is of further note that this gesture is typical, and observed primarily among the earliest Neolithic figurines which are already disappearing in the developed Early Neolithic period (*cf. Hansen 2007.363, Abb. 202*).

Džuljunica radiocarbon dates

The radiocarbon dates from Džuljunica are listed in Table 1. A total of 21 samples were processed by the ^{14}C-AMS (Accelerator Mass Spectrometry) technique at Oxford Radiocarbon Laboratory (Lab Code: OxA). As indicated by the Sample Code (column 3), all ages relate to material recovered from Trench 21, either directly from the balk itself or from its immediate proximity (adjacent planum). Figure 4 shows the provenance of ^{14}C-dated samples from the balk, projected onto the section (A–B) and adhering to the applied documentation system and site-phasing (Dž–I to IV; *cf.* Tab. 1). Although short-lived animal bones (N = 14) constituted the emphasis of our sampling strategy, seven (potentially) long-lived wood-charcoals were also dated in order to verify the ^{14}C-radiometric chemical integrity of bone samples. The series of radiocarbon measurements from Džuljunica comprises a total of 12 ages for Dž–I, and 7 ages for Dž–II. The two youngest Phases Dž–III and Dž–IV are represented by one date each. In all cases, the stable isotope δ^{13}C-values fall within the range of expected values (column 6).

Figure 25 provides an overview of the ^{14}C-data dispersal on the calendric time-scale for Džuljunica compared with ^{14}C-data from Ovčarovo-Gorata (Tab. 2). From the age distribution of samples from Dž–I and Dž–II we conclude that these phases are probably relatively short in duration, each in the range of a maximum of 100 calendric years. A charcoal sample (OxA–25047) from Dž–III has a ^{14}C-age that appears too old (*cf.* Fig. 25). Since this age resembles data from directly underlying phases Dž–I and Dž–II, we conclude that this sample was reworked from earlier deposits. The *youngest* sample OxA–25045 from phase Dž–IV has a ^{14}C-age (6686±39 ^{14}C-BP) that is in good typological agreement with an extended series (N = 13) of highly consistent ^{14}C-ages of bone-samples from Ovčarovo-Gorata (Tab. 2). Notably, the majority of previously measured charcoal samples from Horizon III of Ovčarovo-Gorata have yielded ^{14}C-ages that are clearly too young, for which an explanation may be sought in the high ash content of these samples (Bln–2030; Bln–2031; Bln–2032; *cf. Görsdorf, Bojadžiev 1996*). Although the duplicate measurements (Bln–1544: 6688±60 ^{14}C-BP; Bln–1620: 6463±50 ^{14}C-BP) on the charcoal sample from Ovčarovo-Gorata (Horizon I) are not statistically perfect (p = 0.1%), their weighted average 6576±35 ^{14}C-BP (calculated for explorative purposes) still lies well within the overall range of ^{14}C-ages obtained for bone samples (Tab. 1).

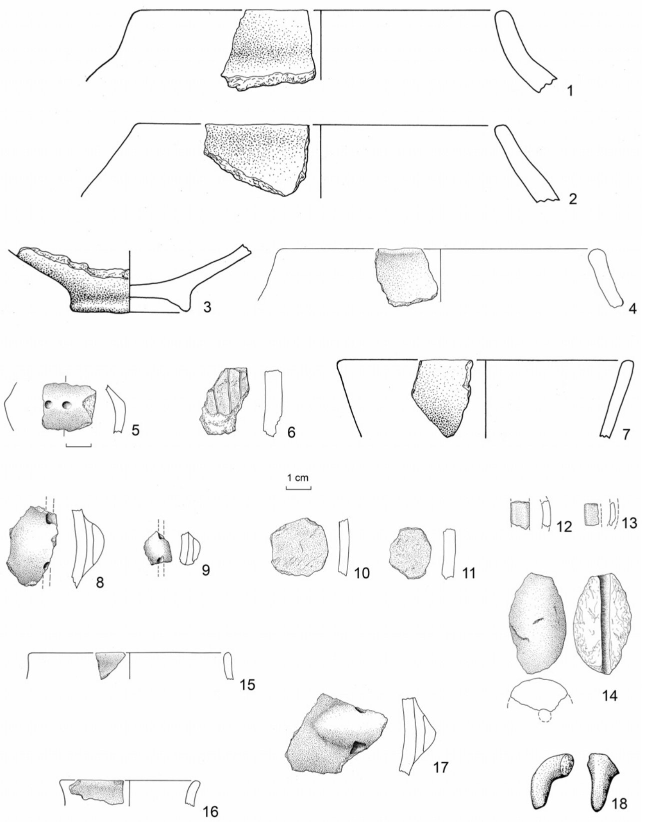

Fig. 13. Džuljunica II. Ceramic and clay finds from the balk: 1–9 n. 21–54; 18 n. 21–60; 10–14 n. 21–61; 15–17 n. 21–63; 10–11 ceramic tokens from pottery sherds; 12–13 fragments of ceramic rings; 14 fragment of a loam weight; 18 horn from a zoomorphic figurine?

The *oldest* sample (OxA–24937) in the Džuljunica series has a ^{14}C-age of 7588 ± 37 ^{14}C-BP. Since this specific bone (assigned to Dž–I) was sampled at an intermediate depth of the section (depth 116.05m), we interpret this measurement as a *radiometric* outlier. In particular, since this measurement is significantly older than all the other ^{14}C-ages attested for Dž–I and II, we can rule out that this sample was *reworked* from older deposits. Such deposits are not identified at the site. For this reason, we exclude OxA–24937 from our stratigraphic age-model (see below).

In addition to the first (*radiometric*) outlier (OxA–24937), the series contains a second (*stratigraphic*) outlier (OxA–24936), albeit with an otherwise acceptable ^{14}C-age (7083 ± 36 ^{14}C-BP). This sample has unique properties: it was taken at a stratigraphic depth of 115.40m, and – as such – was the lowest sample recovered from Trench 21. The status of this age as a (*stratigraphic*) outlier only became clear in the course of stratigraphic age modelling.

Gaussian Monte Carlo Wiggle Matching

Using the metric depth-values of the ^{14}C-data from Džuljunica, as provided in Table 1 (column 8), we constructed a linear stratigraphic age-depth model for phases Dž I–II. Subsequently, this model was implemented in order to achieve a high-resolution chronology for these specific phases using Gaussian Monte Carlo Wiggle Matching (GMCWM). The age-model is founded on three assumptions:

❶ (average) sediment growth from the onset of Dž–I to the end of Dž–II is constant;
❷ sediment accumulation was uninterrupted; and consequently
❸ there exists a linear age-depth relation between the recorded stratigraphic depth of the ^{14}C-dated bone samples and their calendric ages.

These assumptions are – to all intents and purposes – confirmed by our study results (Fig. 28). In the following, we provide details of the statistical analysis that are also illustrated in Figures 26 and 27.

Weighted averages

The method of GMCWM is an extension of the earlier developed wiggle matching method (*e.g., Neustupny 1973; Pearson 1986; Weninger 1986; 1992*). Wiggle matching underlies the basic idea to make use of additional independent information in order to refine the often limited precision and accuracy of dating achievable for single ^{14}C-ages. When single dates are age-calibrated in an unrelated (*individual*) manner, all we achieve is a list of (again unrelated) statistical intervals on the calendric time-scale. Further, the method of calculating weighted averages fails to provide access to the requested higher dating resolution. For example, Table 1 contains three ^{14}C-measurements (OxA-24931, OxA-24932, OxA-25040) that were obtained on different bone samples, all of which are from the same stratigraphic depth (16.16m). Assuming these samples have the same calendar age, which we judge is reasonable, it is possible to combine the values, and in particular, calculate a weighted average with a smaller standard devia-

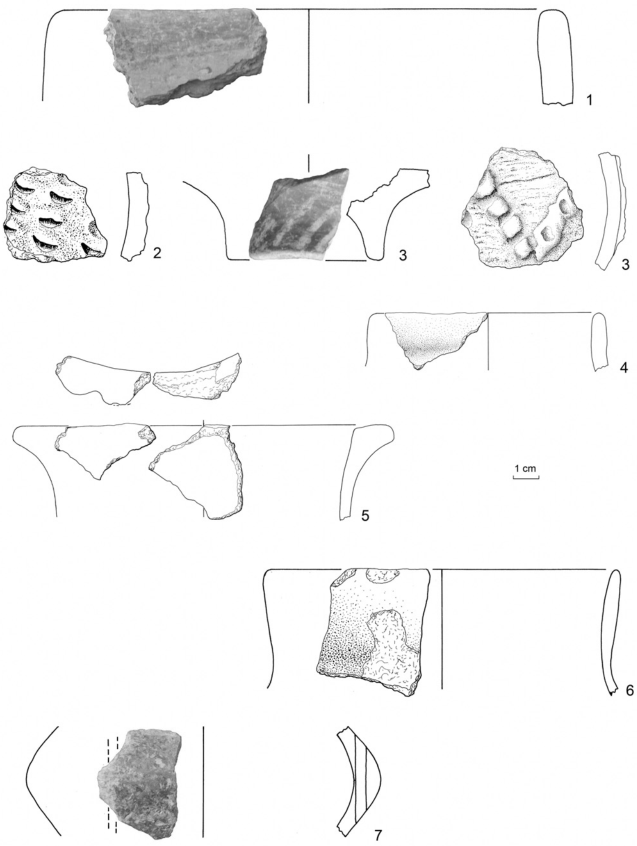

Fig. 14. Džuljunica II. Ceramic finds from the balk and the adjacent planum (trench 21): 1–6 spit 1 (n. 21–73); 7 from the planum; 1 fragment of a dark painted vessel; 3,7 white-on-red painted fragments.

Nr.	Lab-Code	Sample-Code	Material (species)	^{14}C-Age [BP]	δ^{13}C [‰PDB]	Phase	Depth [m]
1	OxA–25045	DZH 21–35	charcoal	6686±39	–25.35	Dž IV	117.31
2	OxA–25047	DZH 21–51	charcoal	7140±40	–24.38	Dž III	117.01
3	OxA–25046	DZH 21–13	charcoal	6950±40	–25.59	Dž II	116.20
4	OxA–24981	DZH 21–80	bone (large adult bovide)	7185±40	–20.76	Dž II	116.41
5	OxA–25043	DZH 21–78	charcoal	7055±40	–25.76	Dž II	116.41
6	OxA–24977	DZH 21–79	bone (large adult bovide)	7136±40	–20.11	Dž II	116.41
7	OxA–24978	DZH 21–85	bone (adult sheep)	7054±39	–20.44	Dž II	116.26
8	OxA–24939	DZH 21–83	bone (sheep)	7171±36	–19.59	Dž II	116.26
9	OxA–24935	DZH 21–62	bone (large adult bovide)	7026±35	–20.46	Dž II	116.56
10	OxA–24931	DZH 21–90	bone (subadult sheep)	7066±38	–20.00	Dž I	116.16
11	OxA–24932	DZH 21–90	bone (subadult sheep)	7053±35	–19.93	Dž I	116.16
12	OxA–25040	DZH 21–92	charcoal	7049±39	–24.83	Dž I	116.16
13	OxA–24938	DZH 21–99	bone (large adult bovide)	7134±35	–19.20	Dž I	116.06
14	OxA–25044	DZH 21–105	charcoal	7095±40	–25.87	Dž I	116.05
15	OxA–24979	DZH 21–110	bone(large adult bovide)	7145±38	–20.26	Dž I	115.96
16	OxA–25033	DZH 21–116	animal bone	7084±36	–20.28	Dž I	115.92
17	OxA–24980	DZH 21–159	bone (large adult bovide)	7011±38	–19.97	Dž I	116.05
18	OxA–24937	DZH 21–153	bone (wild adult pig)	7588±37	–20.24	Dž I	116.11
19	OxA–25042	DZH 21–117	charcoal	7095±40	–24.29	Dž I	115.76
20	OxA–24934	DZH 21–125	bone (large juvenile bovide)	7195±37	–19.73	Dž I	115.70
21	OxA–24936	DZH 21–180	animal bone	7083±36	–19.09	Dž I	115.40

Tab. 1. Radiocarbon dates from Džuljunica (Trench 21).

tion. As shown by χ^2-test, there is a high probability (94.7%) that the numeric spread of the three ^{14}C-ages (7066±38; 7049±39; 7049±39 ^{14}C-BP) is an expression of chance fluctuations in the strength of the respective ^{14}C/^{12}C AMS ion-beams. As such, we can replace the three ages by their combined value (7056±21 ^{14}C-BP, p = 94,7 %). However, although the combined value is characterised by a significantly lower standard deviation (STD = ±21 ^{14}C-BP) than the separate data (±38, ±39, ±39 ^{14}C-BP), both the position and length of the calendric-scale interval (6020–5860 calBC, 95% confidence) is almost identical to the intervals previously obtained for the individual components. The component intervals are: 6050–5850 calBC (OxA-24931), 6040–5840 calBC (OxA-24932), and 6050–5810 calBC (OxA-25040). This result can be summarised as follows: no methods, including stacking or weighting single ^{14}C-ages, both on the ^{14}C-scale or alternatively on the calendric time-scale, provide access to the enhanced dating precision required. Perhaps unexpectedly, although well-illustrated by this example, the limitations of single ^{14}C-age/sample analysis increase with increasing dating precision.

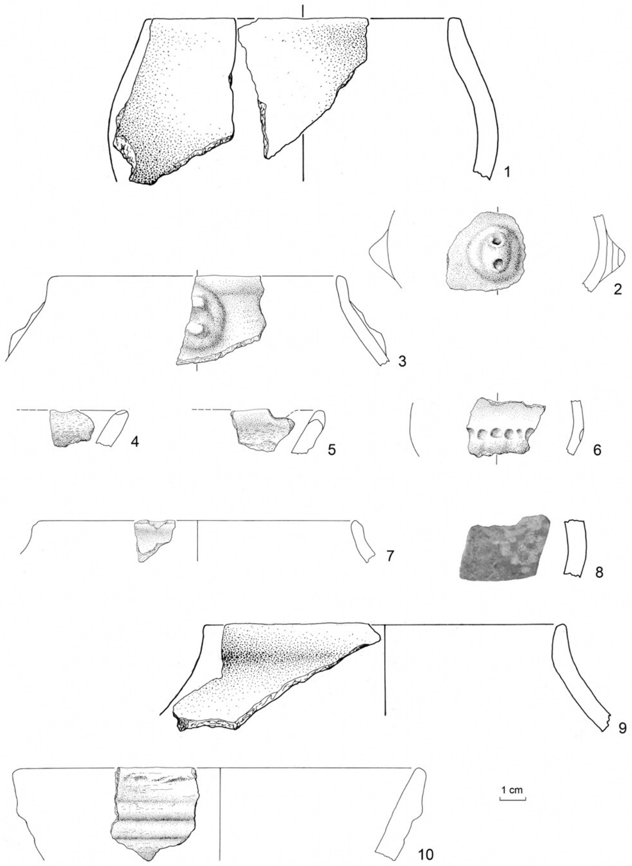

Fig. 15. Džuljunica II. Ceramic finds from the balk; 1–3 spit 1 (n. 21–73); 4–10 spit 2 (n. 21–82); 8 fragment with white-on-red painting.

General considerations on ^{14}C-age calibration

As explained in Weninger *et al.* (*2011*), the theoretical reasons for these limitations are to be sought in the underlying algebra of probabilistic ^{14}C-age calibration. Briefly, in mathematical language, the calibration operation is not only non-linear (due to the wiggles of the ^{14}C-age calibration curve), but in particular, also non-commutative (ordered). In consequence, there is a (one-sided) uncertainty relation between the ^{14}C-scale and the calendar time-scale, which means that all ^{14}C-based chronological results depend strongly on which of the two scales the analysis is initially (or secondarily) performed (*e.g.*, first on the ^{14}C-scale and second on the calendric time-scale, or vice-versa). Better known from quantum mechanics, but where the uncertainty relation between the different *paired* variables (*e.g.*, between energy and time) is two-sided, all such non-commutative systems have a strong tendency towards an irreversible *lock-in* of variables (when measured), onto certain pre-defined states of the study system (*e.g.*, energy levels in atoms). Interestingly, this quantisation effect can also be observed in the results of archaeological radiocarbon analysis, by whatever method, but most clearly in single ^{14}C-age analysis. In view of the high dating precision achieved at the Oxford ^{14}C-AMS-laboratory for Džuljunica samples, and knowing that the observable effects of age-quantisation become stronger with increased dating precision, we therefore confidently forecast that such *lock-in* effects will also appear as a result of Džuljunica ^{14}C-analysis.

Fig.16. Džuljunica III. Foot from a white-on-red painted beaker. Excavated by N. Elenski.

Nr.	Lab-Code	Material	Species/ Function	Locus	Square/ Quadr.	Feature/ Sample Nr.	14C-Age [BP]	Depth [m]	Comments/ Sample Quality
1	Bln–1544	charcoal		Hor. I			6688±60		same sample Bln–1620
2	Bln–1620	charcoal		Hor. I			6463±50		same sample Bln–1544
3	Bln–2030	charcoal		Hor. III	61	Pit	6125±45	0.60	too young high ash content
4	Bln–2031	charcoal		Hor. III	61	Pit	5440±50	0.30	too young high ash content
5	Bln–2032	charcoal		Hor. III	33		6555±70	0.26	high ash content
6	Poz–16984	bone	*Bos* bone point	Hor. I	Ž7		6890±40	0.10	4.1% collagen
7	Poz–16985	bone	*Ovis/Capra* bone point	Hor. I	M6		6890±40	0.20	2.5% collagen
8	Poz–16986	bone	*Ovis/Capra* bone point	Hor. III	115/125		6500±40	1.30	2.2% collagen
9	Poz–18480	bone	*Bos* bone point	Hor. IV	–	MTg 2510A Feldnr. 222	6900±40	–	0.8% collagen
10	Poz–18483	bone	bone point	Hor. II	M1	MTg 2480A Feldnr.142	6750±40	0.10	0.4% collagen
11	Poz–18484	bone	*Bos* bone disc	Hor. III	104	MTg 2554A Feldnr. 149	6640±40	0.10	0.5% collagen
12	Poz–18486	bone	bone point	Hor. I	63	MTg 1955A Feldinv. 10	6800±40	2.40	0.5% collagen
13	Poz–18487	bone	*Ovis/Capra* worked bone	Hor. IV	24	MTg 1962A Feldnr. A18	6660±40	0.20	0.6% collagen
14	Poz–18489	bone	*Bos* worked bone	nd	62/2	MTg 2609A Feldnr. 169	6750±40	1.90	6.2% collagen
15	Poz–18490	bone	bone spoon	Hor. III	115	MTg 2609A Feldnr. 169	6780±40	1.30	9.5% collagen
16	Poz–18491	bone	bone spoon	Hor. II	–	MTg 2603A Feldnr. 139	6810±40	0.15	11.2% collagen
17	Poz–18493	bone	*Bos* worked bone	Hor. I	61/3	MTg 1632A Feldnr. 8	6670±40	0.30	5.3% collagen
18	Poz–18494	bone	*Bos/Cervus* bone disc	Hor. IV	30	MTg 2555A Feldnr. 80	6690±40	0.20	6.6% collagen

Tab. 2. Radiocarbon dates from Ovčarovo-Gorata (43°11' N, 26°39' E). Source: Nr. 1–4 (*Görsdorf, Bojadžiev 1996.128–129*); Nr. 5–18 (*Krauß 2014.282–283*).

As mentioned above, in the present paper we based the stratigraphic analysis of Džuljunica ^{14}C-data on GMCWM. While the alternative method of Bayesian Sequencing (most recently in *Bronk Ramsey 2011*) makes use of the available stratigraphic information in terms of age-relations that are given on an ordinal scale (*younger-older*), the application of GMWCM requires this information to be interval-scaled (*e.g.*, tree-ring counts, pottery seriation, metric depth). Both methods share the disadvantage that it is practically impossible to simultaneously optimise both the precision and accuracy of the archaeological age model under study. In theoretical terms, this is yet another consequence of the above-mentioned non-commutative relation between the ^{14}C and the calendric time-scale. Accepting this fundamental limitation, the major advantage of GMWCM is that we attempt not only to optimise the dating precision, which is a relatively straightforward matter, but in addition use an algorithm whereby the dating probability is implemented as a *proxy* for the otherwise unknown dating accuracy. In the following, we use GMCWM based on the measured metric depth of the short-lived bone samples (Tab. 1). For taphonomic reasons, we exclude the two outliers (identified above) and all charcoal samples from these studies.

The GMWCM algorithm

As described in Marion Benz *et al.* (*2012*), the GMCWM algorithm fits the depth-scaled archaeological data repeatedly to the calibration curve for an optional number of runs (read: age-models) between 1 and 100, each of which is assigned a max. 10 000 statistical iterations (read: input of age-model variables). Prior to each run, the metric depth values [cm] are linearly scaled to calendric ages [yrs] according to the specific age model [yrs/cm] under study. In the course of the analysis, by run-wise lengthening of the calendric-scale distance between samples, the algorithm uniformly expands the age model in annual steps between 0 and 4 [yrs/cm]. These are specific values that are relevant in the present study. The overall aim of this approach is to identify all age-depth models for which there is acceptable statistical agreement between the archaeological ^{14}C-data and corresponding points of the ^{14}C-age calibration curve. The final analytical step is to identify which of the different models is 'best'. As numeric measure for this qualification, in the course of each of the 100 runs, the GMCWM algorithm calculates the summed probability for the archaeological ^{14}C-data set in comparison to the corresponding points of the ^{14}C-age calibration curve.

This calculation covers both the standard deviation (STD) of the archaeological ^{14}C-ages and the STD assigned to the calibration curve. Steered by three independently running random number generators, each of the 100 runs provides 10 000 different results, whereby the algorithm simulates the following age-model errors: (1) Monte Carlo (Gaussian) re-measurement of the archaeological data steered by given standard deviations (STD); (2) Monte Carlo (Gaussian) re-measurement of the calibration curve data steered by STD typically set to values of ±10 ^{14}C-BP, with corresponding Monte Carlo recalculation of the calibration curve; as well as (3) Monte Carlo (Gaussian) calendric-scale variation of the initial age model steered by the input age-depth values.

In the present study, for this third error component, we applied constant errors of ±5 years on the calendric-scale, to allow for corresponding errors in age-depth simulation in the order of ±5–10 [cm]. For each of the 100 runs the obtained distribution of best-fit values contains 10 000 individual calendric age values, each of which represents the best-fitting calendric age (maximum probability) for the specific run. Following each run the results are shown on-screen, first as a histogram for which the calendric-scale width is calculated (Fig. 27 left) and second as a graph that shows the actual position of the archaeological data in comparison to the calibration curve (Fig. 27 right). Following graphic output the algorithm then begins calculations for the next run (age-model). Consequently, in the course of the analysis, the observer is presented with a graphically animated (incrementally expanding) sequence of age models on-screen. Typical run-times are 2 minutes to 6 hours, depending on the numeric precision requested.

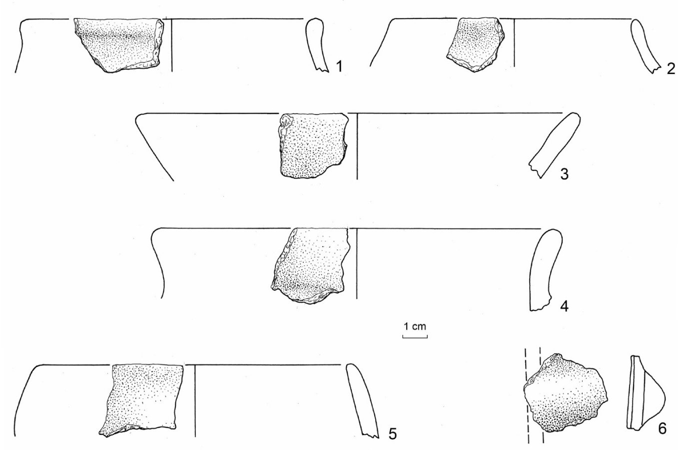

Fig. 17. Džuljunica III. Ceramic finds from the balk (n. 21–47).

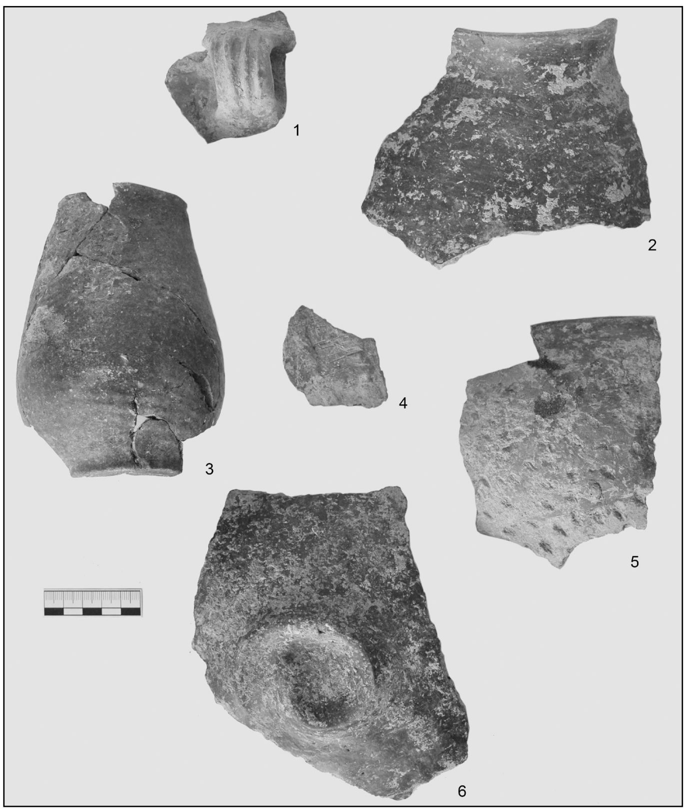

Fig. 18. Džuljunica IV. Pottery finds from excavations by N. Elenski: 1–3 canellated/fluted relief; 4, 6 plastic applications.

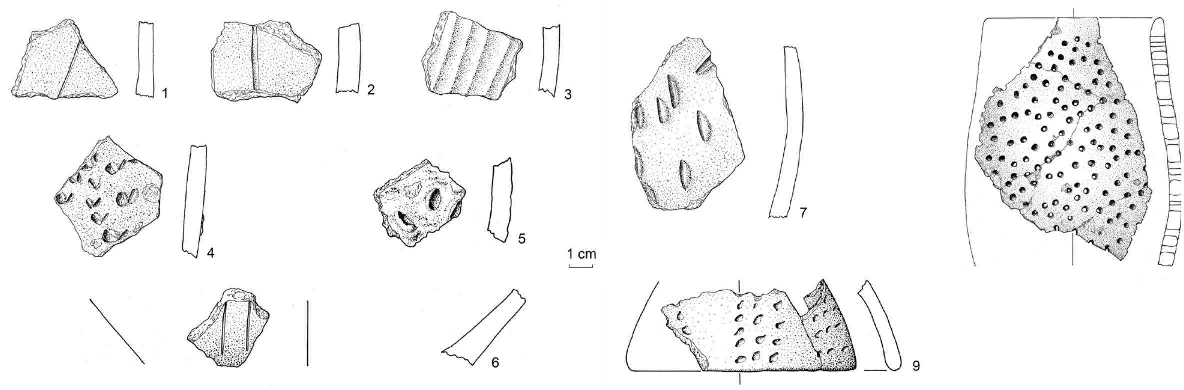

Fig. 19. Džuljunica IV. Ceramic finds from the balk: 1–4 n. 21–26; 5–6 n. 21–30; 7–9 n. 21–34; 1–2, 6 with incised lines; 3 canellated/fluted surface; 4–5, 7 fingernail impressions; 8 sieve vessel; 9 lid with impresso decoration.

When the GMWC-analysis is completed the software finally produces what we call a *statistics graph* (Fig. 26).

Results

As shown in the statistics graph (Fig. 26) the dating probability function (red line) has a maximum value of p ~80% for tell growth of 0.35yrs/cm. Smaller, but still highly significant probabilities (p~35%), are achieved for an extended plateau in the range 1.2–2.2yrs/cm. The probability then deteriorates to values lower than p = 5% at the end of the scale. In comparison, the dating precision (blue line) is highest (*i.e.* the smallest best-fit histogram width ±5 to ±7calyrs) for tell growth in the range of 0–1yrs/cm. A local peak shows less precision for models ~1.3 yrs/cm, followed by higher precision again (±10yrs histogram width) for growth values larger than ~1.5yrs/cm. Finally, the dating precision function also deteriorates towards the end of the scale.

As mentioned above, in developing GMCWM we made efforts to optimise both precision *and* accuracy simultaneously. This was achieved by introduction of an optimising factor, F. Initially we defined F as the linear product of probability and precision. However, as shown by experimental studies with data of known age, sensitivity can be increased by defining F by using the squared probability function. An explanation can be sought in the fact that radiocarbon dates have algebraic properties similar to those in quantum physics, where defining probabilities for measured observables based on the squared values of wave-particle functions is standard practise (*e.g., Omnès 1994. 83*). Interestingly, the analogy works correctly. As can be taken from Figure 26, the F function (green) has its strongest peak for tell growth at ~0.35yrs/cm (similar to the probability function), but a peak in the F-function is now also attained for tell growth of ~1.70yrs/cm. Put together, the statistics graph informs us of the existence of two distinctly different (alternative) age models (we call Model 1 and Model 2), between which we must choose. These two models represent the quantum states into which the chronological system jumps when we try to mea-

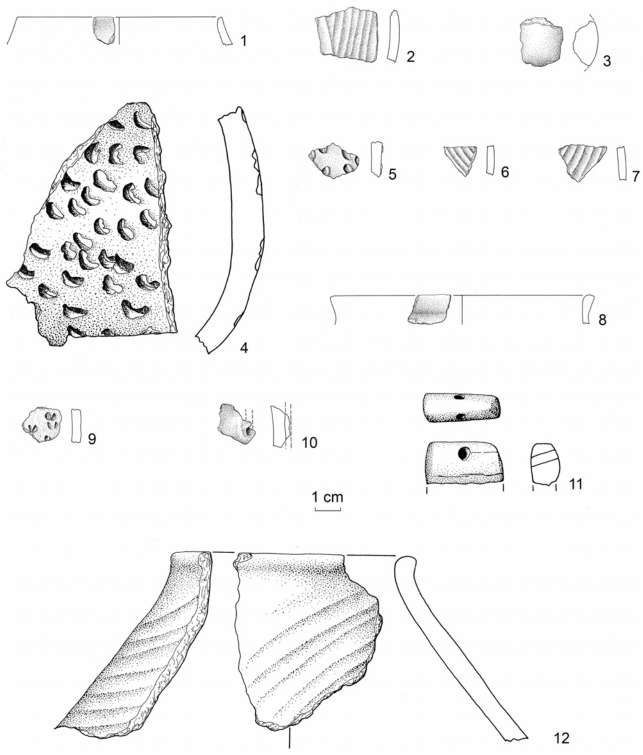

Fig. 20. Džuljunica IV. Ceramic, clay and bone finds from the balk and the adjacent planum: 1–4 n. 21–37; 5–10 n. 21–40; 11 n. 21–43; 12 from the planum; 2, 6–7, 12 with canellated/fluted surface; 4–5, 9 fingernail impresso; 11 bone pendant.

sure (enforce) a continuous sequence of stratigraphic age models.

Accepting Model 1 would imply that the two Džuljunica Phases Dž–I and Dž–II would together cover a time-span of only ~30 calendar years (~0.35yrs/cm x 86cm). Although it has the highest probability, by archaeological reasoning, Model 1 appears too short. In comparison, with an implied time-span of 1.75 yrs/cm x 86cm = 150yrs, Model 2 agrees much better with archaeological expectations based on considerations for realistic tell growth and on pottery style comparisons between Džuljunica and other ^{14}C-dated sites (Ulucak, Çukuriçi, Ovčarovo-Gorata). Finally, when shown in context with the INTCAL09 high-precision calibration of raw data at the laboratories at Seattle and Heidelberg (Fig. 28) it becomes clear that the existence of two alternative best-fitting models is due to a reversed calibration curve wiggle between 5960 and 5900 calBC. In Model 1, all Džuljunica ^{14}C-data (phases Dž–I and Dž–II) lock into the steep slope of the calibration curve between 5950 and 6050 calBC. In Model 2, the Dž I-data still lock into this steep region but the Dž II-data are now attracted to the next following strong wiggle, which has a maximum of around 5930 calBC. Since this wiggle can be identified in the laboratory raw data, but is over-smoothed in the construction of the INTCAL09 calibration curve, we are confident that Model 2 is acceptable, despite its slightly lower overall probability. It appears that some of the Džuljunica Dž–II ^{14}C-data are picking up the corresponding slightly higher atmospheric ^{14}C-ages. This is only possible due to their relatively high dating precision (STD ~35 ^{14}C-BP). Finally, Figure 28 shows the GISP2 δ^{18}O-measurements of Minze Stuiver *et al.* (*1998*) as a proxy for North Atlantic ocean/atmosphere temperature, and GISP2 non-sea salt K+ as a proxy for the strength of Siberian High pressure (*Mayewski* et al. *1997; Rohling* et al. *2002*). It can be deduced from this comparison that the earliest Neolithic was established at Džuljunica some 100 years (perhaps 4 generations) after the end of RCC-conditions (Rapid Climate Change) (*Weninger* et al. *2009*). Figure 29 shows the chronological results achieved for Džuljunica in comparison to other Neolithic settlements in Northeast Bulgaria.

Fig. 21. Zoomorphic idols, so called labrets, from Džuljunica II. Excavations: N. Elenski.

Early Neolithic animal remains from Džuljunica

The dispersal of animal husbandry technologies from western Anatolia into Southeastern Europe is a poorly understood process. Recent studies in western and central Anatolia indicate that animal husbandry evolved in diverse forms in this intervening area between the Fertile Crescent and Southeast Europe (*Çakırlar 2012*). In other words, no single animal husbandry package was introduced to Southeast Europe from Southwest Asia. Instead various kinds of

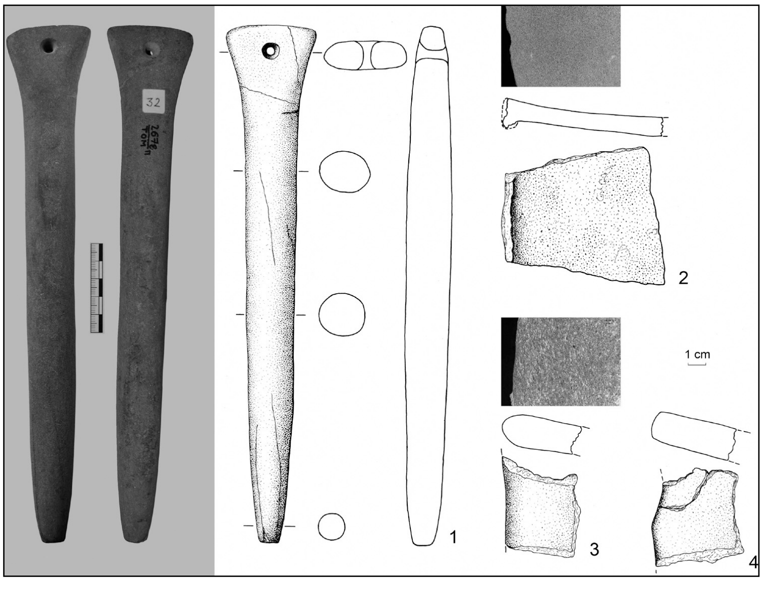

Fig. 22. Items of fine sandstone from Džuljunica I and II. Excavations N. Elenski: 1 sceptre-like object from Džuljunica II, reminiscent of the smaller labrets with perforated head; 2–4 fragments of stone palettes, 3 from Džuljunica I, 2 and 4 from Džuljunica II.

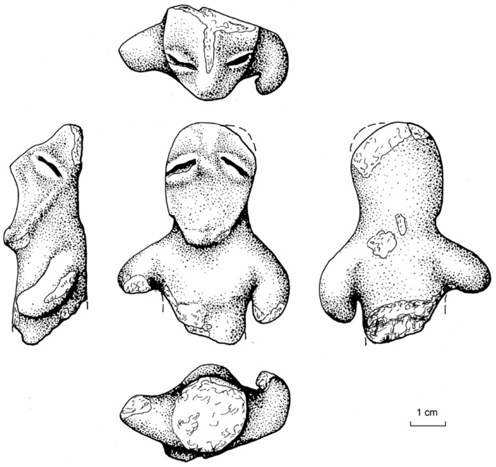

Fig. 23. Torso of an Early Neolithic clay figurine from Džuljunica I. Planum adjacent to the balk (n. 21–111).

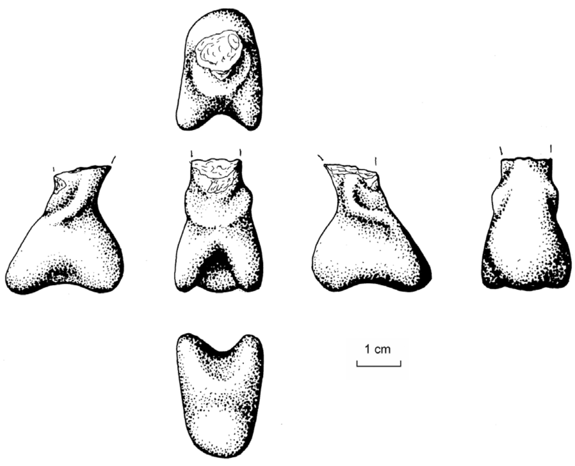

Fig. 24. Headless female Early Neolithic clay figurine from Džuljunica I. Planum adjacent to the balk. Excavations: N. Elenski.

evolving animal husbandries would have been moving across a wide frontier until they eventually reached this region. How were animal husbandry technologies transmitted further west, across the Aegean and into the temperate regions of the Balkan Peninsula? And how were they further transformed there? Zooarchaeological assemblages from well-stratified, radiocarbon-dated deposits representing early Neolithic settlements like Džuljunica are crucial to understanding the integration of herding during the transition to sedentary life in Europe.

Material and methods

We studied 900 specimens from the stratigraphic balk excavated in 2010, which covers the entire Neolithic sequence, and 1264 specimens from the horizontal exposures representing the earliest (Dž –I) Neolithic phases. The assemblages from the balk were recovered through 2mm mesh and for the most part (approx. 89%) include unidentifiable mammal remains. The Dž–I assemblage from horizontal excavations yielded a larger proportion of identifiable specimens (*c.* 45%). The sample size is thus small,

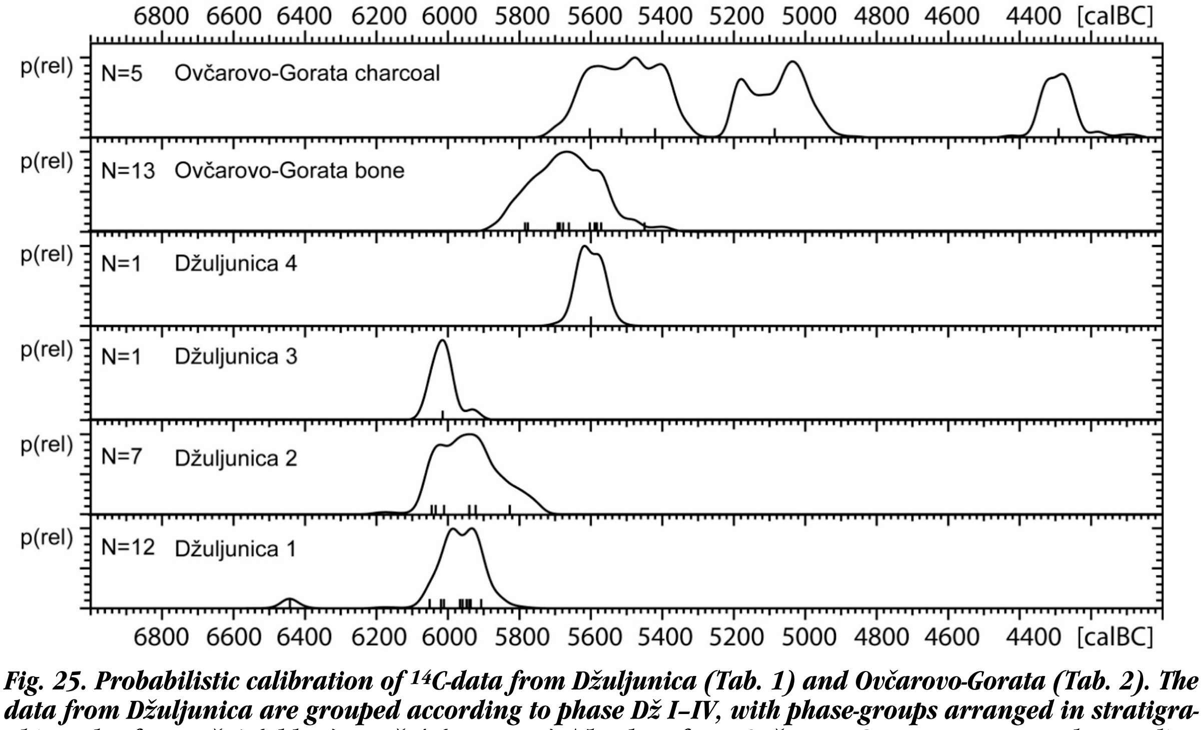

Fig. 25. Probabilistic calibration of ^{14}C-data from Džuljunica (Tab. 1) and Ovčarovo-Gorata (Tab. 2). The data from Džuljunica are grouped according to phase Dž I–IV, with phase-groups arranged in stratigraphic order from Dž 1 (oldest) to Dž 4 (youngest). The data from Ovčarovo-Gorata are grouped according to sample material (bone and charcoal). Radiocarbon calibration based on INTCAL09-data (**Reimer et al. 2009*****). Calibration method: (*****Weninger 1986*****). Graph produced by CalPal-software (*****Weninger, Jöris 2008*****).***

and the study of archaeofaunal assemblages from the younger Neolithic layers of Džuljunica continues. For these reasons, here we refrain from speculating about how animal exploitation developed during the course of Early Neolithic occupation in Džuljunica and focus on the character of animal husbandry as it emerged in Dž–I.

The assemblage was studied in the archaeological laboratory of the New Bulgarian University in Sofia and at the Regional Historical Museum of Veliko Tărnovo. Domesticated pig and cattle (*i.e.* domesticated animals whose wild ancestors are known to have occurred in Bulgaria in prehistory) were identified based on their morphology, specifically by comparing them with standard wild specimens of known sex and provenance (*Degerbøl, Fredskild 1970; Hongo, Meadow 2000; Payne, Bull 1988*). Osteometric measurements followed Angela von den Driesch (*1976*). NISP (= Number of Identified Specimens) is the basic quantification unit used to calculate the proportions of the represented taxa. A more detailed presentation of the material will follow in future publications.

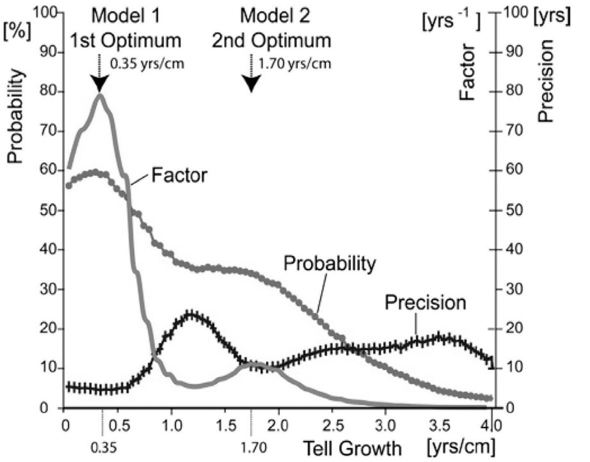

Fig. 26. GMCWM statistics graph for Džuljunica ^{14}C-data (Phases Dž I–II) with simulated tell growth in the overall range 0–4.0yrs/cm, based on 100 runs with increments 0.04yrs/cm. Red – dating probability left scale: Probability [%]); Blue – dating precision (right scale: histogram width, Precision [yrs]); Green – Optimising Best-Fit Factor F (Probability-squared/ Precision [yrs-1]). Optimal results, based on maximal values for F, are achieved for age-models 0.35yrs/cm and 1.70yrs/cm.

Results and discussion

Sheep, goat, and domestic cattle are present in Dž–I. The domestic status of the sheep and goats in Dž–I is clear, because Džuljunica falls well out of the natural distribution area of their wild progenitors (*Uerpmann 1987*). Sheep and goat comprise approx. 50% of the vertebrate material from the horizontal exposures and approx. 65% of the material from the balk (Tab. 3). The most likely cause of this dissimilarity is the difference in the recovery techniques used in the two excavations. It is well known that sieving mitigates bias causing a low turnout of smaller animals (*Payne 1972; Clason, Prummel 1977*). Regardless of artificial differences in proportions, both assemblages demonstrate the important place of imported ovicaprid herds in domestic herd composition in Dž–I.

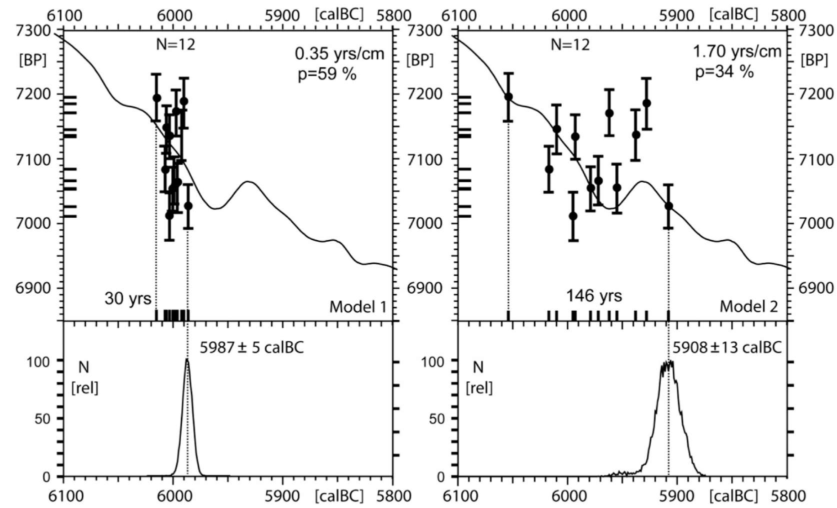

Fig. 27. Comparison of Age-Model 1 and Age-Model 2. Left – ^{14}C-sequence for Džuljunica (Phases Dž I–II) according to Model 1 (0.35yrs/cm); Right – ^{14}C-sequence for Džuljunica (Phases Dž I–II) according to Model 2 (1.75yrs/cm); in comparison to INTCAL09 curve (**Reimer et al. 2009**). Both models provide high-precision fits of Džuljunica ^{14}C-ages to INTCAL09. By archaeological reasoning, Model 1 is too short (**cf.** text). Model 2 agrees well with archaeological expectations based on considerations for realistic tell growth and on pottery style comparisons between Džuljunica and other ^{14}C-dated sites (Ulucak, Çukuriçi, Ovčarovo-Gorata).

Cattle comprise approx. 30–35% of the identified mammalian specimens in Dž–I. The presence of domestic cattle in Dž–I is attested by the relatively small sizes of the *Bos* specimens (Fig. 30). Measurements indicate that aurochs (*Bos primigenius*) are also present in small amounts. This indication fits expectations based on earlier studies from Koprivec near

Taxa represented	Frequency
Bos taurus (cattle)	VA
Ovis aries/Capra hircus (sheep or goat)	VA
Canis domesticus (dog)	R
Bos primigenius (aurochs)	C
Cervidae (deer)	C
Sus scrofa (wild boar)	R
Castor fiber (Eurasian beaver)	R
Lepus capensis (European hare)	R
Unionidae (Freshwater clams)	C

Tab. 3. List of faunal taxa represented in Džuljunica and their relative abundance (R = rare; C = common; A = abundant; VA = very abundant).

Džuljunica (*Manhart 1998*) and Fikirtepe further to the southeast (*Boessneck, Von den Driesch 1979*).

Morphologically domestic pigs are absent from the assemblages studied thus far. Morphologically wild boar (*Sus scrofa*) is represented by very few specimens in both sieved and hand-collected assemblages. The measurements of both cranial and post-cranial elements fall well within published ranges from modern populations (Tab. 4). For the time being, it is difficult to argue for the presence of domestic pig in early Džuljunica. The special role played by pigs and boars in the dissemination of early animal husbandry technologies is only beginning to be understood. While osteometric analysis indicates that morphologically domestic pigs were absent in the 7th millennium BC cultures of Central Anatolia (*Arbuckle* et al. *2014; Russel, Martin 2005*), the same type of analysis shows that domestic pigs were rapidly adopted after the initial phase of Neolithic settlement in northwestern Anatolia around 6100 calBC (*Çakırlar 2013*). They were also present in southern, southwestern, and central-western parts of Anatolia from the earliest Neolithic (*Çakırlar 2012*). Furthermore, ancient DNA analysis demonstrates that wild boar and domestic pig interbred in western Anatolia (*Ottoni* et al. *2013*). In view of these recent studies and observations on the *Sus* sp. specimens from Džuljunica, it is possible to surmise that domestic pigs were added to the herds of Džuljunica at a later period, either through local domestication, the introduction of domestic breeds, or both.

In contrast to the paucity of boar remains, specimens of deer (*Cervus elaphus*, and *Capreolus capreolus*) are common, at percentages similar to what has been observed for Fikirtepe (*Boessneck, Von den Driesch 1979*). These remains show that hunting was practiced fairly regularly by these early Neolithic communities, whose mode of animal exploitation was geared primarily towards herding.

Our results substantiate previous faunal studies that attest to the important role of cattle herding at numerous Neolithic sites in Southeastern Europe and for the dispersal of early farming into temperate Europe (*Benecke 2006; Conolly* et al. *2012*). At Dž–I, cattle, sheep and goat herding played a significant role from the very earliest phase of occupation. Although Džuljunica is located in northern Bulgaria, this situation is in agreement with trends observed at Early Neolithic sites in southern Bulgaria (*Benecke, Ninov 2002*). The proposed link between dairy production and an emphasis on cattle breeding (*Evershed* et al. *2008*) is yet to be explored by appropriate zooarchaeological tools applied to sufficiently large samples. While the abundance and size of cattle, sheep and goat for Dž–I supports the demic diffusion model of Neolithisation for Bulgaria, the paucity and large size of *Sus* sp., together with the possibility of late adoptation of domestic pigs, demonstrate one of the ways in which local innovation shaped the Neolithisation of Southeast Europe.

Conclusions

The investigations undertaken at Džuljunica-Smărdeš in 2010 focused on the excavation of the balk separating trenches 18 and 21. The systematic excavation and documentation of this balk, which comprised a sequence of archaeological deposits beginning in the Early Neolithic, provided us with the unique opportunity to study developments for the eastern Balkan region from the Pre-Karanovo I phase through Karanovo II.

The lowermost settlement deposits (Dž–I) can be assigned to a phase which coincided with the Neolithi-

Speci-men. no.	Element	Measurement	Remarks
162	Ulna	BPC = 26.4mm	Difference from *Hongo, Meadow 2000* standard individual: 1.1mm
617	Radius	BFp = 36.5mm	Difference from *Hongo, Meadow 2000* standard individual: 2.3mm
343	Maxilla with teeth	Breadth of M1 = 15.7mm; Breadth of P4 = 15.8mm	Compare with *Payne, Bull 1988.appen.*

Tab.4. Measurements of three Sus sp. specimens from Džuljunica I and their relationship to modern wild individuals of known sex and provenance.

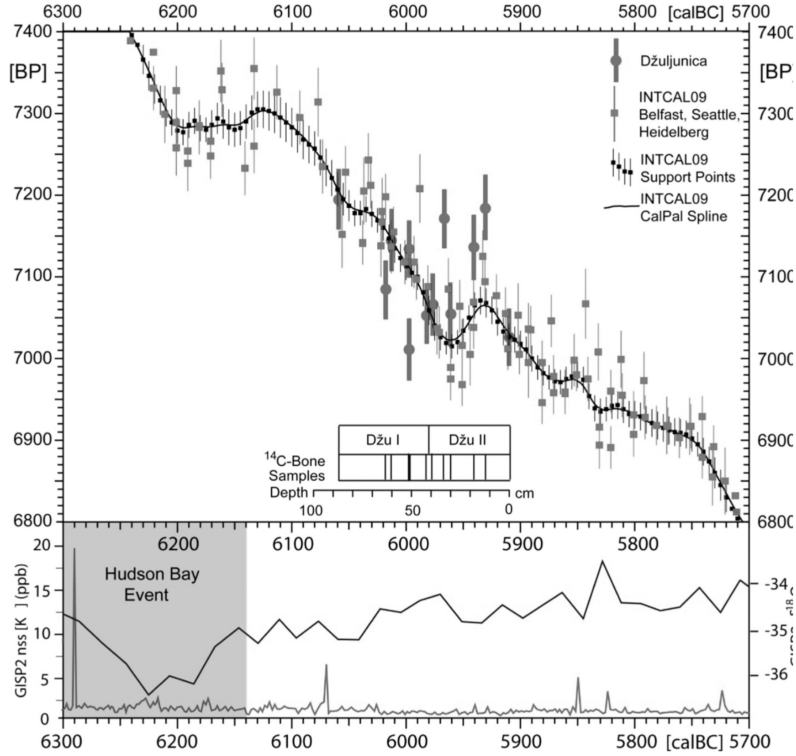

Fig. 28. Linear stratigraphic age model for Džuljunica ^{14}C-data (Phases Dž I–II) according to Model 2 (1.70yrs/cm), in comparison to INTCAL09 curve (**Reimer *et al.* 2009*), INTCAL09 high-precision calibration raw-data (Seattle/Heidelberg), and climate records (GISP2 $\delta^{18}O$ [*Stuiver *et al.* 1998*] as proxy for North Atlantic ocean/atmosphere temperature, and GISP2 non-sea salt K^+ as proxy for the strength of Siberian High pressure [*Mayewski *et al.* 1997; Rohling *et al.* 2002*]; GISP2-age model shifted 40yrs younger according to refined GICC05-ages [*Vinther *et al.* 2006*]).***

sation of the region, for which there are currently no older Neolithic finds. From a typological perspective, material from this level corresponds to finds made at Koprivec and from Poljanica-Platoto.

Additionally, finds from Dž–I attest to clear affinities with material from West Anatolia. This context is also confirmed by radiocarbon data. While the larger figurine discovered at Džuljunica (Fig. 23) already indicates independent Balkan traditions from the outset of Neolithisation, the smaller figurine (Fig. 24) still displays typical Anatolian features. This trend is also reflected in the results of our investigations into the faunal assemblage from the site. While the earliest Neolithic communities arrived in the region with herds of sheep and goat, and domesticated cattle, pig was either domesticated locally or imported into the region later.

Certainly, it cannot be ruled out that the Neolithisation of the Central Balkans did not occur a few generations prior to the earliest occupation deposits from Džuljunica. Data from Thessaly indicate that Neolithisation occurred slightly earlier in Greece, and the river valleys of the Vardar/Axios, Struma/Strymon and Morava would have provided natural routes for

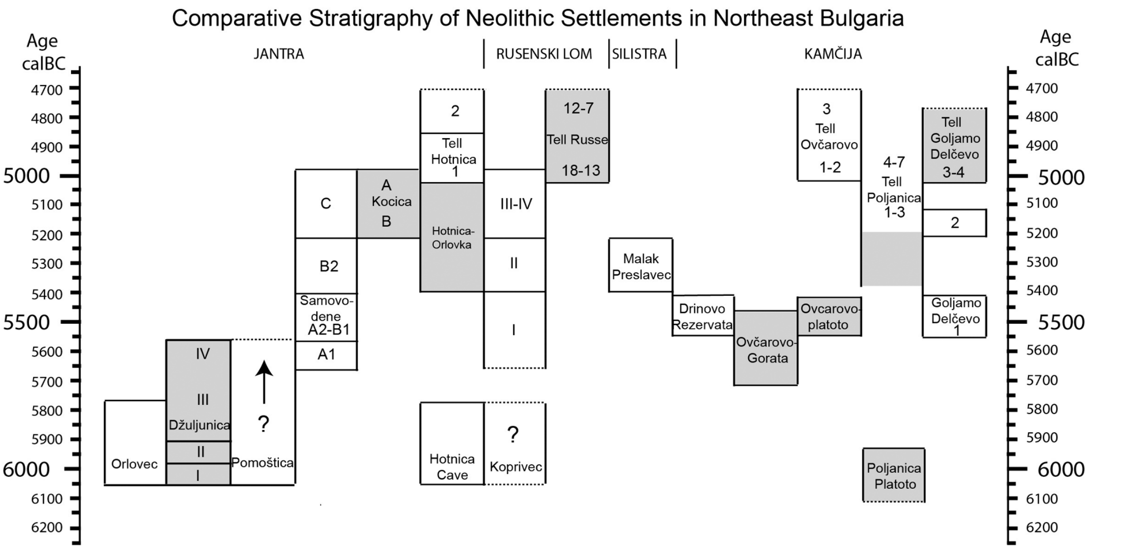

Fig. 29. Schematic comparative stratigraphy of Neolithic settlements in northeast Bulgaria. Grey-shaded boxes indicate radiocarbon-dated sequences.

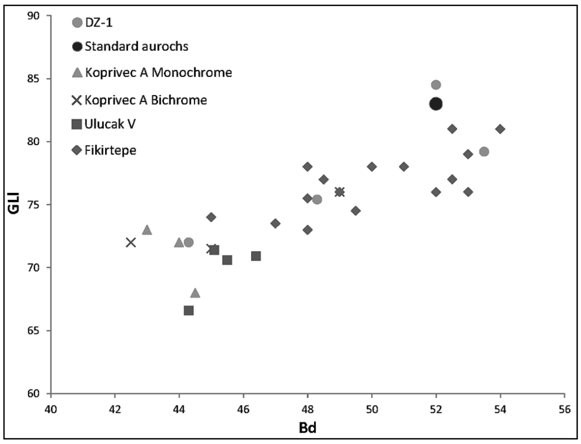

Fig. 30. As a proxy for domestic* vs. *wild cattle populations at the Neolithisation frontier between Anatolia and the Balkans, comparison of length (GLl) and breadth (Bd) measurements of* Bos *sp. astragali (knuckle bone) from Dž-I, roughly contemporary settlements in the greater Early Neolithic European frontier (Koprivec data from* Manhart 1998*; Ulucak V data from* Çakırlar 2012*; Fikirtepe data from* Boessneck and von den Driesch 1979*), and a standard prehistoric aurochs from northern Europe (*Degerbøl, Fredskild 1970*).

the dispersal of the new form of subsistence. Furthermore, it is not insignificant that the arrival of Neolithic lifeways in the region coincided with the end of a period for which palaeoclimate proxies attest to considerable climate fluctuation. From the middle of the 7th millennium calBC until its final century, a Rapid Climate Change (RCC) interval – with the same mechanism as the recent *Little Ice Age* – prevailed. RCC conditions are synonymous, for example, with harsh winters, but also with severe droughts. Additionally, in the century directly preceding the Neolithisation of the Central Balkans, these climate perturbations would have been intensified by the effects of the 8.2ka calBP Hudson Bay event. Causal relationships between climate change and the Neolithisation of Southeast Europe in the late 7th millennium calBC are an area of considerable interest which should be pursued in the future.

By the Dž-II and Dž-III phases, Neolithic communities had dispersed over the entire region, from the Aegean coast to the Carpathian Basin. The widely occurring white-on-red painted pottery (especially with white dots) testifies to a large communication sphere stretching from central West Anatolia (Ulucak and Çukuriçi) to Gura Baciului, at the centre of the Carpathian Basin.

From Dž-IV/Ovčarovo-Gorata (Karanovo II) there is a distinctive trend to regionalisation. In the Eastern Balkans, this trend is expressed in the near disappearance of painted decoration and the introduction of vessels with canellated/fluted surfaces. The smooth transition from this period to the subsequent Middle Neolithic, not identified at Džuljunica, heralds the period of tell development in Southeast Europe.

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Different models for the Neolithisation of Albania

Adem Bunguri
Institute of Archaeology, Tirana, AL
bunguria1@gmail.com

ABSTRACT – *According to the archaeological evidence, the Neolithisation process in Albania seems to have passed through three different phases, with chronological gaps between them. The earliest phase is represented at the Vlusha site, where coarse monochrome pottery was found in the same layer as microlithic tools. The second phase can be traced back to the Konispol site, where Impresso pottery appeared immediately above the Mesolithic layer. The third phase is represented by the Podgorie I site, which is characterised by red monochrome slipped ware, white-painted pottery, polychrome pottery, as well as pottery with impresso and barbotine decoration.*

IZVLEČEK – *Arheološki podatki kažejo, da je proces neolitizacije v Albaniji potekal v treh različnih fazah z vmesnimi kronološkimi prekinitvami. Najzgodnejšo fazo predstavlja najdišče Vlusha, kjer je bila odkrita groba enobarvna (monokromna) lončenina v isti plasti kot mikrolitska orodja. Drugo fazo smo prepoznali na najdišču Konispol, kjer se lončenina, okrašena v stilu Impresso, pojavlja tik nad mezolitsko plastjo. Tretjo fazo predstavlja najdišče Podgorie I, za katerega je značilna rdeče premazana enobarvna (monokromna) lončenina, belo slikana lončenina, večbarvna (polikromna) lončenina, kakor tudi lončenina, okrašena z vbodi in barbotinom.*

KEY WORDS – *Albania; Neolithisation; pottery; interpretative model*

Introduction

Positioned at an intersection of the network of land routes that connect Anatolia, the Balkans and the Western Mediterranean, Albania is a highly favourable location, which determined the cultural features of its Neolithic civilisation (Fig. 1). The Neolithisation process is complex, involving successive social-historical events and interactions which happened in a definite space and time, conditioned by numerous circumstances and geographical and bio-economical conditions in particular (*Budja 1999.121*). The debate about the Neolithisation process has been a long one, and includes various hypotheses, from the indigenous to the migratory models (*Budja 1993. 179–193; Zvelebil 1995.107; Özdoğan 1995.25; Bánffy 2005.75*). Earlier models of Neolithisation based on a single wave of colonisation and a single scenario have recently been supplanted by more complex models involving interaction and reciprocal cultural impacts (*Oross, Banffy 2009.175*). The Early Neolithic culture in Albania combines elements of the Anatolian-Balkan and Adriatic-Mediterranean cultural complexes of this period. As such, the territory of Albania is an important case study area for defining the spatial extent of the Mediterranean and Continental cultural groups that were present in this region during the Neolithic period. We find various regional cultures in Albania that have attracted the attention of prehistoric archaeologists in recent decades who suggested different models, ranging from the indigenous to diffusionist theory.

Our knowledge about the very beginnings of the Early Neolithic is very limited; one or two sites can be ascribed to this period: Vlusha in the south-central part of Albania, and Konispol on the southwest coast. A vertical sequential stratigraphy has been found only in the Konispol Cave, while at the open site at Vlusha there is only horizontal stratigraphy present.

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On the other hand, the Podgorie site has yielded quite good stratigraphical and archaeological evidence to confirm a late stage of the Early Neolithic which resulted from migration. However, according to the archaeological evidence, Albania can be divided longitudinally between two main cultural Early Neolithic complexes, as shown in the following map (Fig. 2).

The archaeology of the Early Neolithic in Albania shows that the culture of this period developed in three chronological phases, even with hiatuses between them, each corresponding to the three different models of the Neolithisation process (Fig. 3).

Model no. 1: Vlusha I–II

Vlusha is a site where Mesolithic and Early Neolithic deposits were found in two different areas of the site, Vidhëz (point A) and Armenina (point B), approx. 300m apart. The site lies on a mountain slope 800m above sea level, on the right bank of the Kapinova River, near the eponymous village in the district of Skrapar (Fig. 4).

The site has been known since 1972, when Luftin Ylli collected several objects discovered by chance at this location which are reminiscent of the Mesolithic tradition of tool production (*Prendi 1982.190; 1990.300, Pl. I, 1–8*). A year later, a small trial excavation was carried out by Muzafer Korkuti, who concluded that the finds dated to a transitional period between the Mesolithic and Neolithic. The last trial excavation at Vlusha, carried out by Ylli in 1990, revealed different stratigraphic sequences and cultures, each indicating two successive periods of development, termed Vlusha I and Vlusha II, and related to the Late Mesolithic and Early Neolithic, respectively.

Vlusha I

The first trench of 3x3m was excavated at Vlusha I (Vidhëz), which revealed a cultural deposit reaching a depth of 0.85m that comprised two separate cultural horizons, as can be seen in its eastern profile (Fig. 5):

❶ The lower horizon, 0.50m thick, consisted of dark brown soil, with late Mesolithic flint silex and no pottery.

❷ The upper horizon, 0.30–0.35m thick, consisted of light brown soil that contained flint silex and no pottery. The cultural layer dates to the late Mesolithic period, perhaps the Tardenoisien phase (*Prendi 1990.300*).

The flint tools are of the same type as those found on the surface; the same flint tools, mainly in grey and whitish colours, with very small dimensions (1.5–2cm) and irregular trapezoidal shapes, which are typical examples of Mesolithic microlithic tools, are apparently in the Tardenoisien tradition. Based on the microlithic character of the silex (Pl. 1.1–8) and the absence of ceramics, the possibility that a Mesolithic settlement existed at Vidhës was considered. However, the suggestion remains open to debate, as the finds were insufficient and not all typologically definable. The excavations at Vlusha revealed that there were two distinct cultural horizons, of which the layer at point A (Vidhëz-Vlusha I) had no pottery, but is securely dated to an earlier period, *i.e.* the Mesolithic, while the layer at point B (Armenina-Vlusha II) dates to an early phase of the Neolithic. However, this aspect requires further investigation, as Vlusha is indeed a site with great potential for studying the process of Neolithisation of this area, given that the earliest Neolithic layer here, Vlusha II, follows directly after the Mesolithic layer, Vlusha I.

Vlusha II

The second trench of 3x3m was excavated in 1990 at point B (Armenina). Vlusha II is of particular in-

Fig. 1. Map of the Balkans and Albania.

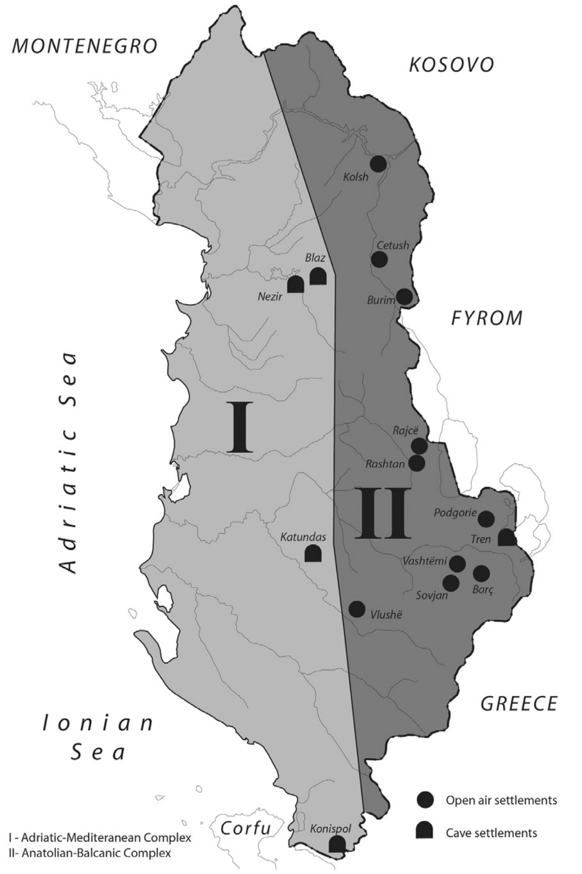


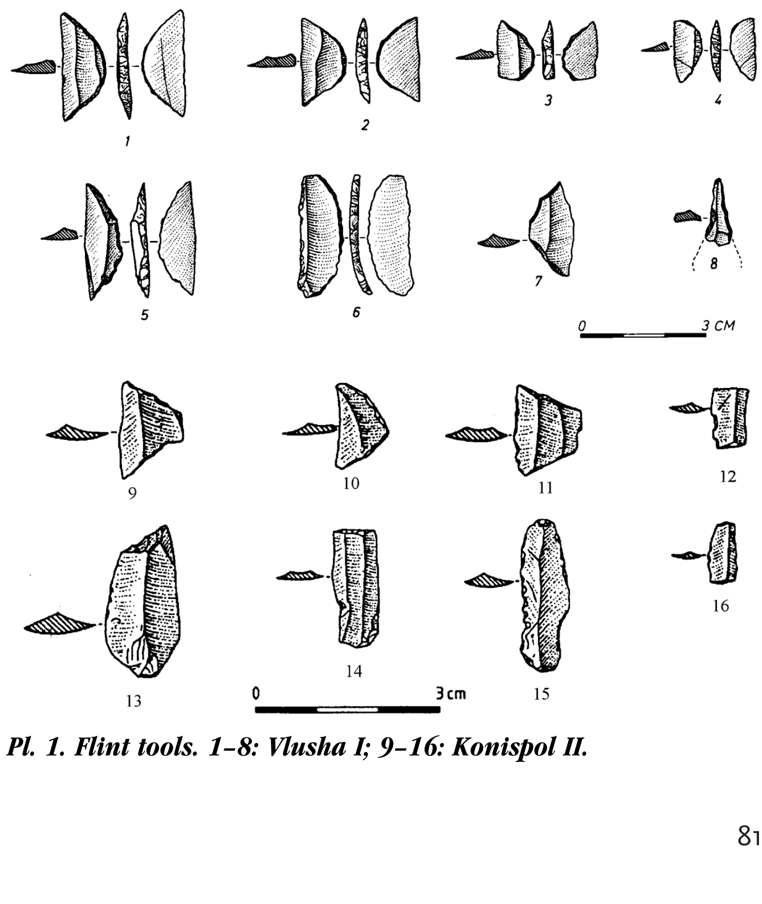
Fig. 2. Map of Early Neolithic cultural complexes in Albania.

terest because of its monochrome pottery and strong Mesolithic tradition. The Early Neolithic deposit discovered at point B (Armenina), which includes monochrome dark grey pottery sherds, has been associated with Mesolithic microlithic flints. The cultural layer was 0.80m thick and clearly divided by two building levels with traces of burned earth and hearths, as can be seen in its eastern profile (Fig. 6):

❶ The first and the earliest horizon is a layer 0.20m thick, light grey layer lying directly over the natural bedrock and consisting of clay and sand, and culturally sterile.
❷ Traces of a fireplace and the remains of a hearth, measuring 0.15–0.30m.
❸ The second occupation horizon consists of two layers. The first layer is 2.20m thick and begins with traces of a hearth. It was made of compact dark brown clay which contains microliths and a few pottery.
❹ The second layer, measuring 0.40m in thickness, consists of light brown clay and a few pottery sherds and flint tools. The layer appears homogenous, containing only pottery, small flint chips, nuclei and a few objects that show traces of use.

The material culture of both occupation horizons at Armenina (Vlusha II) is represented by some flint tools of micro-dimensional silexes (Pl. 2.1–20) and monochrome ware produced with modest technology, highly fragile and poorly fired. It has a dark grey sandy clay fabric, and in a few cases reddish or ochre colouring. Coarse ware of fabric with medium-sized grains predominates, while pottery with a coarser grained fabric is less frequent. The pottery is highly fragmented and contains few diagnostic elements. Spherical and semi-spherical cups predominate, along with conical bowls, generally with a flat base, which in a few cases appear to have small tubular handles, particularly in the case of the coarser fabric ware.

Decoration is rarely present and consists of impressed lines placed around the neck or just below it, mainly observed on the coarser fabric ware (Pl. 3.11–14). Impresso and barbotine style decorations are entirely absent. The excavated area in this sector, except for a few flint tools, produced no tools of polished stone or bone. Bones are generally absent, except for a single jaw fragment with three pre-molar teeth of a large unidentified wild animal, which were



Pl. 1. Flint tools. 1–8: Vlusha I; 9–16: Konispol II.

found at 0.70m depth, in the upper section of the first occupation level.

The material culture is particularly striking because of the presence of micro-dimensional silexes, some of which are similar in shape and retouch style to Mesolithic microliths found during the excavations at Vidhëz (Vlusha I; *Prendi 1990.300*). Of particular chronological and cultural relevance among these finds are the microliths, especially one example of elongated shape with fine retouch on the back, identical in form and production style to microliths that have been previously found here. The general characteristics of the pottery at Vlusha do not correspond to any of the Neolithic cultures known so far in Albania, which makes the cultural and chronological evaluation of this material complex, especially as the material is limited in quantity and has no clear stratigraphic provenance. However, the monochrome pottery, its poor firing quality, the simplicity of the shapes, and the limited and uniform decoration indicate that this material represents a new cultural phenomenon that cannot be chronologically associated with a classic phase of the Early Neolithic period. In this sense, it is interesting that in the layer that contained pottery finds, some microliths are similar to those found at site B (Vidhëz). Thus, we believe that the locality of Vlusha was occupied during both the Mesolithic and Early Neolithic.

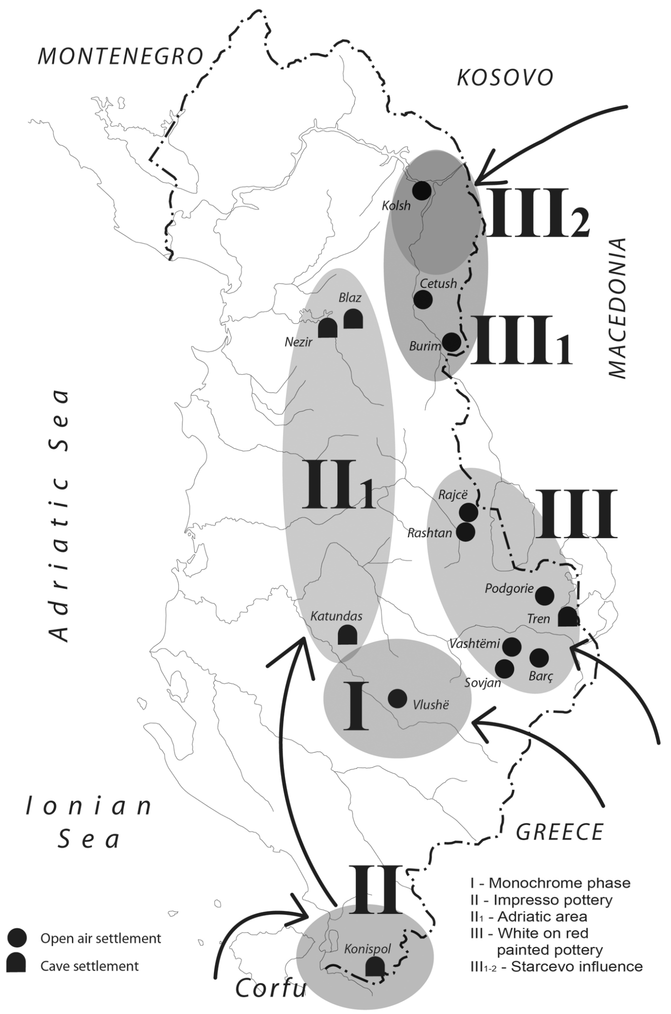
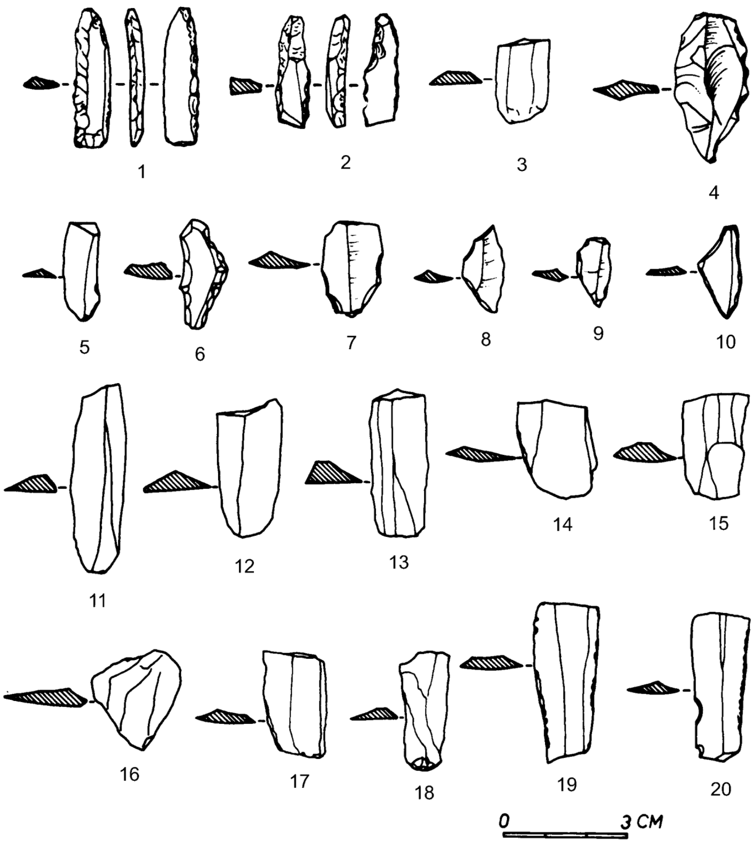


Fig. 3. Map of three phases of Neolithisation in Albania.

It is worth pointing out that Vlusha differs from the above-mentioned settlements in that the elements of the Mesolithic tradition appear in its early phase in association with monochrome ware and not with Adriatic Impresso ware. This phenomenon has been stratigraphically documented at the Sidar settlement on Corfu, where the layer with monochrome Early Neolithic pottery and many (non-microlithic) flint tools, at a depth of 0.50–0.60m (Sidar C, Base), was located over a Mesolithic layer (Sidar D) and covered by an alluvial hiatus of 0.70–0.80m in depth (Sidar C, Middle), followed by a layer of Adriatic Impresso ware accompanied by many flint tools at 0.15m depth (Sidar C, Top; *Sordinas 1969.402–407, Pl. III; 2003.89*). The same stratigraphic sequence was observed at Škarin Samograd in Central Dalmatia, where a horizon of monochrome ware (Samograd I) is followed by a layer of Adriatic Impresso ware (*Müller 1991.311–358; 1988.232–234*). According to the radiocarbon dates, the monochrome pottery from Sidari C Base dates to about 6610–6420 calBC (*Müller 1991.355*) and about 6825–6241 calBC (*Briam, Heyed 2001.200–202*). The impresso pottery of Sidar C Top layer is dated to 6410–5990 calBC (*Sordinas 1968.26; Müller 1991.356*) or 6569–5850 calBC (*Briam, Heyed 2001.200–202*), with a gap of almost 300 years. At Škarin Samograd, the horizon with monochrome pottery (Samograd I), is dated to 5660–5560 calBC, and followed by a layer with Adriatic type B Impresso pottery (Samograd II), which is dated to 5630–5470 calBC (*Müller 1988.219–224; 1991.354–355*), with a gap of 150 years.

The coarse dark grey monochrome pottery at Vlusha IIa, both in forms and decoration, is similar to the monochrome pottery from the Krainici settlement in the Struma valley in Southwest Bulgaria. The decoration on the pottery from both settlements consists only of plastic ornamentation (*Stefanova 1996. 16–17*). In the later one, the earliest building level



Pl. 2. Flint tools from Vlusha IIa.

with monochrome pottery was covered after a hiatus by two other Early Neolithic building levels, in which white-on-red painted pottery appeared. (*Stefanova 1996.16–17, Pl. I.1–4*). A similar situation was observed at the Koprivec settlement in Northeast Bulgaria, where the Early Neolithic layer was formed by two building levels which followed each other without interruption. The earliest building level contained similar monochrome pottery, and its second building level, besides the monochrome, contained some fragments of white-on-red painted pottery (*Stefanova 1996. 17*). Similar cases were reported at the oldest Early Neolithic building level at Pomoshtica and Poljanica plato in Northeast Bulgaria, which were covered by a second building level where some white-on-red painted pottery was found (*Stefanova 1996.17–19*). The monochrome pottery at Koprivec was ^{14}C dated to *c.* 6300–6200 calBC (*Schubert 2005.242, Fig. 2*) and at Poljanica plato to about 6200 calBC (*Schubert 2005.242*) or *c.* 6180–6120 calBC (*Nikolova 1998.128; Budja 2001.36*).

The monochrome pottery and the simple shapes found at Vlusha indicate a possible affinity with the early monochrome ware of Sidar and Škarin Samograd, despite a few local differences, as well as with the early monochrome pottery from Thessaly (ger. Frühkeramikum) (*Milojčić 1959.5, Pl. 5*), with pottery from Krainici in the Struma valley or even with the monochrome pottery from the first building level at Koprivec, Poljanica Plateau, and Pomoshtica in Southwest and Northeast Bulgaria (*Stefanova 1996.16–18, Pl. I–IX*). The monochrome pottery at Kuprivec has been dated ^{14}C to *c.* 6300–6200 calBC (*Schubert 2005.242, Fig. 2*) and at Poljanica plato to *c.* 6200 calBC (*Schubert 2005.242, Fig. 2*) or between 6180–6120 calBC (*Nikolova 1998.128; Budja 2001.36*). However, the closest analogies to the dark grey coloured monochrome pottery of Vlusha IIa were found at the settlement of Krainici in the Struma valley in Southwest Bulgaria (*Stefanova 1996.16–17, Pl. I.1–4; Todorova 2003.264*).

Similar dark brown monochrome pottery with quite simple forms was found in the oldest Haçilar IX layer as well as at Çukuruçi Höyük in Aegean Anatolia, and most recently at the oldest building levels at Barçin Höyük VIe and VId in Northwestern Anatolia, ^{14}C dated to between 6620–6570 calBC and 6500–6400 calBC, which precedes the oldest building level at Fikir Tepe (*Gerritsen* et al. *2013.60–62*). These data show that simple monochrome pottery is the earliset in the Anatolian-Balkan complex of the Early Neolithic, followed in the Eastern Balkans by a white-on-red painted pottery layer (*Todorova 2003.264; Krauß 2011.110*). This chronological priority of monochrome pottery has also been confirmed in the Adriatic-Mediterranean

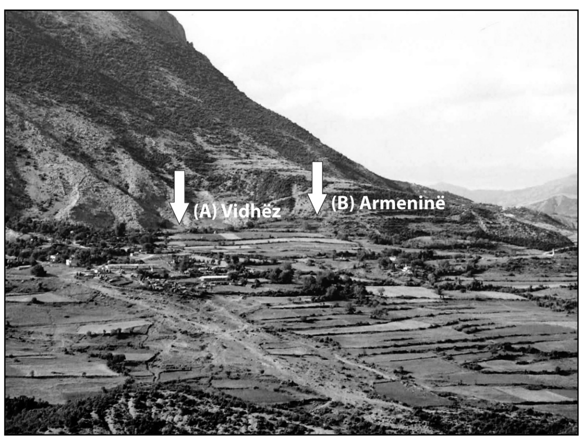


Fig. 4. View of Vlusha.

complex of the Early Neolithic, where the monochrome pottery layer was followed after a hiatus by an Impresso layer (*Müller 1988.219–220; 1991.354*).

These similarities provide indications of the cultural and chronological affiliation of Vlusha with the wider Aegean-Balkan region, as well as connecting the Neolithisation process of this area to that of the Aegean regions. The simple monochrome pottery at Vlusha IIa, weakly fired and dark grey in colour, as well as the lack of Impresso pottery, suggest that Vlusha IIa preceded the Konispol IIIa layer which yielded Impresso pottery. In this context, Vlusha IIa seems to be parallel with Sidar C Base (Corfu) and Škarin Samograd I (Central Dalmatia). Based on this chronological priority of Vlusha IIa preceding the other Early Neolithic cultures in Albania, as well as its analogies with contemporaneous Balkan cultures (*Todorova 2003.264*), we believe that this culture, originating in Anatolia, may be considered a representative of the earliest Neolithic that arrived in Albania.

However, since excavations at this site remain limited, future investigations are required to fully clarify the picture. The strong Mesolithic tradition supports the idea that pre-Neolithic groups were involved in the Neolithisation of the region. On the other hand, the presence of coarse monochrome pottery, known from some other Early Neolithic sites in the Southern Balkans, seems to indicate that the first farmers arrived in this part of Albania through the first wave of Neolithisation, known as 'Monochrome' Neolithic. It appears that two different populations lived together at this settlement, the indigenous groups and the newcomers, undergoing processes of assimilation and integration. According to the archaeological evidence, we believe that small migratory groups were involved, having arrived from one or various directions and for seasonal habitation. The newcomers seem to have arrived at Vlusha along the Anatolian-Balkan route, mainly through the settlement of Krainici in the Struma valley, where the monochrome pottery is more similar. In conclusion, I believe that Vlusha IIa represents the 'leap-frog colonisation' model, following Marek Zvelebil's classification (*Zvelebil 2001.2*).

Model no. 2: Konsipol IIIa

The second model can be traced back to the site at Konispol (Saranda district), in Southwest Albania, where Early Neolithic Impresso pottery appears immediately above the Mesolithic layer. The Konispol cave is located in the southern extreme of Albania in

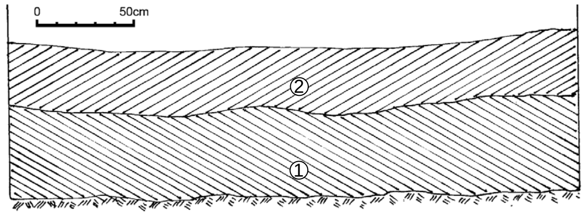


Fig. 5. Vlusha I profile.

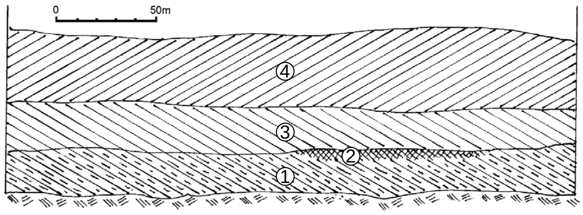


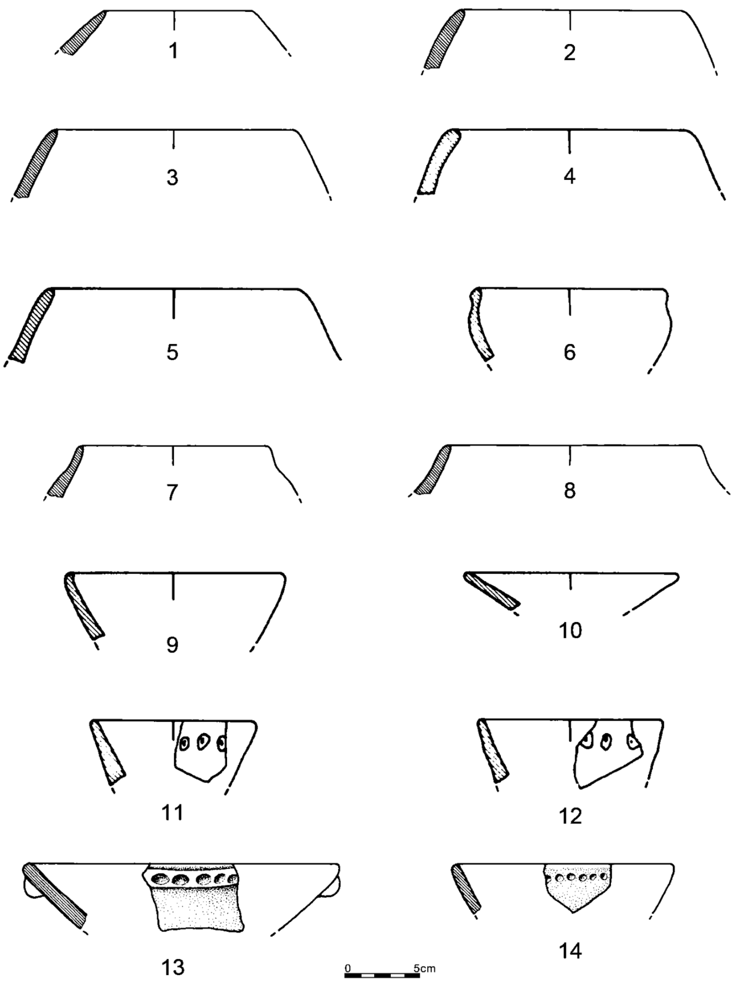
Fig. 6. Vlusha II profile.

the lime formation of the Saraçin Mountains, 400m above sea level, near the Ionian Sea (Fig. 7).

It was uncovered thanks to systematic excavations carried out by a joint Albanian-American team (1992–94). According to the relative chronology established by the excavators, the cave provides the best example of a clear stratigraphic sequence from the Upper Paleolithic (Konspol I), Mesolithic (Konispol II), Early Neolithic (Konispol IIIa), Middle Neolithic (Konispol IIIb), Late Neolithic (Konispol IIIc), Eneolithic (Konispol IV), Early Bronze Age (Konispol V), Iron Age (Konispol VI), and Archaic and Hellenistic periods (Konspol VII) (*Korkuti* et al. *1996.183–202*) (Fig. 8).

Konispol II

The Konispol cave is the settlement where the first compact layer of Mesolithic culture in Albania was discovered, lying immediately above an Upper Palaeolithic layer. That the layer was Mesolithic was demonstrated by the date of each of the two levels within it to the period between 7630±140, calibrated as 7000–6100 calBC (*Forenbaher, Miracle 2006. 93, Pl.2*) and 7510±90 (*Korkuti* et al. *1996.197*), calibrated as 6510–6100 calBC (*Forenbaher, Miracle 2006.93, Tab. 2*). The Mesolithic tools are of high-quality flint, predominantly red and brown, and with fine, high-quality retouch (*Korkuti* et al. *1996.185, 197, 200*). They comprise of small geometric microlithic tools, mainly triangular or trapezoidal scrapers with a fine single blade or terminal retouch, or dogtooth blades with a fine single or bifacial retouch (Pl. 1.9–16). The lithic industry was accompanied by faunal finds, including wild goat (*Capra ibex*) (*Korkuti* et al. *1996.185, 200*). With regard to the technical and morphological aspects, the microlithic finds at Konispol II are similar to those at Vlusha (*Korkuti*



Pl. 3. Monochrome pottery from Vlusha IIa.

et al. *1996.186*). There are also parallels with finds from several Mesolithic sites in the Balkans, such as the cave at Odmut in Montenegro (*Srejović 1974. 3*) and the Francthi cave (phase VIII), despite the small differences in the dimensions of the compared microliths (*Perlès 1990.Fig. 16*). Further analogies can be found between Konsipol II and Mesolithic Sidar on Corfu, despite the fact that the small lithic tools at the latter were produced in a slightly less elaborate manner (*Sordinas 1969.Fig. 6*).

Konispol IIIa

Most of the stratigraphic data were obtained from trench VIII, where the cultural deposit reached 4.20m. The Neolithic layer, Konispol III, consists of three successive occupation levels, namely Konispol IIIa–c, which correspond to the Early, Middle and Late Neolithic phases, respectively. The Early Neolithic layer, Konispol IIIa, ^{14}C dated to 6170–5800 calBC (*Korkuti* et al. *1996. 197*), and follows immediately after the Mesolithic layer, Konispol II (6510–6100 calBC). This stratigraphic sequence is of particular interest for the interdisciplinary study of the Neolithisation process in the south-western region of Albania. According to the excavators, the Early Neolithic phase at Konispol is represented by pottery that, although of limited quantity, is significant in determining the chronological and cultural character of the deposit in which it was found. It is mostly of coarser fabric, made of a mixture of clay and fine sand and very well fired (*Korkuti* et al. *1996.198, Pl. I*). Light slip appears to have been applied to some of the dishes, while others have a smoothed surface. Red and reddish brown are the predominant colours, while dark grey is also observed in a few cases. Depending on the intensity of firing, the background colour of some fragments appears to have double nuances. Typologically, the Early Neolithic pottery at Konispol was not very varied. The most common types of vessels are cups with a straight or slightly inward curved rim, a rare type of cup with a conical trunk, and dishes with a body which gradually narrows towards the neck (*Korkuti* et al. *1996.198, Pl. I*). The Konispol IIIa vessels mostly do not have handles (Pl. 4.1–12).

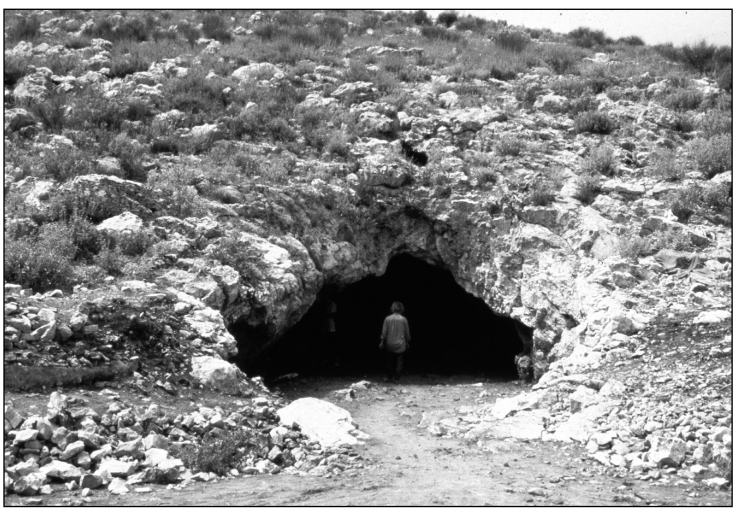
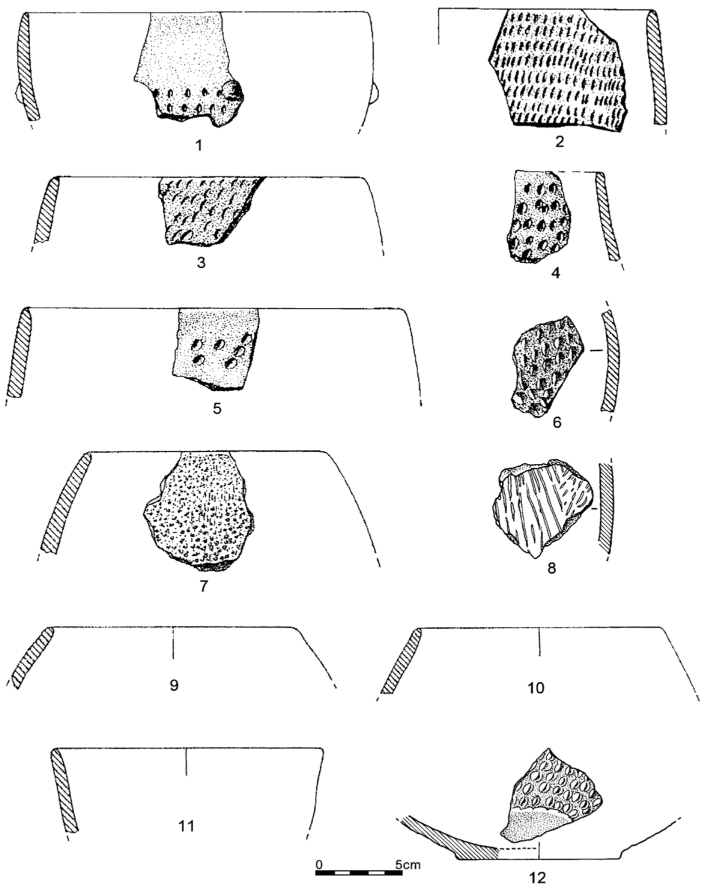


Fig. 7. View of Konispol Cave.

The Impresso pottery connects layer Konispol IIIa with the much wider area of the Early Neolithic Adriatic complex.

The ceramic assemblage at Konispol IIIa has parallels with that of Level C Top at Sidar (Corfu), ^{14}C dated to 6410–5990 calBC (*Müller 1991.356*) or 6390–6020 calBC and 6550–5800 calBC (*Forenbaher, Miracle 2006.95, Pl. 3*) and with the Impresso ware from Koirospilios (Leukas) (*Dörpfeld 1927.Tab. 836*), as well as with other sites on the Italian side of the Adriatic coast. The discovery of a large number of domesticated animal bones in the Early Neolithic layer at Konispol, mainly of goat and sheep, and a small quantity of carbonised grain seeds (*Korkuti* et al. *1996.201*) attest to the emergence of an early form of agricultural and pastoral economy in this area at the time. A complete study of the floral and faunal data recovered from the site, however, is a prerequisite for any closer examination of the question of the Neolithisation of south-western Albania.



Pl. 4. Impresso pottery from Konispol III.

Konispol fits the model of an autochthonous culture, and has yielded data on the transformation of its Mesolithic hunter-gatherers into Neolithic herders, mainly of sheep and goat. We think that the Konispol cave site has to be included among types of site where food production preceded pottery production, a known scenario in Greece (*e.g.*, Francthi cave, Argissa Magula, Nea Nikomedia) and the Eastern Adriatic (*e.g.*, Crvena Stijena, Icoana; *Budja 1993.179, 181*).

We believe that the Impresso pottery came to Konispol by way of contacts and exchange between local herders and farmers. We believe this because of the huge prior chronological data from Sidar C Top at 6410–5990 calBC (*Korkuti* et al. *1996.197; Korkuti 2003.221*), or later as 6390–6020 calBC and 6550–5800 calBC (*Forenbaher, Miracle 2006.95, Pl. 3*), compared with the Konispol layer with impresso pottery dated to 6170–5800 calBC (*Korkuti* et al. *1996. 197; Korkuti 2003.221*) or 6000–5550 calBC (*Forenbaher, Miracle 2006.95, Pl. 3*). The Konsipol cave fits the so-called 'regional contact model' involving trade and the exchange of ideas (*Zvelebil 2001.2*), as well as individual frontier mobility, according to Zvelebil's classification.

Model no. 3: Podgorie I–Vashtëmi

This cultural group is found mainly in South-eastern Albania, with its centre in the Korça basin, where the main sites at Podgorie, Vashtëmia and Barçi were discovered. Frano Prendi named the group, based on the two most important sites, after his excavation at Podgorie in 1982.

At the three settlements, the Early Neolithic cultural deposits lay directly above the sterile levels of the plain, and were not preceded by any other older cultural layer to which the Podgorie I–Vashtëmi cultural group could be related.

Podgorie has yielded the richest data and shows the clearest development of this Early Neolithic group. On the basis of trial excavations, it has been suggested that the occupied part of the site extended over approx. $2500m^2$. Aside from Early Neolithic deposits, late material of the Middle Neolithic, Eneolithic, Early and Late Bronze Age was also found.

The cultural layer consists of seven building levels (3.10–3.20m in depth), developed over three phases, Ia–c (Fig. 9). The two earliest phases, Podgorie Ia–b, represent the classic stages in the development of this culture, while phase Ic is a stage of decline. The main difference between Podgorie Ia and Podgorie Ib is that barbotine decoration appears only in

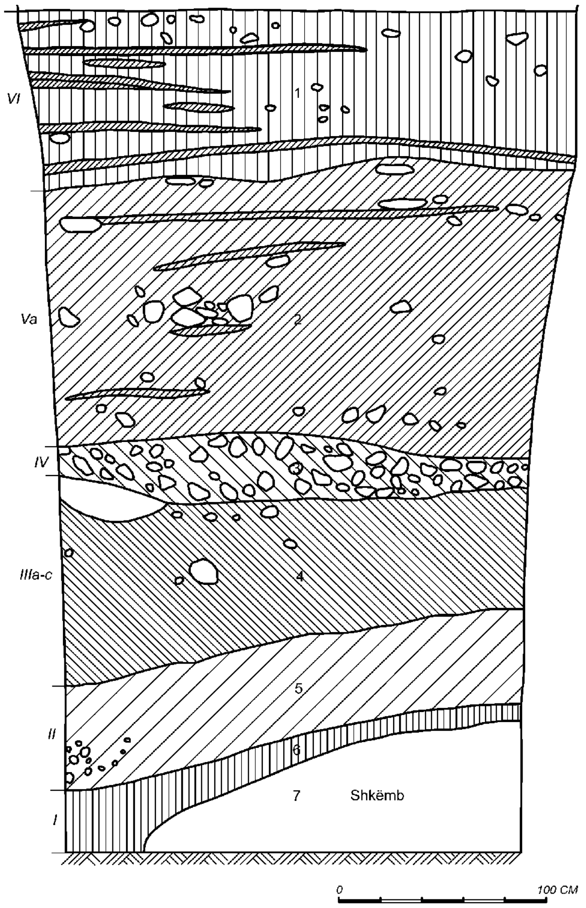


Fig. 8. Konispol profile.

phase Ib, a phenomenon that has also been observed in the neighbouring site's respective layers at Vashtëmi in the Korça basin.

Podgorie Ia phase

The earliest phase, Podgorie Ia, corresponds stratigraphically to horizons I–IV of the cultural deposit. The ceramic groups of this phase are fine monochrome red slipped ware, monochrome dark grey or brownish slipped ware and painted ware (Pls. 5–7). Painted pottery is the main characteristic of this phase, which appears in the following styles and motifs:

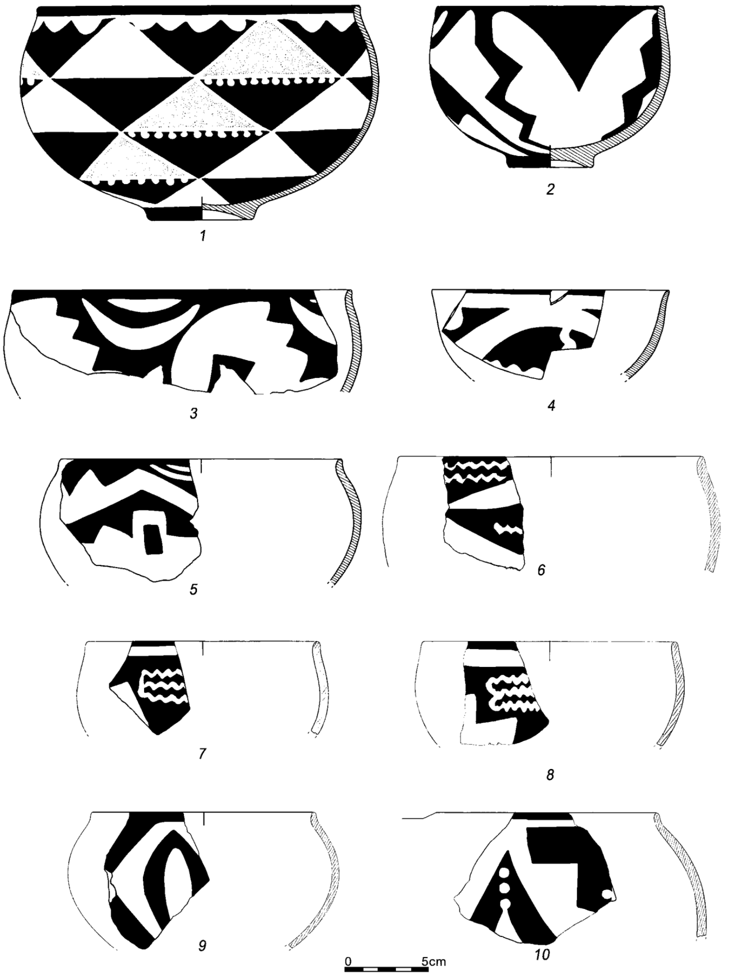
- white-on-red slipped ware, and in fewer cases, grey-to-black, in a style similar to A3a of the pre-Seklo phase (*Wace, Thompson 1912.59*);
- white-on-red or cream slipped ware, in a style similar to A3β of Neolithic Thessaly (pre-Sesklo phase) (*Wace, Thompson 1912.59*) (Tabs. 5.1–10; 6.1–13);
- polychrome pottery in three colours, mainly white and cream on red slipped ware, in a style similar to B3β of phase Ib of Neolithic Thessaly or the proto-Sesklo phase (*Wace, Thompson 1912.59, Pl. VII, 1–16*);
- brown on red slipped ware, with straight or sinuous linear motifs, and sometimes combined with white motifs on a red ground;
- pottery with the entire surface painted white, and dark grey pottery.

The Podgorie Ib phase includes the same pottery categories as Podgorie Ia, as follows: white on red painted ware is also present, but in not in the same quantities as in the earlier phase; Impresso pottery increases in frequency compared to the preceding phase; incised ornaments appear very rarely; nail pinching and nail printing techniques can be identified; shallow grooved lines are rare. Red slipped monochrome ware gradually begins to decrease until it almost disappears completely in the following phase Ic. A new phenomenon that is exclusively related to this phase and distinguishes it as a separate stage in the classic development of this culture is the appearance of barbotine decoration.

The Podgorie Ic phase refers to the last occupation horizon. The main pottery categories in this phase are: autochrome reddish pottery with brownish and dark grey surfaces; matte red monochrome pottery; Impresso and barbotine pottery; red slipped ware is very rare, while matte white-on-red painted pottery disappears, as well as painted ware and red slipped monochrome ware. The Podgorie Ic phase represents the final stage of development of the Early Neolithic culture of Podgorie I.

Podgorie Ia–b has analogies with Anzabegovo-Vršnik Ic based on the white-on-red painted pottery with advanced ornamental features, as well as Impresso style pottery and several typical pottery shapes, especially vessels with three legs. It has analogies with Nea Nikomedia in Greece in the white-on-red painted motifs such as triangles, sinuous and zigzag lines, some shapes of the pottery, as well as Impresso decoration, and with Thessaly (Presesklo and the beginning of Sesklo) in the white-on-red painted ware, similar to that of the proto-Sesklo phase, the typology of several dishes, and also with Hoça Çesme III in the white-on-red painted pottery with advanced ornamental features, Impresso pottery and incision motifs. On the other hand, white-on-red painted pottery also links Podgorie Ia–b with Kovaçevo, Asaği Pinar, Haçilar *etc*.

The polychrome pottery distinguishes Podgorie I–Vashtëmi from other similar cultures, placing this group chronologically at a later developmental stage of the Early Neolithic. Actually, the earliest stages of this cultural group are not known in Albania. On the other hand, its analogies and similarities, mentioned above, suggest that this culture could be considered as deriving from other Early Neolithic cultural groups of the Anatolian-Balkan regions. It seems that the Podgorie I culture represents the third wave of Neolithisation in Albania, which arrived here by the Anatolian-Balkan route according to its cultural similarities to other neighbouring Early Neolithic cultures in Thessaly, Aegean Macedonia, Thrace and North Western Anatolia. This model of the spread of the 'Neolithic package' is included in so-called 'folk migration' as described by Zvelebil (*2001.2*), which stands for the movement of a population from region A to region B, and the replacement of the old local populations, which also produces genetic/cultural changes at the same time. It appears that only during this phase were farming communities fully established in Albania.



Pl. 5. White-on-red painted pottery from Podgorie Ia.

During this phase (II1) we can see the extension of Neolithic groups into the deep hinterlands of Central and Eastern Albania. A strong Adriatic impulse moves from the southwest (*e.g.*, from Konispol) to the east, establishing new sites of later chronological phases, such as the settlement caves at Blaz and Nezir (Mat), as well as the settlement cave at Katundas (Berat).

The Blaz cave settlement was excavated by Frano Prendi and Zhaneta Andrea from 1978 to 1979 (*Prendi, Andrea 1981.19–21*). Its second layer is characterised by coarse pottery, with grey, black or brown burnished exterior and especially Impresso pottery, which predominates. Impressions are the most common technique of pottery decoration. At Blaz II, three types of Adriatic pottery were represented, according to a classification carried out by Johannes Müller (*1991.325–326*). Type A Impresso predominates and covers the entire surface of vessels. In Dalmatia, this type of decoration has been dated to between 6100–5800 BC (*Müller 1991.327*). Cardium impresso is quite rare; only four sherds have been collected. Cardium impresso, including type B Adriatic Impresso, is dated to 5800–5600 BC (*Müller 1991.327*). Only one example of type C Impresso, known as tremolo, with a wave motif, was found at Blaz II. In the Eastern Adriatic, this is dated to 5650–5600 BC (*Müller 1991.327*).

Barbotine pottery (5–6%) has an ochre or reddish colour. Barbotine was applied in organised lines. This pottery does change the Adriatic character of the site, but shows the influence of the Starčevo IIb culture in the southwest. In this layer, a small cultic altar, painted dark brown, belonging to the Starčevo IIb culture, was found next to a rhyton fragment belonging to the Adriatic complex. A similar culture has been discovered at the Nezir cave settlement near Blaz. The Blaz II phase is almost contemporaneous with Zelena Pečina III–Obre I (2nd phase) –Starčevo IIb, as well as Adriatic I (Impresso-cardium II).

Katundas (Berat) was excavated by Muzafer Korkuti in 1986 (*Korkuti 1995a; 1995b.84*). The Early Neolithic culture is characterised by Impresso pottery quite similar to Blaz II, barbotine ware, and semi-coarse pottery in reddish colour. Only one fragment of a white-on-red painted vessel of Podgorie Ia style was found. This is important in chronological terms. Impresso pottery is the main characteristic of Katundas I, which marks the eastern border of the continental areas in which Adriatic elements had arrived.

On the other hand, during the phase (III1) in the north-eastern part of Albania, we can follow an Anatolian-Balkan wave from Starčvo IIb culture which reached all the way to Burim I (Dibër) during its earliest southerly extension (III1) and to Kolsh I (Kukës) during its greatest extension towards the southern and south-eastern Balkans (III2). The earlier Burim I phase is near the end of Starčevo I and the beginning of Starčevo IIa, the same as Anzabegovo-Vršnik Ib and Presesklo, while the older Kolsh I phase is equal to Starčevo IIb–Rudnik III–Anzabegovo-Vršnik III–Galabnik III and Sesklo (Fig. 3). The Early Neolithic cultures developed in close relation with neighbouring cultures, which was reflected by the interaction of a number of cultural elements of one group with another. This can be explained by the direct influence or movement of groups of people from one region to another.

According to the absolute chronology of Early Neolithic culture in Albania, only two Early Neolithic sites have produced radiocarbon dates so far, as follows:

- the beginnings of Konispol IIIa; a layer with Impresso pottery finds that yielded domestic animal bones (sheep and goat horns) (trench IX/20), dated to 6030–5710 and 6170–5800 calBC (*Forenbaher, Miracle 2006.95, Pl. 3*);
- the end of Konsipol IIIa, a layer which contained Impresso ware (trench IX/18), dated to 5840–5450 and 6000–5550 calBC (*Forenbaher, Miracle 2006.95, Pl. 3*).

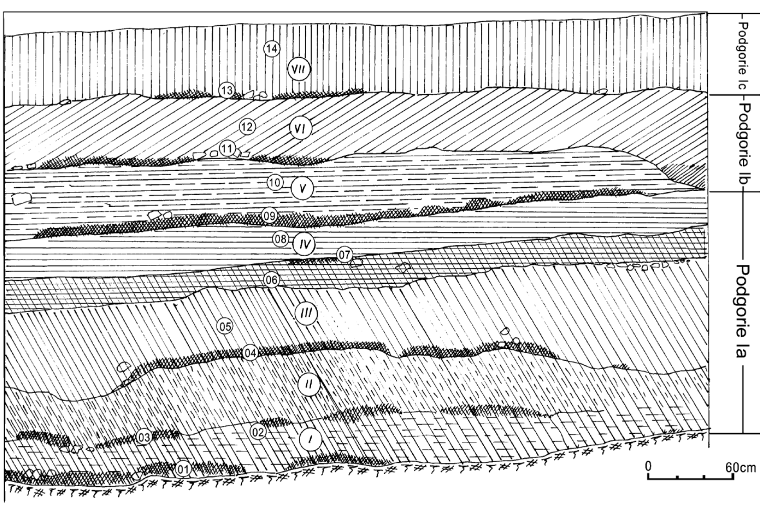


Fig. 9. Podgorie I profile.

According to the relative chronology, the three phases of Neolithisation in Albania produce the following picture:

I. Vlusha IIa = Škarin Samograd I – Sidar C base – proto-Sesklo (partly Früh-Keramikum phase);
II. Konispol IIIa = Sidar C Top – Škarin Samograd II;
III. Podgorie I = Anzabegovo-Vršnik I (mainly phase Ic) – Veluška-Porodin I–II – Starčevo II – Nea Nikomedia – Presesklo (Magulica phase) and the beginning of the Early Sesklo-Cavdar phase.

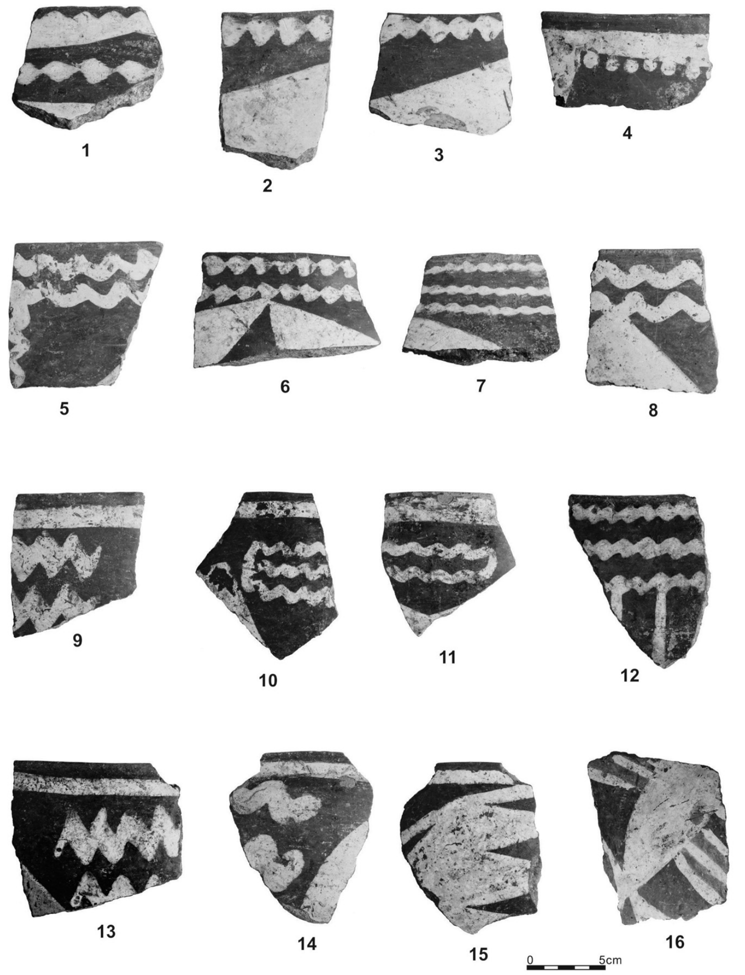
Conclusions

It is necessary to summarise briefly the archaeological evidence about the three essential points of the Neolithisation of Albania discussed above. The present state of knowledge of this period allows for several conclusions to be drawn about the chronological, cultural and genetic aspects, despite the hypothetical nature of some of them, which could change with further investigation.

Thus far, no evidence has been found of the presence of a PPN horizon in Albania. The Blaz I phase, which lacks pottery, and is stratigraphically positioned after a hiatus below the Early Neolithic layer Blaz II, which contained Impresso pottery, cannot be securely associated with a proto-Neolithic phase with forms of productive economy; on the contrary, it pertains to the Epipalaeolithic period. Also, the attempt to consider the proto-Neolithic layer 13 in sector A12 at Sovjan (Korça basin) as the Epipaleolithic is based on the absence of pottery (*Lera* et al. *2007-2008.45*). However, a Neolithic period without pottery has not been observed on the Eastern Adriatic coast of Dalmatia, where all the Early Neolithic settlements have produced pottery (*Batović 1972.18; Benac 1971.336*).

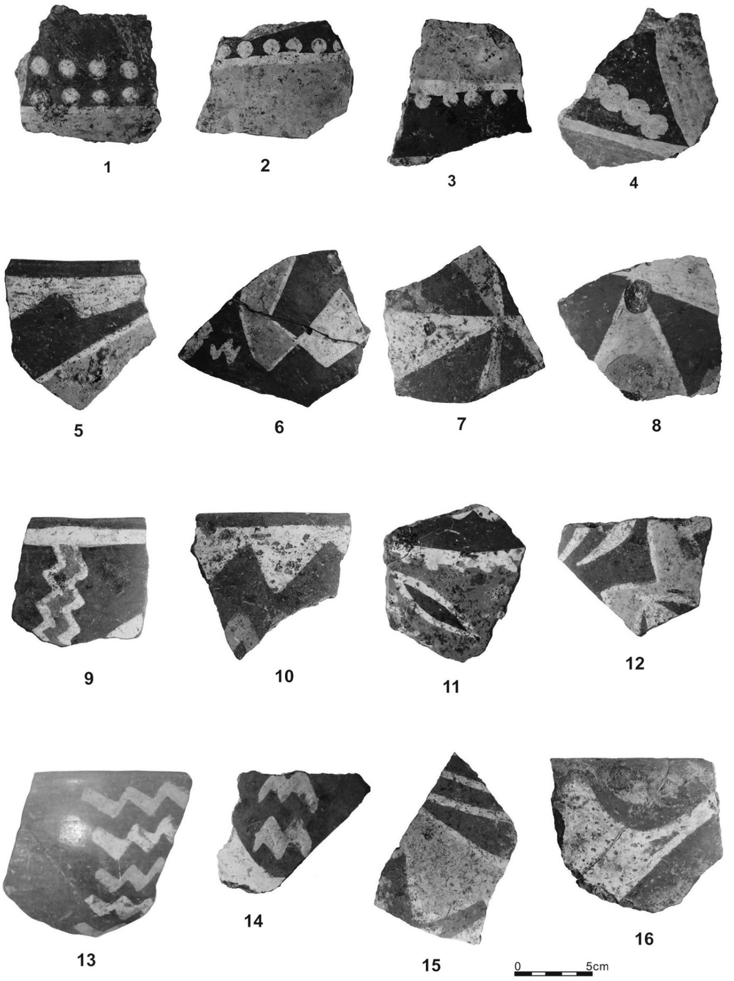
According to the archaeological research in Albania, we can refer to three different models of the Neolithisation process:

❶ The earliest appearance of Early Neolithic culture in Albania is related to the settlement at Vlusha (phase IIa). This culture is characterised by dark grey monochrome pottery, and by flint microliths of a Mesolithic tradition. In this early phase of its development, Impresso pottery does not appear at Vlusha IIa, which appeared in the second phase of the development of the Early Neolithic period, Vlusha II b. This stratigraphy is similar to that at Sidar on Corfu and Škarin Samograd in Dalmatia, where similar monochrome pottery layers were covered by an Impresso pottery layer in the Adriatic style (*Müller 1988.259; Sordinas 1969. 401*). This suggests that, on the territory of Albania, as in continental Greece, Impresso ware must not be considered the earliest type of Neolithic pottery. This is also supported by other sites with Impresso pottery finds discovered in Albania, which without exception date to a later stage of the Early Neolithic than that of Vlusha's monochrome ware. The particularities of the latter attest to its local evolution, but there is no evidence to support an autochthonous origin of the technology required to produce this pottery. On the other hand, if we were to refer to a possible affinity between the pottery of Vlusha IIa and the earliest monochrome pottery of Anatolia (Haçilar IX, Barçin Höyük; *Gerritsen* et al. *2013. 57, 70, Fig. 17–18*), Thessaly (Frühkeramikum; *Milojčić 1959.5, Pl. 5*) and Greece in general (Achilleon I and Sesklo I; *Todorova 2003.264*; and the earliest phase of Elatea; *Sordinas 1969.406*), Southwest Bulgaria (Krainici; *Stefanova 1996.16– 17, Tab. I,1–4; Todorova 2003.264*) and Northeast Bulgaria (Kuprivec, Pomishtica, Poljanica plato; *Stefanova 1996.17*), or the Central Balkans (Divostin; *Krauß 2011.10*), the possibility of the south-eastern origin of its technology tradition being in Anatolia and the Southeast Balkans moving north-west towards the Adriatic through demic diffusion and chaining transmission must not be excluded. Therefore, we believe that Vlusha IIa could be considered as representative of the first and earliest Anatolian influences in Albania, where indigenous populations with Mesolithic traditions have been present. With regard to the dynamics of the Neolithisation process of this settlement, this phenomenon would attest to the arrival in Vlusha of small groups of migratory farmers who brought the technology of pottery production and were influential in the acculturation of the indigenous Mesolithic population. Given the importance of the Mesolithic lithic tool industry at Vlusha IIa, it is possible to conclude that a hybrid process of the Neolithisation of Mesolithic peoples occurred at this site, which formed its culture through the co-existence of the indigenous and migratory populations which were associated with the assimilation and integration processes. In this context, Vlusha IIa would be included in the so-called 'leap-frog' model of colonisation (*Zvelebil 2001.2*). However, the transition process from the Mesolithic to the Early Neolithic, for example, from Mesolithic hunters to Early Neolithic herders and farmers at Vlusha IIa, is far from completely understood. There is a lack of evidence of whether the bearers of the Early Neolithic culture at Vlusha IIa learned the Neolithic way of life, which is why we believe that this settlement would have been used only seasonally. However, whatever the case may be, this remains an aspect which requires further investigation.



Pl. 6. Photos of white-on-red painted pottery from Podgorie Ia.

❷ The second phase of Neolithisation in Albania refers to the Konispol III phase, where we find the model of an indigenous settlement that developed directly from the Mesolithic, supporting the indigenous



Pl. 7. Polycrome pottery from Podgorie Ia.

scenario. This is supported by the stratigraphic sequence at Konispoil, where the Early Neolithic layer with Impresso pottery of Konispol IIIa was deposited immediately, with no hiatus, above the Mesolithic layer of Konispol II. Konispol IIIa is contemporaneous with the Eastern Adriatic cultures of Sidar C Top, Škarin Samograd II, Crvena Stijena III, Zelena Pečina III, and Smilčič I. It was the Impresso ware which helped us to classify Konispol IIIa as the earliest representative of Adriatic influences in Albania, originating from the Eastern Mediterranean. We believe that the Impresso pottery at Konispol was acquired by cultural diffusion and acculturation processes from its closest neighbour, Sidar C Top on Corfu Island, only 35km away, where this kind of pottery was ^{14}C dated to 6410–5990 calBC (*Müller 1991. 356*). This date is earlier than the date for the Impresso pottery from Konispol IIIa phase, which is dated to 6170–5800 and 6000–5550 calBC (*Korkuti* et al. *1996.197; Korkuti 2003.221; Forenbaher, Miracle 2006.95, Tab. 3*). In conclusion, we can say that Konispol IIIa would be included in the so-called 'regional contact' category (*Zvelebil 2001.2*), which entails trade and exchange relations with neighbouring communities, including the exchange of ideas and innovations. The second wave of Neolithisation seems to have taken an alternative route via the Aegean and Ionian Seas to the coast of the Ionian Sea, with first farmers arriving from the Eastern Mediterranean region.

❸ The third phase of Neolithisation in Albania refers to the second Anatolian wave, characterised by monochrome red slipped ware, and red-on-white painted pottery, represented by the cultural group of Podgorie I–Vashtëmi, while polychrome pottery was found only at the Podgorie I site. This quite advanced Early Neolithic ware was not preceeded in the Korça basin by an earlier development phase. Meanwhile, earlier phases of monochrome red slipped ware and red-on-white painted monochrome have been discovered in Western Anatolia (*Erdogu 2005.97*), Eastern Thrace (Hoça Çeşme and Aşaği Pinar; *Özdoğan 2003.351; Perlès 2003; 2005.286*), Aegean Macedonia (Nea Nikomedia), Eastern Macedonia (Anzabegovo-Vršnik I), Pelagonia (Veluška-tumba I) *etc*. These analogies lead us to the conclusion that the bearers of this cultural wave seem to have travelled along the Anatolian-Balkan route. This migration towards Southeast Albania included a third model of Neolithisation, so-called "*folk migration*" as described by Zvelebil (*2001.2*).

During this advanced Early Neolithic phase in the Korça basin, ritual secondary burials were carried out, as well as the differentiation of grave goods contained in them, which means there were socio-economic inequalities. Similar cases have been reported in Nea Nikomedia in Aegean Macedonia (*Rodden 1962.286, Tab. XLII; Theocharis 1981.Fig. 20; Perlès 2001.265, Fig. 12, 3; Sèfèriedés 1995.89*), in Mavropigi-Filosari in Western Macedonia (*Karamitrou-Mentessidi* et al. *2013.5, Fig. 7; Papathanasiou, Richards 2011.257, Fig. 7*), dated to 6300–6000 calBC (*Papathanasiou, Richards 2011.257*), in Western Thessaly (Prodrom; *Stratouli* et al. *2010.96*), Turkish Thrace (Hoca Çeşme; *Sèfèriedés 1995.89*), and in Aegean Anatolia (Burçin Höyük; *Roodenberg* et al. *2013.1–10, Fig. 2–4*) *etc*.

On the other hand, based on some clay biconoids (*Renfrew 2003.413*), known as sling-stones or sling shots, discovered at Podgori-Vashtëmi group, as well as on the other Early Neolithic cultural groups in Pelagonia (*Simoska, Sanev 1975.47, Pl. II, 7; Naumov* et al. *2009.Pl. 72, 7; Kitanovski* et al. *1987.14, Pl. III, 2*), Thessaly (Sesklo; *Wace, Thomson 1912.Fig. 62*), North-East Greece (Sitagroi I–II; *Renfrew 2003. 413–414, Pl. 10*), Aegean Macedonia (Nea Nikomedia), Anatolia (Çukuriçi Höyük; Barçin Höyük – *Gerritsen* et al. *2013.88, Fig. 22, 2*; Uluçak Vb – *Çilingiroğlu 2013.71, Fig. 4, c*) *etc*., we believe that war and conflicts appeared in this phase of the Early Neolithic. According to the dominant opinion, such biconoids are Early Neolithic weapons (*Rodden 1962. 285; Korkuti 1982.113; Séfériadés 1995.90*). The appearance of conflicts and war at the end of the Early Neolithic would also be supported by the earliest prehistoric fortification, documented at Hoça Çesme IV (*Özdoğan 1998.439, Fig. 3.a–b; 2003. 340*), as well as the ramparts reinforced with palisade that emerged at Aşaği Pinar in Southeast Thrace (*Özdoğan 2003.342*). This new cultural change leads us to the conclusion that during this period, the real Neolithic way of life had become established in the Korça basin and other regions of Albania; it was only during this phase that farmers really become completely Neolithicised in Albania.

The above picture, and especially the cultural similarities of Podgorie I to other neighbouring Early Neolithic cultures in Thessaly, Aegean Macedonia, Thrace and North Western Anatolia, lead us to the conclusion that the first and the third wave of Neolithisation may have been connected with the Anatolian-Balkan route.

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'Pre-Neolithic' in Southeast Europe: a Bulgarian perspective

Maria Gurova[1], Clive Bonsall[2]
1 National Institute of Archaeology with Museum, Bulgarian Academy of Sciences, BG
gurovam@yahoo.fr
2 School of History, Classics and Archaeology, University of Edinburgh, UK
C.Bonsall@ed.ac.uk

ABSTRACT – *This paper discusses why large areas of the central and northern Balkans lack evidence of Mesolithic settlement and what implications this holds for future research into the Neolithization of the region. A marked shift in site distribution patterns between Upper Palaeolithic and Mesolithic is interpreted as a response to changing environmental conditions and resource availability. It is suggested that some important questions of the pattern, processes and timing of the transition to farming across the Balkan Peninsula may only be answered through new archaeological surveys of the Lower Danube valley and exploration of submerged landscapes along the Black Sea, Aegean and Adriatic coasts.*

IZVLEČEK – *V članku razpravljamo o vzrokih za pomanjkanje dokazov o mezolitski poselitvi velikega dela srednjega in severnega Balkana ter o posledicah, ki jih lahko imajo te ugotovitve za prihodnje raziskave neolitizacije v regiji. V poselitvenih vzorcih med poznim paleolitikom in mezolitikom smo prepoznali premik, ki ga razlagamo kot odziv na spremembe v okoljskih pogojih in razpoložljivosti naravnih virov. Predlagamo, da je mogoče na nekatera pomembna vprašanja, povezana z vzorci, procesi in ritmom prehoda h kmetovanju na Balkanskem polotoku, odgovoriti le z novimi arheološkimi pregledi Spodnjega Podonavja in z raziskovanjem potopljenih pokrajin ob obalah Črnega, Egejskega ter Jadranskega morja.*

KEY WORDS – *Balkans; Mesolithic; demographic change; Neolithization; exchange networks*

Introduction

While there is general agreement that the Neolithic farming system was introduced to Southeast Europe from the Near East, just how farming reached and spread through the Balkans remains an important topic of discussion. Was agriculture brought in primarily by Anatolian farmers who replaced the resident hunter-gatherers, or did farming advance largely through the spread of ideas and technology rather than people? How many waves of expansion were there and what routes were followed?

In those areas where a Mesolithic presence has been documented – in parts of Greece, Dalmatia and the Iron Gates, for example – indigenous hunter-gatherers are sometimes seen as active participants in the Neolithization process. Conversely, where the Mesolithic has proved difficult to identify (as in Bulgaria) the Neolithic is assumed to have begun with the arrival of immigrant farmers who entered a landscape that was 'almost completely uninhabited in the early Holocene' (*Todorova 1995.82*).

In this paper we consider why large areas of the central and northern Balkans, especially Bulgaria, lack evidence of Mesolithic settlement and what implications this holds for future research into the Neolithization of the region.

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Where were the foragers?

In the context of a discussion of forager-farmer interactions, Marek Zvelebil and Malcolm Lillie (*2000*) published a map of Southeast Europe on which they proposed several 'areas of concentrated hunter-gatherer settlement' north of the Aegean (Fig. 1). In the central and northern Balkans areas of high Mesolithic population density were identified in the Iron Gates of the Danube, the northeast Adriatic and upper Sava River catchment, the southern Dinaric Mountains, and the Danube Delta and neighbouring Black Sea littoral.

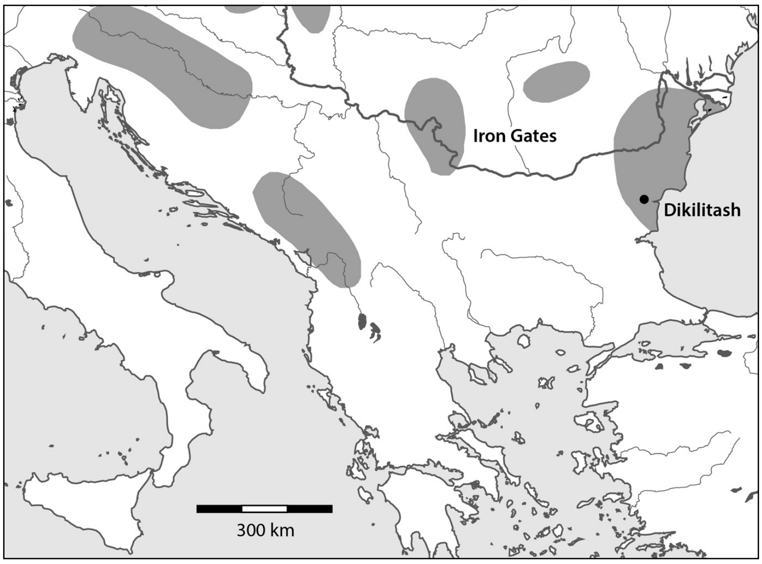


Fig. 1. 'Areas of concentrated hunter-gatherer settlement' in Southeast Europe (after* Zvelebil, Lillie 2000.Fig. 3.4*).

The only one of these 'population clusters' for which there is strong supporting evidence is the Iron Gates, where some twenty Mesolithic sites have been identified along the banks of the Danube in Romania and Serbia, the majority of which also have Early Neolithic occupations (*Boroneanţ, Bonsall 2012.Fig. 1; Borić, Price 2013*). Of the other Mesolithic 'population clusters', the northeast Adriatic and Dinaric Mountains are represented mainly by cave and rockshelter sites; there are no large open-air sites equivalent to those in Iron Gates.

Zvelebil and Lillie's 'Danube Delta-Black Sea cluster' appears to rest on the evidence of occasional finds of supposedly Mesolithic artefacts from Romanian Dobrogea (*Bolomey 1978; Păunescu 1987*) and the Pobitite Kamani (Dikilitash) area some 20km to the west of Varna in northeast Bulgaria (*Dzhambazov, Margos 1960; Gatsov 1989*). The Pobitite Kamani area is an extensive heathland developed on Lower Eocene sands. Lithic artefacts were collected from surface blow-outs and erosion scars over an area of more than 50km^2, and the assemblage of over 12 000 artefacts is generally regarded as a 'palimpsest' resulting from human activity at different time periods. Several authors have identified a 'Mesolithic' component within the assemblage, including microliths. Published illustrations indicate the presence of curved backed and geometric forms (including trapezes). The curved backed pieces and some geometric elements find their closest Balkan parallels in the Epigravettian, notably at sites in the Iron Gates reach of the lower Danube valley (*Gatsov 1989*). The trapezes from Pobitite Kamani often have straight truncations and appear to have been made on blades. In the Balkans trapezes of this type are characteristic of the Final Mesolithic ('Castelnovian') of the circum-Adriatic region, which has been interpreted as a region-specific tradition that originated in North Africa (*Perrin 2012*). To the east of the Dinaric Mountains, however, blade and trapeze industries appear to be absent from Late Mesolithic contexts, for example from sites along the Lower Danube in the Iron Gates (*C. Bonsall, pers. obs.*). In contrast trapezes with straight truncations and made on blades are a frequent component of Early and Middle Neolithic sites throughout the Balkans (*e.g., Lichardus* et al. *2000; Zlateva-Uzunova 2009; Gurova 2014*). The trapezes that occur sporadically in the Mesolithic of Franchthi Cave in the Peloponnese differ in that they are often made on flakes (*vs* blades) and have sinuous truncations (*Perlès 2001*). The balance of probability, therefore, is that the trapezes from Pobitite Kamani are of Neolithic and not Late Mesolithic date.

The bigger picture

Figure 2 compares the locations of radiocarbon dated Upper Palaeolithic (*c.* 40–11.7 ka calBP) and Late Mesolithic (*c.* 9.2–8.0 ka calBP) sites in the Balkans. The map is based on published sources that were available to us at the time of the Ljubljana Seminar in 2013. The list of sites may not be exhaustive, but we suggest the overall picture is broadly representative.

The respective distributions are strikingly different. Upper Palaeolithic sites (the majority of them in

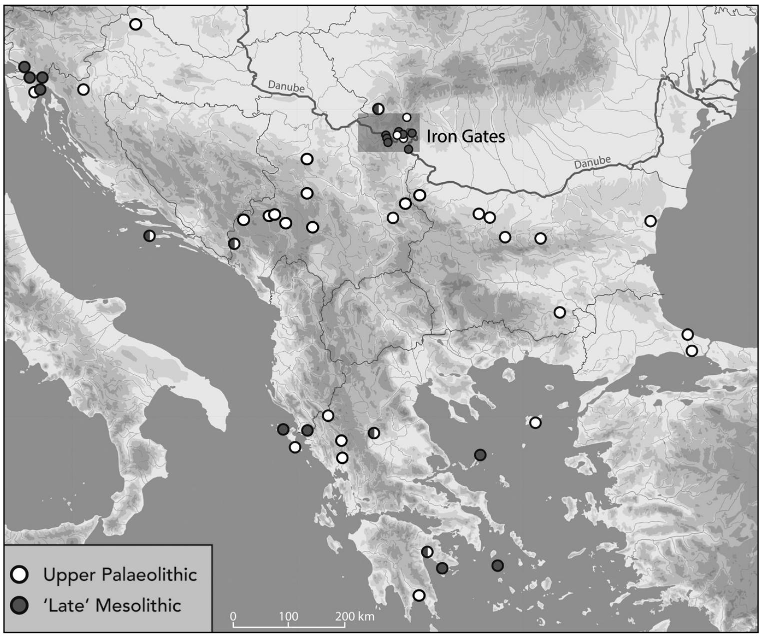


Fig. 2. ^{14}C dated Upper Palaeolithic and Late Mesolithic sites in the Balkans.

caves or rockshelters) are found in most areas of the Balkans, including deep into the interior. In contrast, Late Mesolithic sites have a distinctly peripheral distribution within the Balkans, most sites being located within 50km of the sea or the Danube (by far the largest river in the region).

The absence of Mesolithic sites from large areas of the Balkans has sometimes been attributed to a lack of research – including an emphasis on cave investigation at the expense of extensive, open-air survey – or the effects of geomorphological processes on site survival or visibility. To some extent, these factors must have affected Mesolithic site distributions. For example, the surveys and salvage excavations that led to the discovery of the Iron Gates sites between 1964 and 1983 did not extend downriver of the Iron Gates II dam, and this may account for the lack of Mesolithic (and indeed Early Neolithic) sites along the Bulgarian section of the lower Danube Valley. Where targeted surveys have been undertaken, as in parts of Greece (*Runnels 2009*), Albania (*Runnells* et al. *2004*), Istria (*Komšo 2006*) and Slovenia (*Frelih 1986; Mlekuž 2001*), open-air Mesolithic sites have been discovered where previously only cave sites were known. However, this research has had little or no impact on the predominantly peripheral distribution of *Late* Mesolithic sites within the Balkans.

On the other hand, there are aspects of the Mesolithic distribution in the Balkans that are difficult to explain in terms of variable research intensity or taphonomic processes. One is the absence of Mesolithic remains from the many cave sites in Bulgaria that have produced evidence of Upper Palaeolithic occupation (Fig. 2) – sites that because of lower sea levels during the Last Glaciation were even further inland than they are today. Another is the 'Late Mesolithic gap' that is a common feature of radiocarbon sequences in caves located in *peripheral* areas of the Balkan Peninsula. Caves that were used in the Early Mesolithic often lack evidence of occupation during part or all of the Late Mesolithic. At Edera Cave in the Trieste Karst at the head of the Adriatic no activity is recorded between the end of the Early Mesolithic *c.* 9.0 ka calBP and the earliest Neolithic *c.* 7.6 ka calBP (*Biagi* et al. *2008*). Similarly, at Pupićina in Istria there is a gap of over 2000 years between the latest Mesolithic and earliest Neolithic occupations (*Forenbaher, Miracle 2005; 2006; Forenbaher* et al. *2013*). Paolo Biagi and Michela Spataro (*2001*) attributed the 'radiocarbon gap' in sites like Edera and Pupićina to a general Mesolithic population decline and the disappearance of hunter-gatherers from whole areas of the Balkans.

There is a clear demographic trend from the Upper Palaeolithic to the Late Mesolithic in the Balkans. The various lines of evidence suggest that the *interior* of the Balkan Peninsula, which was extensively exploited in the Upper Palaeolithic, was not heavily populated by Mesolithic hunter-gatherers especially in the period after *c.* 9.0 ka calBP. However, this does not necessarily signify an overall population decline.

Why the demographic shift?

Palaeovegetation records for the Balkans (*e.g., Huttunen* et al. *1992; Connor* et al. *2013; Magyari* et al. *2013; Tonkov* et al. *2014*) show fluctuations between semi-desert, steppe and forest-steppe ecosystems between *c.* 37.5 and 10.5 ka calBP, corresponding to the Upper Palaeolithic and initial Mesolithic, followed by a major expansion of temperate forest during the early Holocene (Fig. 3). Forest composition and canopy cover were strongly influenced by climate, altitude and soils, but crucially much of the

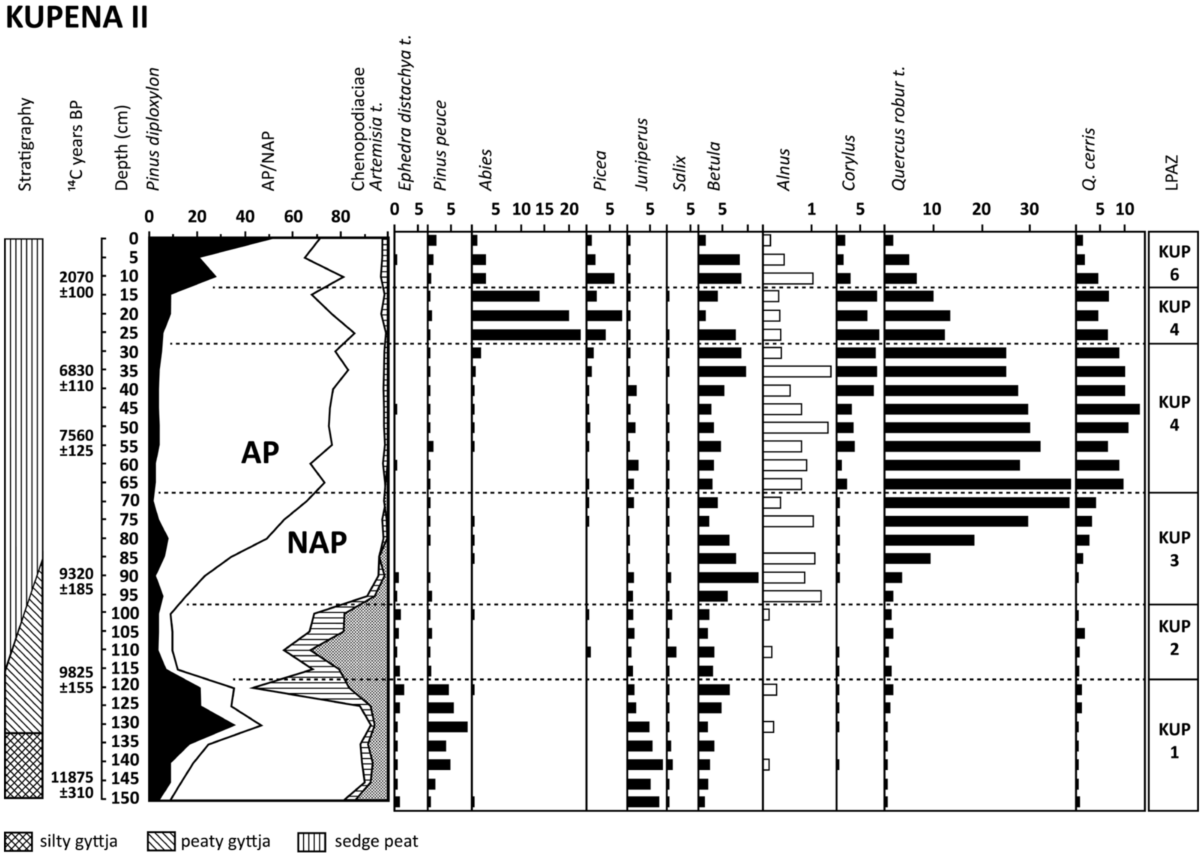


Fig. 3. Pollen diagram from Kupena II, western Rhodopes Mountains (redrawn from* Huttunen *et al.* 1992*).

central and northern Balkans below 700m a.s.l. was covered by closed canopy deciduous woodlands by 9.0 ka calBP, if not earlier (*Willis 1994*).

Compared to steppe (grassland) environments, temperate forests have much lower ungulate biomass (*Discamps 2014*). Dense canopy cover also provides concealment for animals hence protection from predators, which further impacts on the productivity of hunting (Fig. 4). Closed canopy forest is also likely to have posed significant challenges for inter-group communication and participation in viable mating networks. Moreover, closed canopy forest is relatively poor in edible plants (*Diamond 1997; contra Clarke 1976; Zvelebil 1994*). In temperate forest ecosystems the highest ungulate and edible plant biomasses are found at forest margins, for example at the upland treeline, in areas recently burned by wildfires, or along sea, lake and river coasts and associated wetlands.

Overall, early Holocene forest expansion across the Balkans would have resulted in a substantial reduction in carrying capacity for human populations reliant on hunting and gathering. In some areas of Europe the reduction in animal biomass was compensated for by the availability of aquatic resources in inland rivers, lakes and wetlands. The Balkans, however, have few large rivers or navigable waterways; while lakes are comparatively few, often small and shallow, or at high elevations. The region lacks the numerous glacial lakes and connecting waterways of some other inland regions of Europe, which provided both aquatic food resources and communication routes for Mesolithic populations.

Across Mesolithic Europe as a whole there was a trend of increasing exploitation of aquatic resources against the background of early Holocene forest expansion. This trend is seen in site distribution patterns and archaeofaunal inventories, as well as in C- and N-isotope values of human remains, to the extent that later Mesolithic populations in many parts of Europe are perhaps more accurately characterized as 'fishers' rather than hunter-gatherers.

Given the poverty of inland aquatic resources in the Balkans, the main demographic consequence of early Holocene forest expansion was most likely a redistribution of population from the interior toward sea and river coasts, with hunting activities concentrated at forest margins.

Tasmania, a large island to the south of Australia, provides a striking ethno-archaeological example of human abandonment of a heavily forested interior in favour of the coast. Like the central and northern Balkans, Tasmania has a predominantly mountainous landscape and temperate climatic regime. In the southwest of the island the largely open scrub and heathland landscape of the Late Pleistocene was replaced by dense rainforest during the early Holocene (*Colhoun* et al. *1999*). Although Late Pleistocene occupation of the interior is well documented (*Lourandos 1997*), ethnographic records indicate that at the time of European settlement in the early 19th century the densely forested areas were not occupied by aboriginal peoples, who were concentrated in settlements along the coast (*Plomley 1966*).

In Southeast Europe evidence of Late Mesolithic coastal settlement is sparse and likely to be difficult to find owing to a general regional rise of sea level during the Holocene. The post-glacial sea level history of the Balkan coastline has been complicated by tectonic and isostatic factors (*cf. Lambeck* et al. *2004*), but for the most part early Holocene shorelines lie below present sea level with the result that many shore-related Mesolithic and Early Neolithic sites on the Black Sea, Aegean and eastern Adriatic coasts will have been submerged or in many cases, perhaps, destroyed by marine erosion (*Bailey 2007; Benjamin* et al. *2011; Özdoğan 2011a*).

The few sites along the Aegean and Adriatic coasts that show direct evidence of marine exploitation in the form of fish or shellfish remains, such as Franchthi, Maroulas and Sidari, occupied elevated positions above rocky shorelines, and some of these sites may have been 'field camps' (*cf. Binford 1980*) or processing camps rather than residential base locations.

Currently, well-documented examples from the Balkans of Mesolithic shore-related settlements occur mainly in the Iron Gates section of the Danube valley. Sites such as Padina, Vlasac and Schela Cladovei were hundreds or thousands of square metres in extent with architectural, burial and other evidence of permanent or semi-permanent occupation over centuries or millennia (*Radovanović 1996; Boroneanţ 2012*). Moreover, they were not just a Late Mesolithic phenomenon; paired AMS ^{14}C dating and stable isotope analyses of human remains indicate that fishing was practised in the Iron Gates (and probably along the entire length of the lower Danube) at least as early as the Late Palaeolithic, became increasingly important during the Mesolithic, and was still significant economically during the Early Neolithic (*Bonsall 2008; Borić 2011; Bonsall* et al. *2012; 2015*).

The Iron Gates sites have tended to be regarded as exceptional, yet paradoxically they may have been typical of Mesolithic and Early Neolithic coastal adaptations in Southeast Europe. Fishing villages or hamlets like those in the Iron Gates likely existed along the Bulgarian section of the Lower Danube, as well as in protected embayments, lagoons and river estuaries along the Black Sea, Aegean and Adriatic coasts. As Douglass Bailey observed: "*If the rise in the Black Sea removed from the region's landscapes a large coastal plain … then that flooded plain must contain much of the missing pre-Neolithic record, perhaps in localized concentrations similar to what was found in the [Iron Gates] Gorges*" (*Bailey 2007.521*).

Many sites may not have survived the Holocene marine transgression; others may lie at depths (or be covered in a thick layer of sediment) that make underwater archaeology difficult or impossible with

Fig. 4. Caves in the limestone cliff of Belyakovo Plateau, near Veliko Turnovo, Bulgaria. In the Upper Palaeolithic such sites provided convenient short-term shelters and good vantage points for watching game movements. In the heavily forested landscapes of the early Holocene this strategic advantage would have been lost (photo: Clive Bonsall).

current technology. However, recent discoveries of submerged Neolithic settlements along the Mediterranean coast of Israel (*Galili, Rosen 2011a; 2011b*) and the northern shore of the Marmara Sea in Turkey (*Özdoğan 2011a*) at up to 12m below sea level, suggest it is only a matter of time before submerged Late Mesolithic settlements are discovered around the Balkan coastline.

The pattern of coastal settlement and resource procurement likely varied regionally, influenced by the character of the coastline and resource availability. In contrast to the 'soft shore' environment of the Lower Danube, the Adriatic and Aegean coasts in particular provide extensive rocky shorelines, with more dispersed shellfish and fish resources. Mesolithic exploitation of such shorelines may have been similar to that in western Scotland where residential sites were located in protected embayments, and more remote areas of the coast were exploited using a logistical collecting strategy that involved the establishment of outlying fishing-and-processing camps, often taking advantage of the shelter (from sun, heat and rain) offered by coastal caves (*Bonsall 1996; Bonsall* et al. *2009*).

The model of Pre-Neolithic settlement of the Balkans presented above, which envisages an increasing emphasis on aquatic resources and concentration of population in coastal fishing communities, does not preclude Late Mesolithic use of inland areas, especially where there were local concentrations of wetland and aquatic resources. But large areas of the interior with dense canopy cover and few aquatic resources may have been visited rarely or not at all.

Fishers and farmers: implications for Neolithization

What role did coastlines and fishing communities play in the expansion of farming within the Balkans?

Most researchers accept that the spread of the Neolithic through the Aegean and the Mediterranean basin generally involved communities with a significant seafaring capability, and who probably combined farming with fishing and shellfish gathering. This model has been applied to the spread of the Impressed Ware Neolithic along the western shore of the Balkan Peninsula (*e.g., Forenbaher, Miracle 2005*).

Yet the Neolithization of the Balkans east of the Dinaric Mountains is still seen by most researchers largely in terms of an overland spread initially following river valleys that led inland from the Aegean coast (*e.g., Nikolov 1987; 1990; Lichardus-Itten 1993; Todorova, Vaysov 1993; Lichardus-Itten* et al. *2002, 2006*). Only a few researchers (*e.g., Bailey 2007; Özdoğan 2011b*) seem to have considered the possibility of an early maritime spread along the (now submerged) Black Sea coastal plain.

However, several lines of evidence, concrete and circumstantial, favour this possibility:

❶ The lack of Early Neolithic sites along the Black Sea coast probably has more to do with geological processes and our inability to locate sites, than a lack of interest in coasts and coastal resources by early farmers.

❷ Some of the earliest known Neolithic communities in the southern Balkans and neighbouring parts of western Anatolia combined farming with the exploitation of coastal resources, for example at Fikirtepe (*Düring 2011*), Yeşilova (*Derin 2008*) and Franchthi (*Perlès* et al. *2013*).

❸ The earliest known Neolithic sites in the Balkans interior (Fig. 5) are several centuries younger than the earliest known sites in mainland Greece and the Aegean. Moreover, the similarity of the earliest Neolithic ^{14}C dates (6100–6000 calBC) across the Balkans from southern Bulgaria to Transylvania (a straight-line distance of *c.* 600km), is difficult to explain purely in terms of a south-north overland spread. A simultaneous expansion along the Black Sea littoral and river valleys leading inland from the Black Sea – including those of the Danube and its southern and northern tributaries – would fit better with the radiocarbon record.

❹ For reasons discussed above, the densely forested interior may have proved as difficult for pioneer farmers as for hunter-gatherers. Therefore, an initial maritime/coastal spread aided by the availability of watercraft was arguably the easier option.

Pioneer colonization of the interior would have been difficult, if not impossible, without participation in 'interaction spheres' – loosely defined as information and exchange networks (*cf. Caldwell 1964*) – through which pioneer farmers were able to maintain social and economic ties with established farming-fishing communities living in peripheral (coastal) areas.

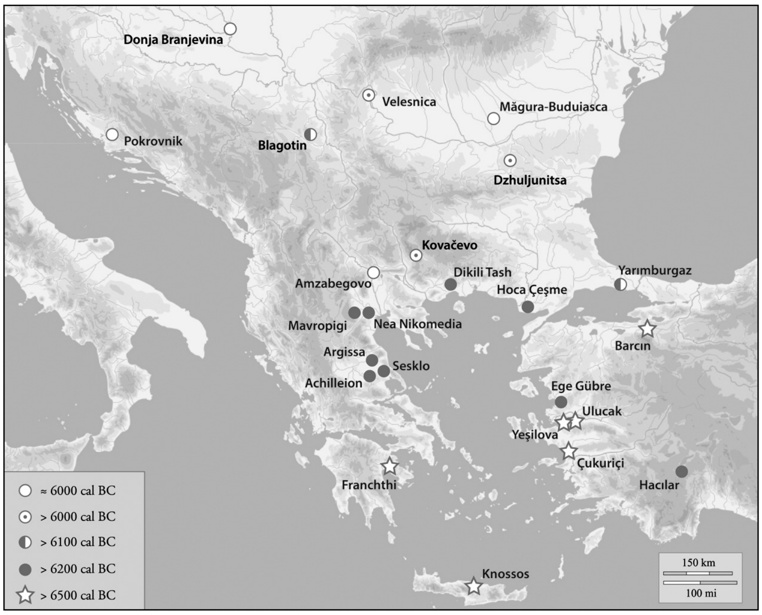


Fig. 5. Earliest radiocarbon dated evidence of farming in different parts of the Balkans-Aegean region.

Exchange networks operated among both Mesolithic and Early Neolithic groups in many parts of Europe, including the Balkans. In some cases there is evidence of the continuation of Mesolithic networks into the Neolithic. Marine shells used as body ornaments circulated widely among Upper Palaeolithic and Mesolithic groups in Southeast Europe (*Cristiani* et al. *2014*) judging by evidence from Greece, the Adriatic coast and the Iron Gates. Shell ornaments were also exchanged during the Early Neolithic although the forms and perforation techniques changed, reflected for example in the introduction of *Spondylus* ornaments and flat discoid beads made from marine bivalve shells (*Séfèriadès 1995; Perlès 2001*).

The existence of an important interaction sphere in the southern Balkans at the Meso-Neolithic transition is reflected in the distribution of obsidian originating from the Aegean island of Melos. Exploitation of this source necessitated the use of boats. Melian obsidian circulated among Late Upper Palaeolithic and Mesolithic groups on the Aegean islands and the Greek Mainland. Its use increased in the Early Neolithic – at Early Neolithic Argissa-Magoula (Greece) obsidian accounted for *over one-third* of the chipped stone tools – when it also appears in the eastern Aegean and western Anatolia. In a thought-provoking paper, Agathe Reingrüber (*2011*) has argued that the archaeological distribution of Melian obsidian is indicative of a network of *seafaring groups* that was already in existence in the Mesolithic and continued into the Neolithic, and which was crucial in the spread of farming across the Aegean into mainland Southeast Europe.

In the Late Mesolithic and Early Neolithic Balkans north of Greece obsidian is scarce, and its provenance uncertain. The very limited amount of material found on Early Neolithic sites in the central and northern Balkans east of the Dinaric Mountains may all come from sources in the Carpathians rather than Melos (*Williams-Thorpe* et al. *1984; see also Tripković 2004*).

In Early Neolithic Bulgaria, Serbia and southern Romania the 'demand' for high quality lithic materials was largely satisfied by yellowish-brown flint with white or pale-brown 'spots', often referred to in the archaeological literature as 'Balkan flint'. This high quality material often dominates chipped stone assemblages of the Karanovo I–II and Starčevo-Körös-Criş cultures.

Early Neolithic use of Balkan flint has been most intensively studied in Bulgaria (Fig. 6; *Gurova 2008;*

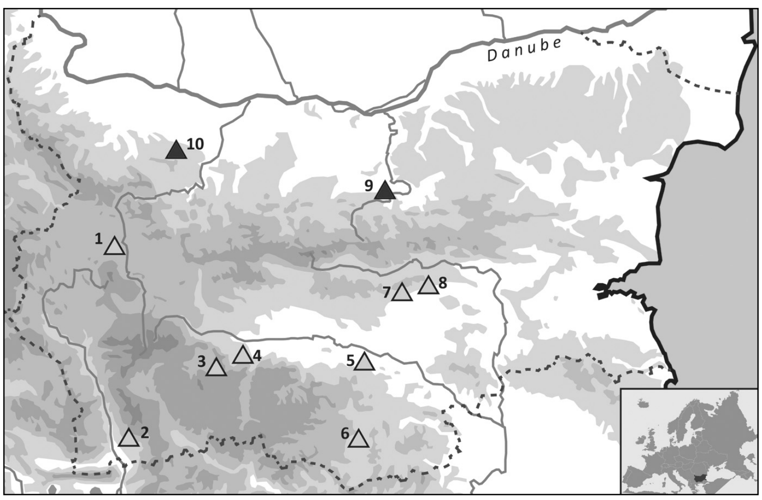
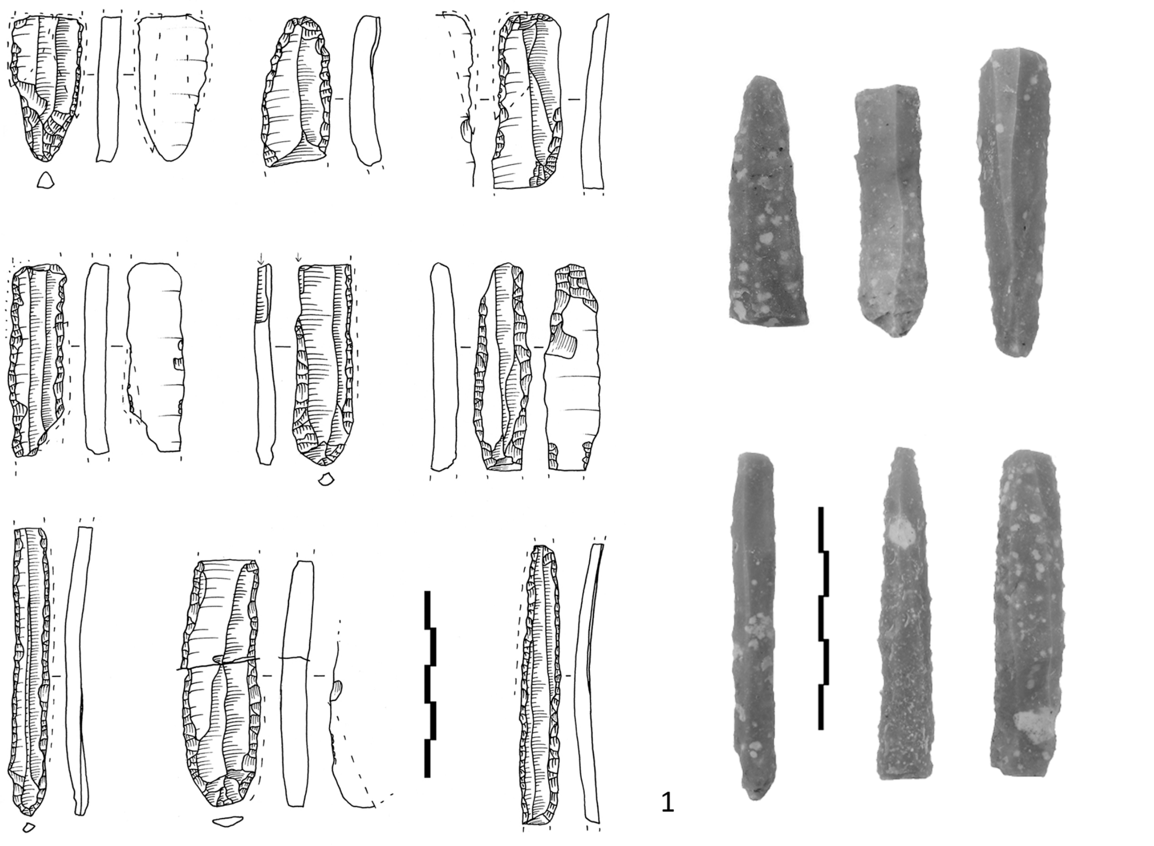


Fig. 6. Bulgarian Early Neolithic sites with Balkan flint artefacts (all sites) and 'formal toolkits' (red triangles): 1 – Slatina; 2 – Kovačevo; 3 – Rakitovo; 4 – Kapitan Dimitrievo; 5 – Yabalkovo; 6 – Sedlare; 7 – Azmak; 8 – Karanovo; 9 – Dzhuljunitsa; 10 – Ohoden (revised after* Gurova 2008.Fig. 1*).



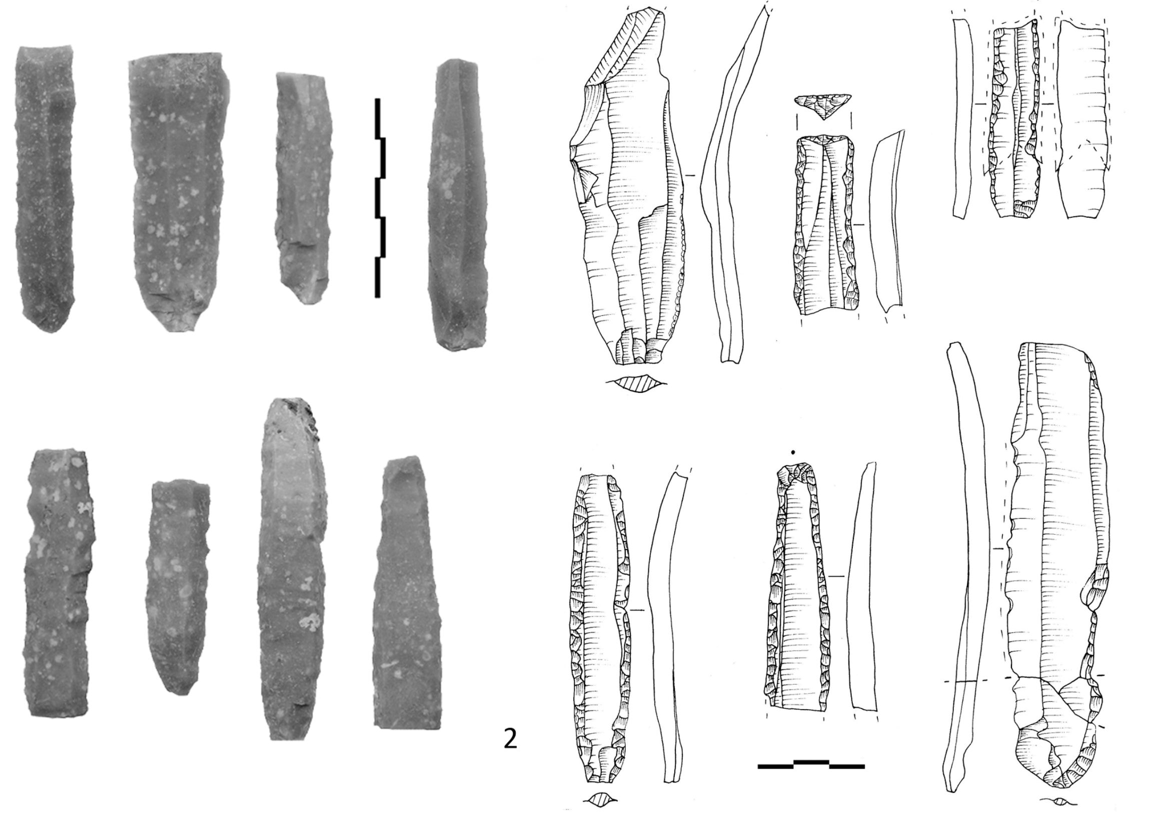


Fig. 7. Balkan flint formal toolkit from the Early Neolithic sites of Yabalkovo (1) and Slatina (2) (Photo and drawings: M. Gurova).

2011; 2012a; 2012b; Gurova, Nachev 2008). The Balkan flint component of Karanovo I–II culture lithic assemblages is characterized by what Maria Gurova has termed a 'formal toolkit' with a distinctive suite of retouched tools made on large regular blades produced by punch technique. The formal tools comprise blades with continuous (sometimes partial) semi-abrupt to abrupt retouch along one or both lateral edges, sometimes with pointed or rounded retouched ends, as well as sickle inserts (Figs. 7 and 8) (*Gurova 2008*). The sudden appearance of this highly developed lamellar (sometimes misleadingly termed 'macroblade') industry remains one of the most intractable problems of the Balkan Neolithic (*Kozłowski 2007.49*).

The repetition of the Balkan flint 'formal toolkit' over such a large territory and its co-occurrence with other distinctive socio-cultural traits between *c.* 5900–5600 calBC, implies the existence of a sophisticated exchange network with a high degree of interaction.

Fig. 8. Early Neolithic sickles with Balkan flint inserts: 1 microphotographs of typical cereal polish (x 100); 2 sickle inserts from Kovačevo; 3 sickle inserts from Yabalkovo; 4 sickles from Tell Karanovo (Figure: M. Gurova).

Considerable uncertainty surrounds the origin of the Balkan flint that was exploited by Early Neolithic groups in Bulgaria. Macroscopic, thin section and trace element analyses of archaeological and geological samples suggest that the most likely source or sources of the Balkan flint found at Karanovo I–II culture sites is in Cretaceous chalk-limestone formations of the Moesian platform in northern Bulgaria, most notably the Pleven-Nikopol region (*Gurova, Nachev 2008; Bonsall* et al. *2010; Gurova* et al. *in preparation*[1]).

'Pre-Karanovo I' use of Balkan flint is attested at the Early Neolithic site of Dzhuljunitsa *c.* 6050 calBC (Fig. 9) (*Gurova 2008; 2009; 2012a; 2012b*). However, Balkan flint it seems did not occur in the earliest Neolithic occupation phase at Kovačevo in southwest Bulgaria (*Gurova 2011*), also dated to *c.* 6050 BC (*Reingrüber, Thissen 2005; Higham* et al. *2011*). This very limited evidence may indicate that Neolithic use of Balkan flint began earlier in the north of Bulgaria than in the southwest.

But what were the origins of the Balkan flint interaction sphere? Did it originate with or after the arrival of farming in northern Bulgaria, or did Neolithic farmers take advantage of a pre-existing exchange network?

Much less is known of the exploitation of Balkan flint in Southeast Europe *before* the Neolithic. In Bulgaria the earliest documented archaeological occurrence was in the Gravettian and Epigravettian of Temnata Cave (*Pawlikowski 1992*). According to Dinan (*1996a; 1996b*) Balkan flint was also used in the Epigravettian of the Iron Gates. Whether it continued in use during the Iron Gates Mesolithic is problematic. Most sites in the Iron Gates also had Early Neolithic occupations; so the stratigraphic integrity of many 'Mesolithic' assemblages cannot be guaranteed and the characteristic features of *Late* Mesolithic assemblages in particular are hard to define.

The lack of Mesolithic sites in Bulgaria means that the extent of Balkan flint use during the early Holocene is unknown. But

1 A project entitled 'Prehistoric Flint Sourcing in NW Bulgaria and NE Serbia: field survey and laboratory analyses' was awarded in 2011 by the America for Bulgaria Foundation (ABF) and co-ordinated by the American Research Centre in Sofia (ARCS). The results are in preparation for publication by team members.

if there were Mesolithic fishing villages along the Bulgarian section of the Danube (as argued above), it seems inconceivable that they would not have exploited the rich Balkan flint outcrops in the region – if only the alluvial placer deposits along the Danube at Nikopol on the Bulgarian shore (Fig. 10) and at Ciuperceni in Romania. Transport of this material by boat to settlements further down the Danube and along the Black Sea coast would have been relatively easy, but much more difficult upriver to the Iron Gates because of river speeds that in places exceeded 18kph.

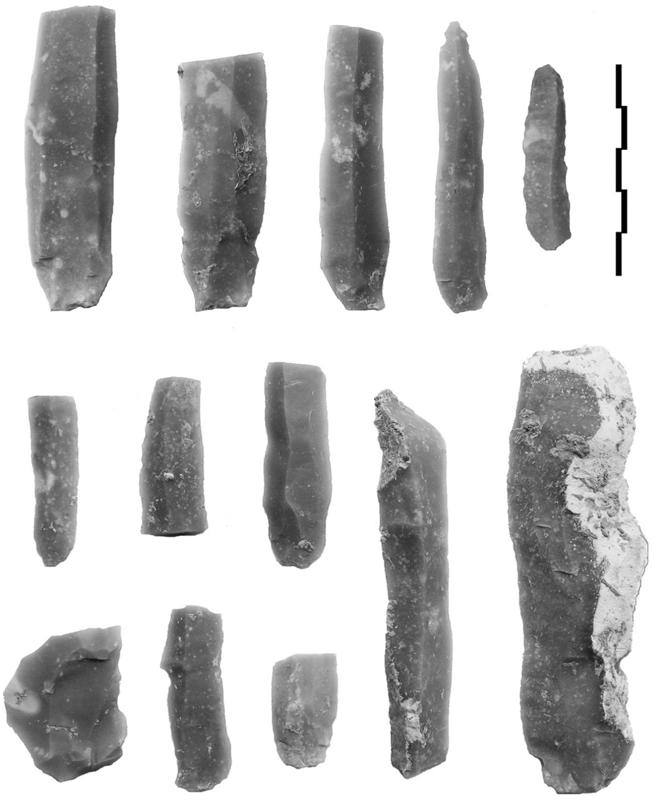


Fig. 9. 'Pre-Karanovo I' culture Balkan Flint artefacts (mainly debitage) from Dzhuljunitsa (Photo: M. Gurova).

Conclusions

The lack of evidence for Late Mesolithic settlement over large areas of the Balkan Peninsula has simultaneously dictated the direction of research into the Neolithic transition in Southeast Europe and acted as a serious impediment to it.

In this paper we have presented a model of Pre-Neolithic settlement of the central and northern Balkans that envisages extensive exploitation of the Peninsula by Late Pleistocene hunter-gatherers, followed by increasing reliance on aquatic resources as post-glacial forest expansion led to a progressive reduction in ungulate biomass, with Mesolithic populations becoming concentrated in fishing villages along sea coasts and the lower courses of major rivers. This model does not preclude logistically-organized use of the near hinterland by Mesolithic groups operating from residential bases on the coast, but remote areas of dense, closed canopy forest were likely avoided.

Many Mesolithic coastal sites would have been inundated by the Holocene marine transgression. But sites like Schela Cladovei and Vlasac in the Iron Gates were perhaps typical of the Late Mesolithic fishing villages that once existed along the length of the Lower Danube and the Black Sea coast.

The earliest Neolithic settlements in the Balkans may also have been located along sea and river coasts and combined farming with fishing, as in the Iron Gates. Many of these sites, too, would have been inundated by marine transgression.

Rapid recolonization of the hinterland by farmers began before 6100 calBC, would have been initiated from population centres on sea and river coasts, and was made possible by participation in established interaction spheres. One such exchange network had been operating in the Aegean since the Late Upper Palaeolithic, reflected in the distribution of Melian obsidian. We suggest there was also an exchange network involving Balkan flint (which may have originated in the Upper Palaeolithic) operating among Late Mesolithic groups in the Bulgarian section of the Danube valley and adjacent parts of Black Sea littoral, which expanded to encompass large areas of the central and northern Balkans during the Early Neolithic after 6000 calBC?

The current lack of information on the coastal aspect of early Holocene settlement of the Balkan Peninsula limits our ability to understand the processes involved in the transition to farming in the region. It follows that the future of Mesolithic and Early Neolithic studies in the Balkans, and Bulgaria in particular, may lie in targeted archaeological surveys of the Lower Danube valley downriver from the Iron Gates II dam and in systematic exploration of submerged landscapes along the Black Sea, Aegean and Adriatic coasts.

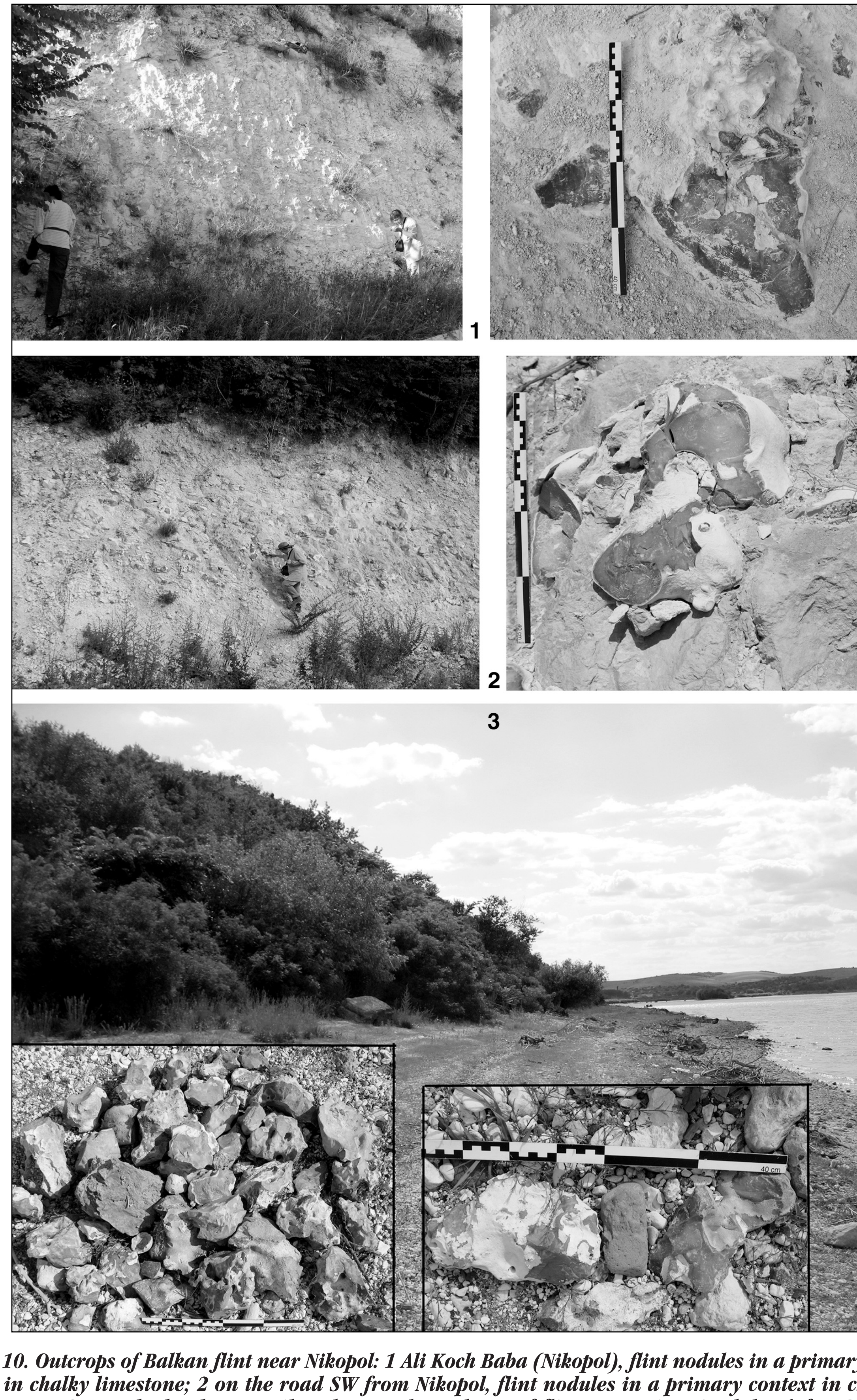


Fig. 10. Outcrops of Balkan flint near Nikopol: 1 Ali Koch Baba (Nikopol), flint nodules in a primary context in chalky limestone; 2 on the road SW from Nikopol, flint nodules in a primary context in chalky limestone; 3 Danube bank near Nikopol, secondary placer of flint concretions/nodules (after* Gurova 2012.Fig. 13*).

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Archaeological evidence for 9th and 8th millennia BC at Girmeler Cave near Tlos in SW Turkey

Turan Takaoğlu [1], **Taner Korkut** [2], **Burçin Erdoğu** [3] **and Gül Işın** [2]
1 Department of Archaeology, Çanakkale (18th March) University, TR
turantakaoglu@gmail.com
2 Department of Archaeology, Akdeniz University, Antalya, TR
tanerkorkut@akdeniz.edu.tr; gulisin@akdeniz.edu.tr
3 Department of Archaeology, University of Thrace, Edirne, TR
berdogu@gmail.com

ABSTRACT – *A mound settlement in front of the Girmeler Cave near the major Lycian city of Tlos in SW Turkey revealed evidence for occupation during the late 9th and 8th millennia BC. The ccupation is characterized by a structure with at least two layers of lime-plastered floor, hearths and bins and a wattle-and-daub superstructure, all pointing to a sedentary community engaged in intensive hunting and gathering. The trial trenches at Girmeler Cave also yielded evidence of an Early Pottery Neolithic period at the end of the 8th millennium BC. The remains of several buildings with terrazzo floors and wattle-and-daub superstructures were found. It is likely that the cave served as a sacred site in the Early Pottery Neolithic period. There was a hiatus between the late 9th/early 8th millennium BC and the Early Pottery Neolithic occupations at the site.*

IZVLEČEK – *Naselbina na gomili pred vhodom v jamo Girmeler v bližini pomembnega likijskega mesta Tlos v jugozahodni Turčiji razkriva dokaze o poselitvi v času poznega 9. in 8. tisočletja pr. n. št. Značilnost poselitve je struktura z vsaj dvema plastema z apnom prekritih tal, ognjišč, odpadnih jam in butane nadgradnje, kar kaže na sedentarno skupnost, ki se je ukvarjala z intenzivnim lovom in nabiralništvom. Testne sonde v jami Girmeler so prinesle dokaze o poselitvi v obdobju zgodnjega keramičnega neolitika ob koncu 8. tisočletja pr. n. št. Odkriti so bili ostanki več zgradb s teraco tlemi in butano nadgradnjo. Verjetno je, da je jama v zgodnjem keramičnem neolitiku služila kot svet kraj. Med poznim 9./zgodnjim 8. tisočletjem pr. n. št. in poselitvijo v zgodnjem keramičnem neolitiku je prepoznana prekinitev.*

KEY WORDS – *Anatolia; Pottery Neolithic; cave site; burials; rituals*

Introduction

Girmeler Cave, situated in the valley below the major ancient Lycian city of Tlos to the east of the modern town of Fethiye in Southwestern Turkey, presents archaeological evidence of one of the most poorly understood periods of the region, the 9th and 8th millennia BC (Fig. 1). The cave, located at the end of a promontory of limestone hill, is formed from two long galleries that are almost parallel (Fig. 2). Gallery I, about 100m long, is a narrow cave. Gallery II, 150m in length and larger than Gallery I, has two entrances opposite one another and contains stalactites and stalagmites. There is a natural hot thermal spring close to the site, which might have been one of the reasons that led to the selection of this locality for occupation from as early as the late 9th millennium BC to the Byzantine period.

Girmeler Cave was first recognised as an archaeological site by Fethiye Archaeology Museum in the 1980s, when a mound type settlement at the cave mouth was bulldozed away illegally to establish thermal installations (*Köktürk 2000*). This mound

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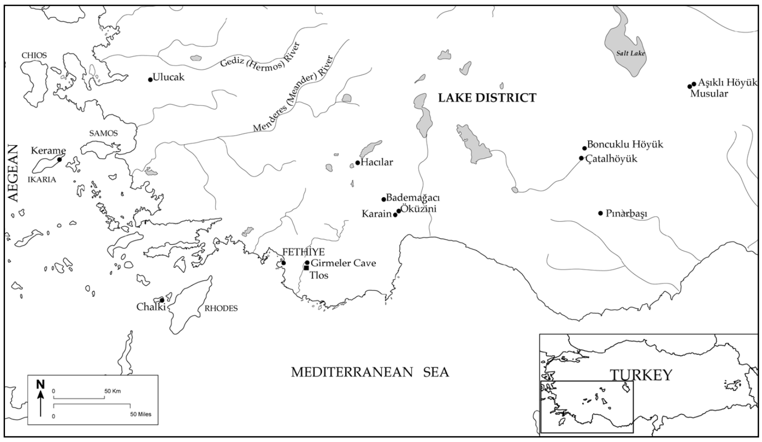

Fig. 1. Map locating Girmeler Cave and other major sites mentioned in the text.

once stood in front of the cave that was continuously occupied from almost as early as the late 9th millennium BC to the Byzantine period. Because nearly 6m of the top layers of the mound were destroyed, only the lowest layers containing evidence of occupation for the late 9th/early 8th millennium calBC remained. Small portions from the edges of the mound were also preserved in the mouths of Gallery I and II which provides a limited picture of the stratigraphy of the site. This paper introduces data derived from four trial trenches opened in the lowest layers of the mound in front of the cave and in the preserved parts of the mound in the mouth of Gallery I. David French (*2008*) introduced some of the finds that remained after the destruction of the mound.

The archaeological investigations represented by four trial trenches and surveys were conducted between 2011 and 2013 by a team representing the Tlos Excavation Project under the auspices of the Turkish General Directorate of Antiquities and Museums. Because Tlos is among the major sites mentioned in the 2nd millennium BC Hittite texts such as *Tlawa*, the pre-Classical past of the city and its territory attracted a great attention among Lycian specialists (*Korkut 2013*). It was during the exploration of the pre-Classical sequences at Tlos and its territory that the site came to our attention and was included in the research programme.

The late 9th/early 8th millennium BC occupation: a sedentary community?

Two trial trenches (A and C) in the lowest layers of the mound revealed archaeological evidence of late 9th/early 8th millennium calBC structures and related features. In Trench A, this occupation is about 7.6m below the original surface level of the mound, suggesting the intensity and longevity of the settlement. Part of a structure with a lime-plastered floor was discovered in Trench A in 2013 (Fig. 4). The plastered floor with small stones has evidently been renewed at least twice. Two postholes gouged into the plaster floor were also noted. The structure appears to have had superstructures of wattle and daub. This structure also has a number of features, including two circular sunken mud plastered basins and a rectangular pit. These features show the long-term and regular use/reuse of the structure. The finds include an oval basin filled with ash, and burnt and fire-cracked stones. The basin might have been used for cooking facilities. Two circular hearths of the earlier phase were found beneath this oval plastered basin. Close to the hearths of the early phase are two shallow rectangular features with roughly oval corners, both filled with ash. At least two more hearths were also found in the early phase, but their exact connection with the structure is obscure. When the structure was abandoned, further pits for burned lime and various sizes of hearth were placed over its remains. Three AMS radiocarbon dates (Wk-37966: 8906±37 BP; Wk-37967: 8876±33 BP; Wk-35608: 8868±25 BP) obtained from samples taken from these deposits in Trench A fall between *c.* 8200–7900 calBC.

In order to reach virgin soil, the southeast corner of Trench A was deepened, but the sounding yielded a line of stones and clay lumps with a dense concentration of animal bones and chipped stone implements in red palaeosols. Red paleosols were also discovered just below the surface in Trench C in front of Gallery II. Less than half a metre of the deposit was excavated in Trench C because a rock fall sealed the trench. A burial leaning against the cave wall was found in Trench C (Fig. 5). The burial revealed a flexed articulated adult on his/her left side in a contracted position. Three flint artefacts were found *in situ* around the skull.

In Trenches A and C, flint was the raw material for the manufacture of chipped stone tools (Fig. 6). No obsidian was found. Because it was collected from a variety of mixed sources, flint is often very variable in character; in this case, red-brown is the most common. A flake-based technology can be observed in the chipped stone industry of the Girmeler

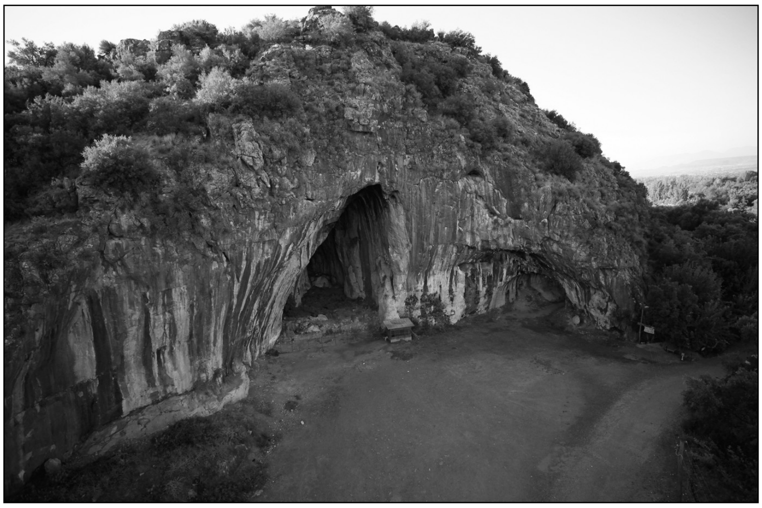

Fig. 2. Aerial view of Girmeler Cave from the south showing the mouths of Gallery I (left) and Gallery II (right). A mound once stood in the front of the cave.

Cave. Tools are rare, but flakes are numerous; they were made from small flint blocks by direct percussion technique with the help of a hard expedient tool. Cores often have multiple platforms with a limited amount of flakes taken from each. Blade cores are rare. All were bidirectional blade cores, and only a few traces of core preparation are present. Most of the blanks were used directly, without retouch. Tools include end and circular scrapers on flakes, perforators, blade, and bladelets. A sickle blade with parallel lateral edges is unique. It must be mentioned that no microliths were found in the four trial trenches at the site.

The preliminary analysis of animal bones from Trenches A and C indicates that *Sus scrofa* (wild boar), *Cervus elaphus* (red deer), *Dama dama* (European fallow deer), *Caracal caracal* (caracal), and *Lepus europaeus* (European hare) were the most common species represented, indicating that hunting was part of the subsistence strategy of settlers at the site. Fish and birds were also consumed. Caprines and aurochs were not detected at all among the available animal bone assemblage. In addition, two perforated and burned *Nassarius* shell beads were found in the habitation debris of the structure in Trench A. One small stone with a polished groove which could be identified as a shaft straightener was also found in the habitation debris. A total of 19 worked bones have also been identified among the habitation debris in Trenches A and C (Fig. 7); three are pendants made from the bones of *Lepus europaeus*, each with a hole for suspension, while 13 are awls pointed either at one end or both ends. The remaining three worked bones are tips of bevel-ended tools. The habitation debris in Trench A also revealed grind stones, mainly large querns bearing extensive abrasive use wear on their ventral surfaces.

The late 9th/early 8th millennium calBC occupation at Girmeler Cave was characterised by a total absence of pottery. The structure with at least two layers of lime-plastered floor, wattle and daub superstructures, and floor furnishing in Trench A points to a sedentary community. However, it is unclear whether sedentism could be viewed as an extension of radiating mobility or as a generically distinct way of life. The site is contemporary with well-known 9th millennium calBC Central Anatolian sites such as Aşıklı, Pınarbaşı and Boncuklu. This period in Central Anatolia is characterised by sedentary communities engaging in intensive hunting and gathering. Oval structures with mud-brick walls and a central hearth existed at both Aşıklı and Boncuklu (*Özbaşaran 2012; Baird* et al. *2012*). The architectural tradition at Pınarbaşı is different, as the site is characterised

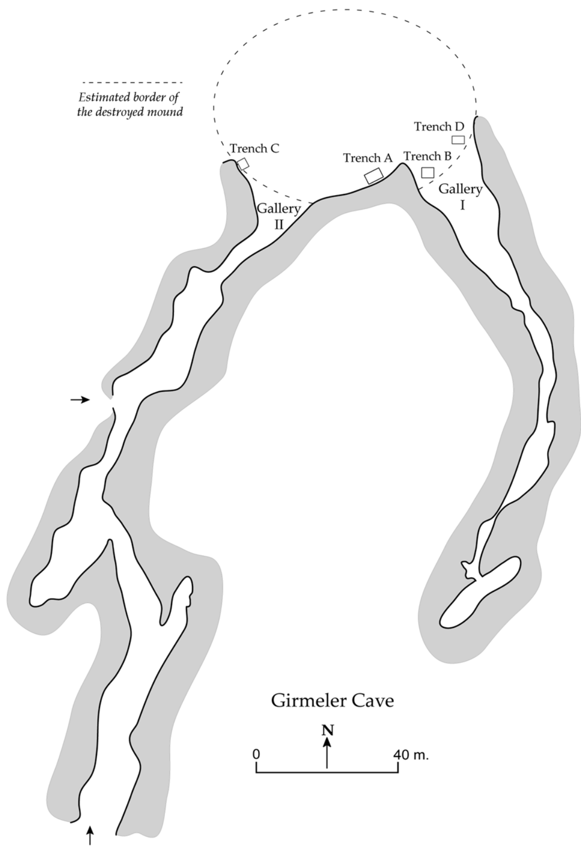

Fig. 3. Map of Girmeler Cave showing trial trenches.

by sunken curvilinear buildings with wattle and daub superstructures (*Baird 2012*). Human remains have been discovered beneath the floors of Aşıklı and Boncuklu, but not at Pınarbaşı. The structure in Trench A at Girmeler Cave may be associated with the curvilinear, wattle and daub architectural tradition of Pınarbaşı, with the difference being the lime-plastered floor.

Fig. 4. Trench A with the remains of a late 9th/early 8th millennium BC structure with a lime-plastered floor and related features such as hearths, bins, basins, and postholes.

Subsistence in Central Anatolia in the 9th millennium calBC depended on hunting mainly cattle, boar, deer, sheep and goat, and gathering plants for food. Cattle, sheep, and goat are totally absent from Girmeler Cave. Differences in archaeological assemblages of faunal remains might be explained by differences in the strategies of 9th millennium calBC communities. The chipped stone assemblages of Central Anatolian sites were dominated by obsidian and characterised by microliths. The chipped stone assemblage at Girmeler Cave is different from that of the Central Anatolian assemblages. Microliths are totally absent; flake-based technology is dominant. All these differences may show a different form of sedentism in Southwestern Anatolia.

Some dates from layer Ib1 at the Öküzini Cave fall into the end of 9th millennium calBC, *i.e.* contemporary with Girmeler Cave. Layer Ib1 of the Öküzini Cave is described as a mixture of microlithic industries with Neolithic elements, and may be assigned to the Aceramic Neolithic Period (*Albrecht* et al. *1992*). Despite the more or less contemporary dates, there are no identical similarities between the assemblages of the two caves.

The end of the early phase of the Aegean Mesolithic also dates around the end of the 9th millennium calBC. The available evidence from the semi-permanent settlements at Maroulas on Kythnos in the Cyclades and Kerame I on Ikaria in the Dodecanese both show that the lithic industry of this period consisted of flake-based technology. Denticulated-notched forms, end-scrapers, perforators and arched backed pieces were the most frequent chipped stone tools at these two sites (*Sampson* et al. *2012*). A small scale excavation at Kerame I yielded no architectural structures except hearths and several stone rings, while the remains of more than 30 stone circular dwellings were found at Maroulas (*Sampson* et al. *2010*). The structures consist of small stones placed in an upright position on the periphery and flat slabs on the floor. Burials were recovered beneath the floors of the circular dwellings or between them. In the Aegean, the west trench in the Cyclopes Cave on Youra was dated to the middle of the 9th millennium calBC. The lithic industry here is also characterised by a flake technology in which flaked tools, end-scrapers, retouched flakes and notched tools dominate (*Sampson* et al. *2008; Kaczanowska, Kozłowski 2008*). Surface finds from Chalki in the Dodecanese also suggest a similar chipped stone industry within the Aegean Mesolithic tradition, but the presence of microblade technology and a more numerous group of geometric and parageometric inserts makes this industry different. The chipped stone industry at Girmeler Cave bears general similarities with the Aegean Mesolithic, although tools such as blades with parallel lateral edges also find parallels in Neolithic contexts.

The late 8th millennium BC occupation: an Early Pottery Neolithic sacred site?

Archaeological evidence for Early Pottery Neolithic at Girmeler Cave was mainly recovered from part of the mound that remained after destruction at the mouth of Gallery I. The profile of the mound at the mouth of Gallery I measures 20m in length and about 1–1.5m in height. In the 2012 and 2013 seasons, two small trial trenches (B and D) were opened in this area to obtain a picture of the stratigraphy over the late 9th/early 8th millennium BC occupational debris. In front of Gallery I, a number of superimposed terrazzo floors were exposed in the section, along with parts of a building with a terrazzo floor

Fig.5. Trench C with a late 9th/early 8th millennium BC burial in contracted position.

directly on top. The building was probably burned ritually and regularly in order to mark the end of the 'life' of the structure. Almost all burned debris contained scattered seeds, probably wheat, some of which stuck to the lime floors, apparently as part of a closing ritual. The last terrazzo building was destroyed by a natural disaster. Very large rocks fell onto the building from the ceiling of the cave. Other terrazzo floors and burned debris in the profile of the mound indicate that at least three additional terrazzo buildings once lay at the mouth of Gallery I.

overlying them (Fig. 8). The examination of the surviving parts of the standing walls suggests that this building was made of wattle-and-daub. The wall was plastered on the inside and outside with fine layers of lime. The terrazzo floor of this building was made with lime and small stones with thickness varying from 9cm to 12cm. A number of lumps of clay with impressions of split planks and twigs were found among the structural debris over the terrazzo floors (Fig. 9).

The other terrazzo floors of underlying buildings were cleaned in the 1x3m sized Trench D, which was opened to reach the bedrock. A total of nine superimposed layers of terrazzo floors and eight layers of burned debris were revealed. The first terrazzo building was formed directly on the stony virgin soil. It seems that when the building fell into disuse, it was deliberately burned and another built

Pottery is the most common artefact found in this period. The bottom layer yielded pottery typical of Bademağacı Early Neolithic I /9–8. The very oldest pottery at Girmeler Cave is rare, consisting mainly of coarse, grit-tempered grey to black clay, with a reddish-brown surface colour. In the upper layers, red and black-slipped, fine-burnished pottery begin to appear. No decoration is seen on the pottery. Medium to large deep bowls with rounded sides predominate the assemblage. The eastern-most surface of Gallery I and the entrance to Gallery II (*French 2008*) yielded Late Neolithic/Early Chalcolithic white-on-red and red-on-buff painted pottery, similar to those of the Lake District region.

The chipped stone tools recovered from the Early Neolithic occupation were made from flint, although two obsidian tools of probably Melian origin were also identified. The chipped stone technology differs from that of the late 9th/early 8th millennium BC occupation. Typical artefact assemblages include large blades. Grind stone tools, especially large saddle querns and pestles, also existed. A full-grooved stone fishnet sinker was also discovered.

As mentioned above, the remains of the mound at the mouth of Gallery I are formed of buildings with terrazzo floors. Terrazzo floors were constructed of burnt lime and crushed limestone and were polished. The embedded crushed limestone gives these terrazzo floors a slightly mottled appearance. The earliest known lime plaster pyrotechnology dates to *c.* 12 000 calBC in the Levant, although floors made of lime

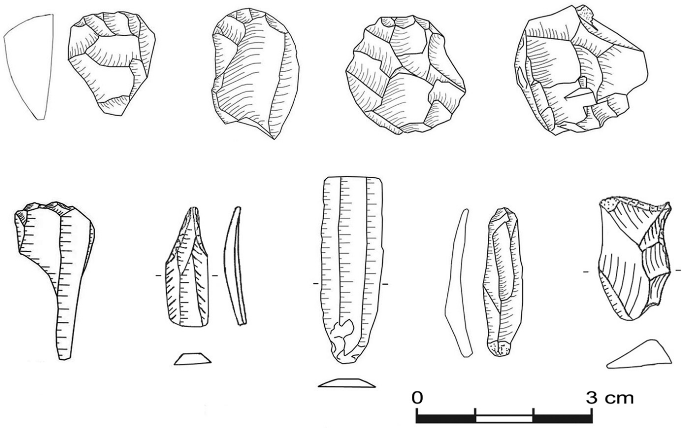

Fig. 6. Late 9th/early 8th millennium BC flint artefacts from Trenches A and C.

plaster are not recorded in the Middle East until *c*. 9000 calBC (*Kingery* et al. *1988*). Buildings with terrazzo floors are generally associated with special buildings in the Aceramic period of Southeastern Turkey (*e.g.*, Göbeklitepe, Çayönü, and Nevali Çori), and also from Aceramic Central Anatolia (*c*. 8500–6600 calBC). Both Terrazzo Building T at Aşıklı Höyük and Terrazzo Building A at Musular have been interpreted as special buildings where ritual activities might have taken place (*Duru, Özbasaran 2005.26*). Buildings with terrazzo floors also existed around 7000 calBC at Early Neolithic settlements in the Lake District, including Hacılar and Bademağacı (*Duru 2012*). Special buildings marked by their red-coloured lime plastered floors were also found in Ulucak, Western Anatolia, *c*. 7000 calBC (*Çilingiroğlu* et al. *2012*). It is possible that the buildings with terrazzo floors at Girmeler Cave might have been more or less contemporary with those of the Lake District. A single radiocarbon date (KIA-44211) recovered from this area in the trial trenches of 2011 provided a date around 7460–7070 calBC (*Becks, Polat-Becks 2013. 166*).

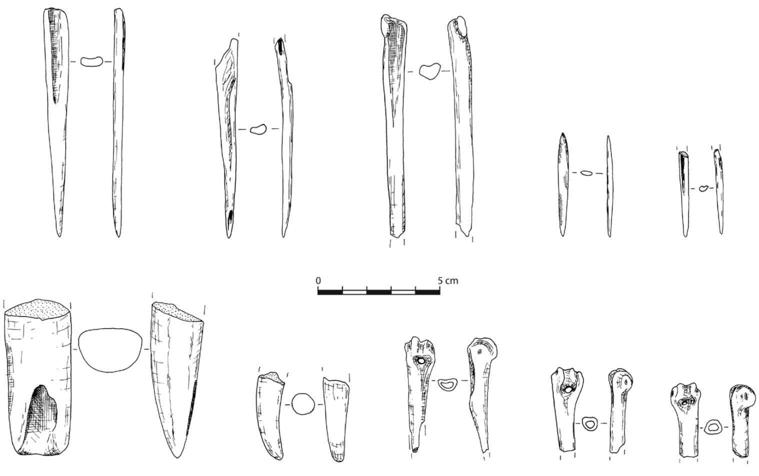

Fig. 7. Late 9th/early 8th millennium BC bone objects from Trenches A and C: (a-e) awls, (f) part of a bevel-ended tool, (g) tip of a round-ended tool, (h-j) fragments of pendants with holes for suspension.

The terrazzo buildings identified at the mouth of Gallery I at Girmeler Cave might have also been used for ritual and ceremonial purposes. Caves are not only physical geographic landmarks, but also part of the very structure of the spirit world. They are the dwellings of deities, a place where one can pass from one cosmic zone to another (*Duerr 1985*). Caves may also symbolise the dead and the underworld, the womb, childbearing and new life. Although usually portrayed as terrifying, dangerous or unpredictable places, caves appear in many myths as sources of growth, life and rebirth. They were probably sacred meeting centres in the Neolithic Period.

Concluding remarks

Girmeler Cave is one of the first extant early sedentary sites with a subsistence based mainly on intensive hunting and gathering in SW Turkey. The differences between the archaeological assemblages of faunal remains and the chipped stone tool production at Girmeler Cave and other sites of this period, such as in the Lake District, Central Anatolia, and the Aegean islands, show that sedentism developed along quite different paths in SW Turkey. The Early Pottery Neolithic period at Girmeler Cave, on the other hand, is characterised by buildings with terrazzo floors at the entrance to Gallery I, indicating that these buildings might have had sacred functions. The Early Pottery Neolithic culture identified at Girmeler Cave more or less shared the same cultural tradition to which the cultures of the Lakes District also belonged in this period. Whether a hiatus occurred between the late 9th/ early 8th millennium BC occupation dating between 8200 and 7900 calBC and Early Pottery Neolithic occupation dating around late 8th millenni-

Fig. 8. Trench D and the remains of buildings with terrazzo floors representing early pottery Neolithic at the preserved edge of the mound at the mouth of Gallery I.

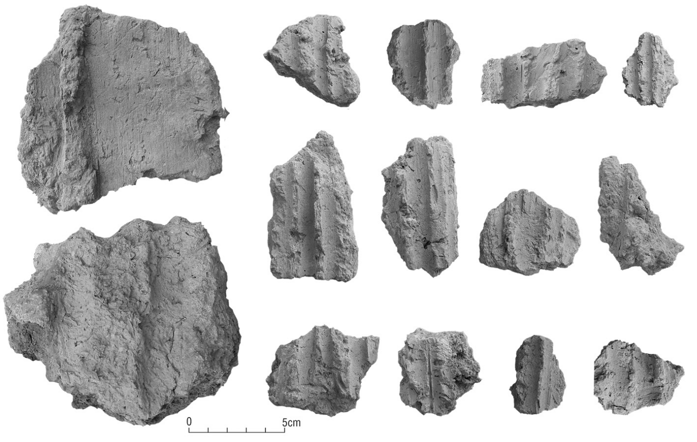

Fig. 9. Lumps of clay with impressions of split planks and twigs found in occupational debris just above the terrazzo floors.

um BC is difficult to estimate with certainty due to the extensive destruction at the site and the nature of the topography, which slopes down from east to west. However, the horizontal association of sections of four trial trenches indicates that the late 9th/early 8th millennium calBC occupation unearthed at Trench A constitutes the lowest layer. Although remains representing Early Pottery Neolithic occupation are absent above Trench A because they were moved away during the destruction of the mound, a deposit of some 0.80m thick grey-brown silt overlying the late 9th/early 8th millennium calBC occupation is observable here. It is also clear from Trench D that the Early Pottery Neolithic occupation rested on bedrock, as the ground level in this part is higher than in the western part. This indicates that not all parts at the front of the cave were used in the late 9th/early 8th millennium calBC. The differences in the material assemblages of the late 9th/early 8th millennium calBC and Early Pottery Neolithic occupations also confirm that a hiatus existed between these two periods. Therefore, the new data from Girmeler Cave sheds some light on aspects of culture and subsistence at two different, crucial cultural stages of SW Turkey, which has long been considered void of human occupation during the Neolithic and pre-Neolithic periods.

ACKNOWLEDGEMENTS

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'Temples' in the Neolithic and Copper Age in Southeast Europe? *

Clemens Lichter
Badisches Landesmuseum Karlsruhe, Karlsruhe, DE
clemens.lichter@landesmuseum.de

ABSTRACT – *Several buildings dated to the Neolithic period and Copper Age in Southeast Europe have been designated as 'temple', 'sanctuary', 'cultic structure' or 'place of cult' in scholarly works. The present contribution discusses the problems of identifying religious architecture; it elucidates some of these archaeological records and evaluates arguments with which the designation 'temple' or 'cultic structure' is justified. Thereby, the author concludes that no structure has been found among the houses excavated in Southeast Europe that can be classified as a 'sanctuary'. Instead, there are many indications that ritual activities took place in every dwelling and that these were specially decorated for such occasions. The author also considers so-called 'special buildings' of the Neolithic period in the Near East and discusses their absence in Southeast Europe.*

IZVLEČEK – *Številne neolitske in bakrenodobne zgradbe v Jugovzhodni Evropi so v strokovnih delih opredeljene kot 'templji', 'svetišča', 'kultne zgradbe' ali 'kultni prostori'. V prispevku razpravljamo o problemih prepoznavanja verske arhitekture; pojasnjujemo nekatere od tovrstnih arheoloških zapisov in ovrednotimo utemeljitve, ki upravičujejo opredelitve, kot so 'tempelj' ali 'kultna zgradba'. Ugotovili smo, da med izkopanimi zgradbami iz Jugovzhodne Evrope ni nobenega objekta, v katerem bi lahko prepoznali 'svetišče'. Nasprotno, obstajajo številni znaki, da so ritualne aktivnosti potekale v vsakdanjih bivališčih, in da so bila le-ta posebej okrašena za ta namen. Obravnavamo tudi t. i. 'posebne zgradbe' iz obdobja neolitika na Bližnjem Vzhodu in razpravljamo o njihovi odsotnosti v Jugovzhodni Evropi.*

KEY WORDS – *Neolithic; Chalcolithic; religion; cult buildings; sanctuary; Anatolia; Southeastern Europe*

Introduction

In the beginnings of scientific studies on prehistory, first material (stone) and later technology (production of stone artefacts, pottery production) were propounded as defining criteria for the Neolithic period. Vere Gordon Childe's works drew socioeconomic criteria into the centre of interest, describing the Neolithic as an epoch of food production and a sedentary way of life, criteria that are still definitive today. Alongside material and economic criteria, sociological aspects have also been regarded as useful in dividing prehistory and thereby defining the Neolithic period (*Morgan 1878*). In the past decades, ideological criteria have appeared increasingly, that is, more consideration has been given to spiritual culture and deliberations made about religion and cultic practices in prehistoric archaeology (*e.g., Biehl* et al. *2001; Bradley 2005; Hansen 2003; Insoll 2004; Renfrew, Zubrow 1994; Rowan 2012*).

* This article is a revised and augmented version of the paper: 'Tempel' in der Jungsteinzeit und Kupferzeit Südosteuropas?', presented in the German language in 2010, in J. Šutekova, P. Pavúk, P. Kalábková and B. Kovár (eds.), *Panta Rhei – Studies in the chronology and cultural development of South-eastern and Central Europe in earlier Prehistory presented to Juraj Pavúk on the occasion of his 75th Birthday*. Studia Archaeologica et Mediaevalia XI (2010): 581–591. This renewed contemplation of the topic was inspired by M. Budja, whom I thank for accepting the text for publication in Documenta Praehistorica. My thanks also go to E. Schalk (Berlin), who undertook the translation of the German text.

One example of this change in paradigm is illustrated by the interpretation of Bronze Age hoards: well into the 1970s and 1980s, they were conventionally viewed as depositions buried by bronze smiths or traders, or as intentionally hidden goods, implying uncertain, economically difficult or contentious times. In recent years, however, this category of finds has been predominantly interpreted as votive offerings or dedications: the formerly 'mundane' interpretation has given way to a religious one.

Another example is the significance of cult and religion in the emergence of the Neolithic in the Near East (*Cauvin 1994; Gebel* et al. *2002*) and the role of ideology in the dissemination of the Neolithic way of life (*Lüning 2007*).

Initially, nothing can be said against the assumption that traces of religious activities in the archaeological record are just as frequent as their place in the daily life of people at that time. The difficulty, however, lies in recognising these traces. Archaeological finds and contexts are not self-explanatory; their meaning and interpretation are based on conclusive analogies. Thus, finding evidence for religious practices in non-literate civilisations is a difficult task.

Are Neolithic clay figurines cultic figures, representations of ancestors, or children's toys? Were Neolithic ditched enclosures fortified complexes or cult sites? These inquiries go beyond our cultural comprehension and background. We distinguish between the religious and the mundane, which is a concept that cannot be applied to prehistory. In prehistoric times, religious practices were probably not phenomena that can be viewed as detached from other practices; rather, they were components of all practices (*Brück 1999*). Therefore, according to our understanding, mundane activities could also have been motivated by religion. Prehistoric stone and copper axes could have served as weapons or tools; but as symbols of power they also fulfilled a social or even religious function.

Groups of supposed 'ritual' Neolithic objects have always been of interest, as can be seen in the multitude of publications (*e.g., Hansen 2007; Becker 2011; Nikolov 2007; Schwarzberg 2005; 2011*). The designations customarily used for some of these find categories – 'idol', 'cult vessel', 'cult table' – emerged without knowledge of their functions, and are a sign of the common practice of assigning unusual or rationally inexplicable objects to the religious sphere. Due to the aforementioned problem of substantiation, it is also difficult to designate buildings as 'religious architecture'. Ultimately, remains can be approached only through thorough analysis. This applies to objects utilised in supposed ritual activities just as much as structures, whether they are pits or dwellings. Here, the archaeological record is of special significance. A precise analysis of the finds and find contexts with regard to their surroundings as well as their relation to one another is the basic prerequisite for approaching this issue.

The development of a category of criteria for a 'cult building', with the aim of establishing the physical characteristics of corresponding cult practices has, in Mycenaean Greece for example, a longstanding tradition. Robin Hägg (*1968*) followed this aim by viewing material remains in order to identify cult practices and thereby also cult sites. For him, the essential classificatory criteria seemed to be specific devices, such as altars, 'offertory stones' or benches upon which liquids or other forms of offerings without fire were placed and which could also be used for incense offerings. Further criteria included, for example, the interior furnishing of structures with wall paintings, as well as the presence of objects of cultic character, such as figurines or anthropomorphic vessels. Since then, Hägg's catalogue of criteria has had further additions and nuances (summarised in *Albers 1994*), but its basic features are still valid. Needless to say, the criteria that pertain to Mycenaean Greece cannot be transferred to the Neolithic or Copper Age in Southeast Europe, several thousands of years earlier. General formulations about signs of the existence of religious activities as found in archaeological remains are still vague (*Renfrew, Bahn 1991.359–360; Renfrew 1994.51–52*).

A further possible approach to religious architecture in prehistory is the (presupposed) handing down of religious practices, which allows conclusions to be drawn from existing knowledge about the distant past. Examples for this are provided, for instance, by the stratigraphies of temples in Mesopotamia: starting with temple architecture known from the Uruk period, the function of the underlying sequence of buildings can be determined, so that the cult architecture in many sites can be traced back well into the 6th millennium BC (*e.g.*, the building sequence beneath the Ur-Nammu ziggurat in Eridu: *Safar* et al. *1981.86–114*). This argument is based on an almost continuous sequence of occupation and an assumed constancy in location of the corresponding structures. With the argument of continuity, Iron Age sanctuaries sited on those of the Late Bronze Age in Greece could be identified (*van Leuven 1978*). By contrast, examples of discontinuity in the development of cult architecture are especially notable in the post-Mycenaean, Protogeometric and Geometric periods between the 11th and 8th centuries BC. There is little evidence of cult architecture, which in addition would differ markedly from that of Mycenaean times (*Mazarakis Ainian 1997*). During these periods, religious activities were probably performed once again inside individual households. There is hardly any distinction between cult buildings and the houses of the social elite. The attempt in the Aegean sphere to discern structures that overlap in time and in this way to link them firmly with the Neolithic cult buildings did not produce any reliable results. Thus, the derivation of Neolithic cult architecture in view of later forms is unsuccessful due to the enormous time span. For the same reason, the use of the catalogue of criteria pertaining to the Bronze and Iron Age is limited when discussing Neolithic cult objects and architecture (*Rutkowski 1986*).

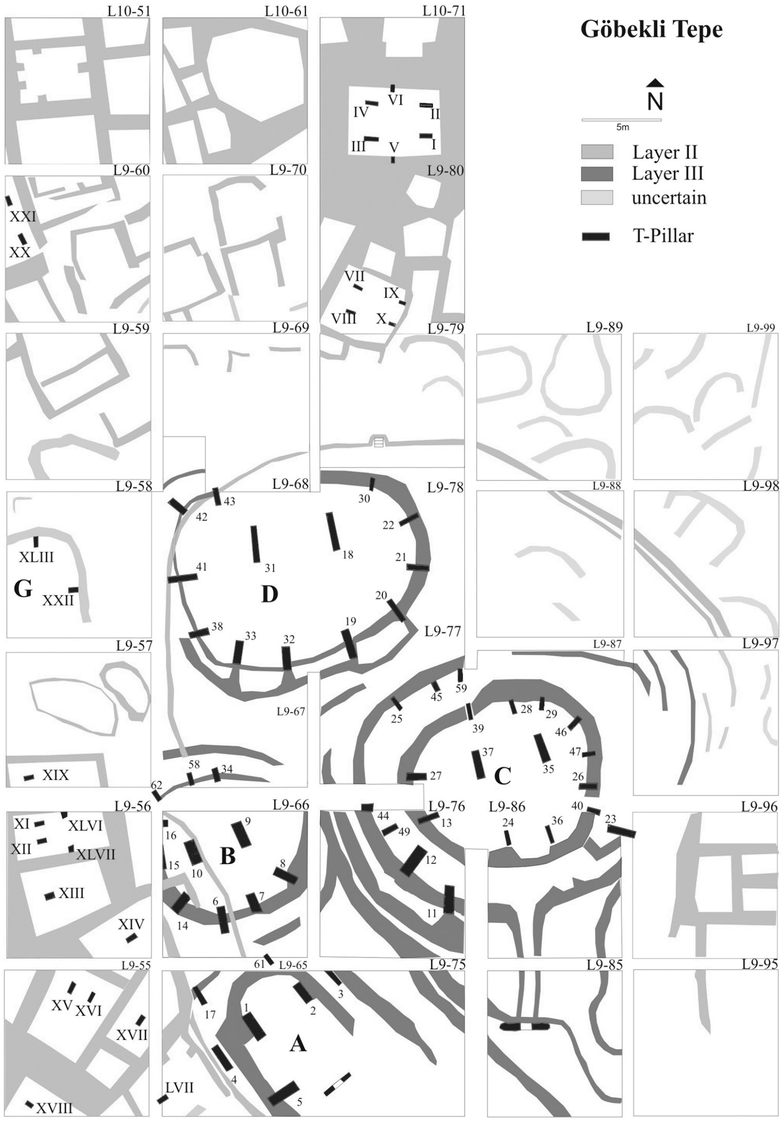

Fig. 1. Göbekli Tepe: Schematic plan of enclosures A–D (after* Schmidt 2011.Fig. 2*).

Finally, it cannot be assumed *a priori* that the superimposed, religious structure of the Bronze or Iron Age resembled that of the Stone Age.

The terms and their use

The term 'temple' derives from the Latin word *templum*, a ritually specified area. In colloquial speech, it is understood as a non-Christian cult building. Ritual acts in temples were carried out by cult personnel (priests, priestesses), who in addition made use of sacred objects, such as artefacts for offering. In Mesopotamia, a temple was a building sheltering a deity represented by a depiction. The temple was considered the 'house' or 'residence' of the deity (*Sallaberger 2013.519*). Therefore, ancient oriental temples display a similarity with coeval domestic architecture. An important point here is the concept of the existence of anthropomorphic gods. Oriental temples are characterised by, for example, altars, cult pedestals and also foundation gifts, building inscriptions, and votive inscriptions, as well as objects normally not present in domestic dwellings (summarised in *Miglus 2013.530–531*). The basic features of Mesopotamian sacred architecture were compiled and described by Ernst Heinrich (*1982*). With the indistinct designation 'cult house' (ger. Kulthaus) Heinrich documents buildings (*Heinrich 1983.319*) that possess certain peculiarities of temples, as well as dwellings whose arrangement served sacred purposes to a great extent. Heinrich himself writes that the term for cult house remains dubious and is not limited to any types.

Compared to the terminology applied in classifications such as 'vessel', 'building' or 'axe', the use of terms such as 'cult vessel', 'cult building' and 'ceremonial' or 'ritual axe' necessitates an interpretation on the basis of further evidence. However, because the religious superstructure of corresponding activities and the artefacts utilised or residual contexts are unknown, most of the results of these interpretations are ambiguous. The basic prerequisite for using terms such as 'cult building' or 'cult axe' should be that the 'cult object' should have been repeatedly used for this purpose and that the 'cult building' should have mainly (if, indeed, not exclusively) served religious purposes. Buildings of the Neolithic period in the Near East which, in view of their size, ground plan, construction and interior furnishing, clearly differ from dwellings, are designated 'special buildings'. This term allows an impartial approach to the corresponding architecture, regardless of its actual function.

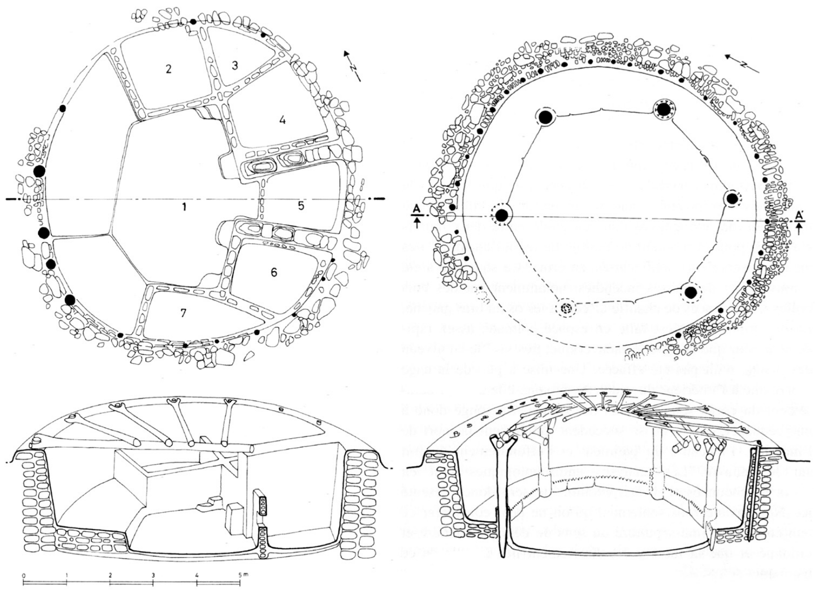

Fig. 2. Jerf el Ahmar: special building EA 30 and EA 53, plan and reconstruction (after* Stordeur *et al.* 2000.Figs. 5 and 9*).

Special buildings of the Neolithic Near East

Excavations in recent decades have revealed a very heterogeneous picture for the end of the 10th to 8th millennia BC in the area where the Neolithic emerged: the 'hilly flanks' of the Fertile Crescent, particularly in the so-called 'Golden Triangle' (*Aurenche 2007*).

As early as the Pre-Pottery Neolithic A (PPNA, *c.* 9600–8500 BC), several 'special buildings' with round or oval ground plans were already present, for example, in Göbekli Tepe near Şanlıurfa (*Schmidt 2006; 2007; 2011*) and Jerf el Ahmar in Northern Syria (*Stordeur* et al. *2000*) (Figs 1–2). Comparable complexes with somewhat smaller dimensions were also present at the site of Gusir (*Karul 2011*). Departing from this nomenclature, Klaus Schmidt (*2006*) uses the term 'temple' for the complexes in Göbekli Tepe (*cf.* critical commentaries by *Banning 2011; Bernbeck 2013*).

The circular structures in Göbekli Tepe (*Schmidt 2011*) measure as much as 15m in diameter. Characteristic installations include benches located at the walls, and T-shaped pillars reaching up to 5m in height and grouped in concentric rows around a central pair of pillars. The surface of the pillars is decorated in flat relief displaying animals or abstract symbols. Stylised arms and hands render some pillars as anthropomorphic beings. Totem-like, round stone images complete the imagery. Dwellings at sites like Nemrik (*Kozłowski 2002*) and Quermez Dere (*Watkins 1990*) display similar features, with two rectangular pillars, erected in pisé technique and plastered, standing in the centre of the building.

In the course of development, at the latest as of the mid Pre-Pottery Neolithic B (PPNB, *c.* 8500–7300 BC), the ground plans of buildings became rectangular, a change that is also seen in domestic buildings. Corresponding to this development are later buildings in Göbekli Tepe (*e.g.*, the 'lion pillar building'; *Schmidt 2007.84*), the so-called 'cult building' in Nevalı Çori (*Hauptmann 1993*) and several special buildings in Çayönü (*Schirmer 1983; Özdoğan 1999; Erim-Özdoğan 2011*). In the PPNB, three special buildings are known in Çayönü alone: the 'terrazzo building', the 'skull building' and the 'flagstone building'. They differ distinctly from the domestic storage buildings (*Sicker-Akman 2007; Biçakcı 2001*) with regard to their size, ground plans, monumentality, construction and technology (*i.e.* terrazzo floor) as well as inventory. They were evidently not utilised for storage, or as dwellings or working places. Wulf Schirmer (*1983*) already presumed a ritualistic or representative function of these buildings. The walls of the oldest phase of the 'skull building' in Çayönü have an oval to circular course and, thus relate to older building forms of the PPNA. Consider-

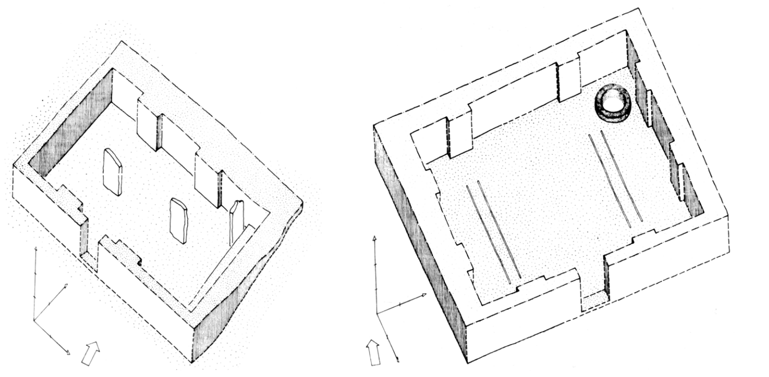

Fig. 3. Çayönü: isometric reconstruction of the 'flagstone building' (left) and the 'terrazzo building' (right) (after **Schirmer 1990.Figs. 11 and 13*).***

in the tradition of the complexes in Göbekli Tepe (Figs. 5–6).

Many of the 'special buildings' were rebuilt several times, a feature that points to their long-term use. Various clues, such as the superimposition of one building upon another, the undamaged ground plan, the blocked doors and the addition of mud bricks, as well as the remains of certain, indicative objects in the buildings, allow the assumption of an 'interment' of the building itself (*Özdoğan, Özdoğan 1998*). In the end, the complexes at Göbekli Tepe were filled up (*Schmidt 2006*). Furthermore, no later structures were erected on these sites quite deliberately, which is probably the main reason for their good state of preservation. Viewed all together, building these complexes involved an enormous expenditure of labour. Estimates of this vary greatly: Banning (*2011. 633*) considers that pillars were created and erected by a few tens of individuals, whereas Schmidt (*2006*) believes larger groups were involved, who were needed to produce and transport the T-pillars. Whether or not the building activities were controlled by an 'elite', this supposition has not yet been verified by the building process itself (*Kurapkat 2009*). Through the collaborative erection of 'special buildings' – without doubt a basic characteristic of the process – their dimensions and interior equipment could have been achieved. After the end of the PPN, no continued construction of special buildings is recognisable. Evidently, the rituals of foragers and hunters lost significance with the establishment of Neolithic life, and thus their symbols and practices gradually disappeared.

ing the skulls and bones of more than 450 individuals that were brought there over a longer time span, the 'skull building' was presumably a site for the preparation and repository of the dead. The function of the 'terrazzo' and the 'flagstone building' has still not been clarified. Two stone stelae stand in the centre of the 'flagstone building' in Çayönü. In Nevalı Çori, also in the PPNB, is a corresponding building that differs from the other buildings in the settlement in having an almost square ground plan (*Hauptmann 1993; 1999*). Two monumental T-shaped pillars stand in its centre, while smaller T-shaped pillars are aligned along the interior wall (Figs. 3–4).

A tradition of such 'special buildings' can be traced back to the 10th millennium BC. Hence, in the area of the origins of the Neolithic in Upper Mesopotamia, special buildings had been in existence since the beginning of the PPN, buildings that differed in almost all respects from domestic architecture and which in no case were constructed as dwellings or places of work. Namely, until now, no domestic objects or hearths have been found in these peculiar structures. Instead, their special furnishings include sculpture, reliefs or painting.

Recently Edward B. Banning (*2011*) concluded that complexes A–F in Göbekli Tepe were not special buildings, arguing that the site consists almost exclusively of such structures. However, Banning did not take into consideration that 'special buildings', whose appearance resemble those in Göbekli Tepe, have been found alongside domestic architecture at several other sites. The 'skull building' in Çayönü surely was not used for domestic purposes, and the 'flagstone building' in Çayönü and the so-called 'cult building' in Nevalı Çori display features that differ distinctly from those of domestic architecture and, thus, as far as architecture is concerned, they stand

Central Anatolia

The Neolithic in central Anatolian Çatal Höyük presents a completely different image as far as settlement type, architectural traditions, artefact assemblages *etc*. are concerned (*Mellaart 1967; Hodder 2006; 2012*). Compared to Upper Mesopotamia, the differences are found in both the material culture as well as in cult practices (*Hauptmann 2002*). Contrary to the many buildings designated 'shrine' or 'sanctuary' by the first excavator, James Mellaart (*1967*), no special buildings like those found in Upper Mesopotamia can be distinguished in Çatal Höyük (*Hodder 2005; 2006*). This negative context could of course be due to the choice of the excavation area,

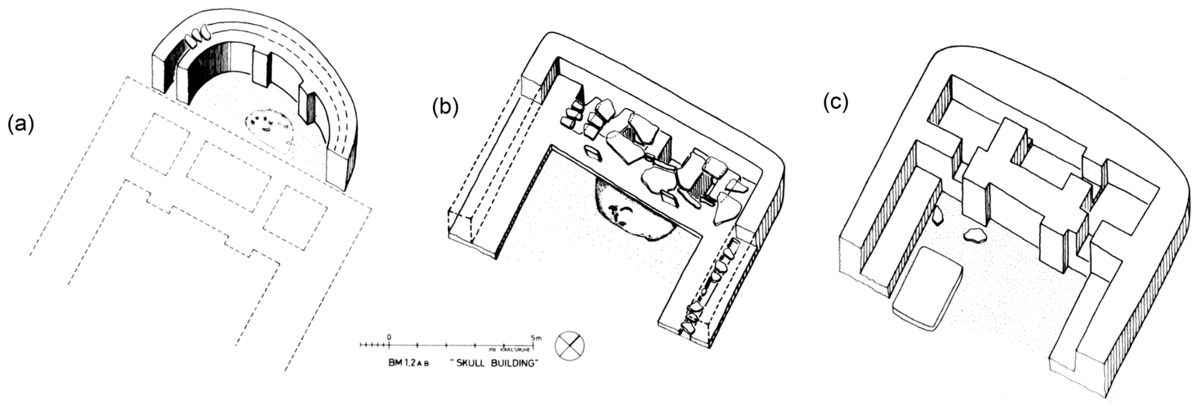

Fig. 4. Çayönü: isometric reconstruction of the 'skull building' with earlier (a) and later (b, c) phases (after* Schirmer 1990.Fig. 12*).

in which no special buildings were located, or for chronological reasons, since the Çatal Höyük site dates mainly to the 7th millennium BC (Fig. 7).

Evidence that such special structures were built in Central Anatolia was supplied by building 'T' in Aşıklı Höyük, a quadrangular structure (*Esin, Harmankaya 1999; Özbaşaran 2012*). In view of the building's furnishings, the floor – a mixture of the local native tuff with water and an overlying layer of red clay – is reminiscent of the 'terrazzo building' in Çayönü and the 'cult building' in Nevalı Çori. But this is the only thing that can be considered to be of a symbolic nature (*Özbaşaran 2012.140*), whereas a canal within building 'T' resembles features known from the site at Musular, some 350m west of Aşıklı (*Özbaşaran* et al. *2012.160*). Building 'A' at Musular and building 'T' from Aşıklı seem to be related to economic activities, *i.e.* the butchering of game animals.

The buildings in Çatal Höyük which Mellaart designated as 'shrines', contain wall paintings, bucrania and other decorative plastic figures, and also functioned as dwellings or work areas (*Hodder 2006; 2012; Hodder, Cessford 2004*). The individual structures appear as independent economic units, with spaces for preparing food, for storage and for producing artefacts such as stone tools, and even for storing raw materials. Furthermore, the dimensions of mud bricks used for the buildings differ from house to house, which leads to the conclusion that every house had its own moulds for making mud bricks and that bricks were produced individually for each building project; so self-reliance as compared to other households is also illustrated by the use of mud bricks.

Based on various factors, Ian Hodder interprets the wall paintings, relief decoration and figurines in the rooms as short-term ornamentation of the rooms undertaken on the occasion of specific rituals that were of importance to the household. Namely, numerous superimposed layers of painting and plaster were detected in some buildings, which show that the interior walls were frequently plastered anew, and that the wall paintings were visible for only a relatively short time of a few weeks or months before being painted over (*Hodder 2006*). These activities could have related to initiation rites for young men, in which a hunt was undertaken and then portrayed in images. 'Dangerous parts' of the animals, for example, the bull's skull, were attached for a short time to the wall in commemoration. One important indication that these hunts were primarily of ritual or social significance is the fact that the wild animals depicted were not essential to the community's subsistence, or played only a secondary role as a source of food. Thus far, there is no evidence in Çatal Höyük for the ritual cremation of buildings, a topic often debated in research (*Twiss* et al. *2008*).

Possible differences or even features for categorising construction forms as in the Upper Mesopotamian PPN cannot be determined in Central Anatolia. An institutionalised cult that was practised in a distinctive building, as evidenced by special buildings in Upper Mesopotamia, is not present in Anatolia.

'Cult buildings' and 'temples' in Southeast Europe

Considering criteria and arguments presented to justify the designations 'temple', 'cult building' or 'sanctuary' for the sites of Căscioarele (*Dumitreşcu 1970*), Kormadin (*Jovanović 1991*), Madžari (*Sanev 1988*), Mramor (*Jovčevska 1993*), Nea Nikomedea (*Rutkowski 1986*), Parţa (*Lazarovici* et al. *2001*), Vésztő-Mágor (*Hegedűs, Makkay 1990*), Vrbjanska

Čuka (*Kitanovski* et al. *1990*), Zelenikovo (*Garašanin, Bilbija 1988*), Zorlenţu Mare (*Lazarovici, Lazarovici 2006*) and Zuniver (*Jovčevska 2006*), several common aspects become evident. The arguments proffered are: the dimensions of the feature, its central position within the settlement, wall decorations, interior furnishings and the inventory, in association with burials or the use of fire during the 'burial' of the building. At the Dolnoslav site near Plovdiv (*Radunčeva 1991; 2003*) almost every dwelling has been described and classified as a sanctuary.

The type and manner of argumentation occasionally eludes scientific discourse entirely: Ljubinka Babović (*2006.3*), for example, writes that all the buildings at Lepenski Vir should be designated as sanctuaries, solely because stone was utilised as building material, a durable material that would also be a symbol for eternity.

In a critical valuation of buildings from the Southeast European Neolithic and Chalcolithic designated as sanctuaries, the human component – the striving towards discovering and presenting something extraordinary – must not be neglected. Finally, it is noteworthy that in some areas, 'sanctuaries' appear with particular frequency (*e.g.*, in Macedonia: Madžari, Mramor, Vrbjanska Čuka, Zelenikovo, Zuniver), or they are always discovered by certain scholars or their students; whereas in other areas, by contrast, 'sanctuaries' seem to be absent. Such a bias stands in the way of a neutral analysis of find contexts.

In addition, it has to be pointed out that almost every author dealing with the assumed 'sanctuaries' or 'cult buildings' at the southeast European sites mentioned above quote Mellaart's publication on Çatal Höyük (*Mellaart 1967*). Mellaart's ideas about 'shrines' in Çatal Höyük exerted a wide influence. Meanwhile, the aforementioned re-evaluation of Mellaart's 'shrines' puts all these considerations into question.

Position in settlements

Borislav Jovanović (*1991*) argues that sanctuaries were consistently erected in the centre of settlements. This would then explain why no sanctuaries have been found hitherto in settlements like Vinča or Gomolava, despite large-scale excavation areas there: namely, the excavated surfaces lay outside the settlement's centre. According to the excavators, the sanctuaries at Parţa were located in the centre of the settlement (*Lazarovici* et al. *2001.204*). Nicolae Ursulescu (*2001*) also positions sanctuaries in the centre of the settlement. Similar statements have been made about the site of Gălăţui Movila Berzei (*Lazarovici, Lazarovici 2006.533*) and Cucuteni settlements (*Lazarovici, Lazarovici 2007.228; 2008*). Thus, not all the authors define what and where the centre of a settlement actually was. Is it the centre of the built area of the settlement, the most densely constructed area, or the highest point of the built area, as in tell settlements?

Concluding the centre of a settlement at the place of the supposed sanctuary's location is circular reasoning that should be avoided. As has already been demonstrated, many special buildings of the PPNB stood on the periphery of settlements, that is, at a distance from dwellings and work areas.

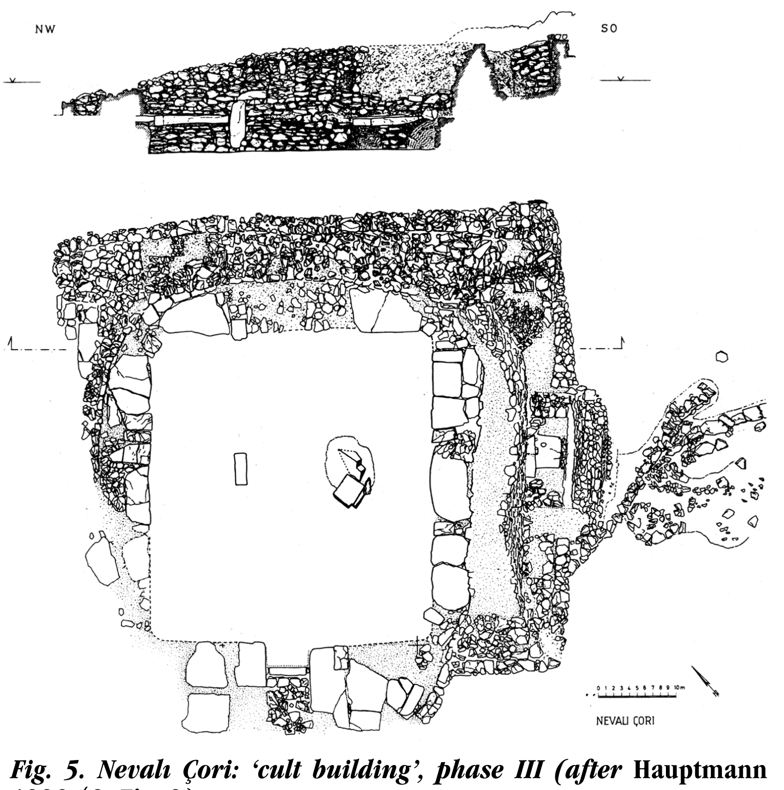

Fig. 5. Nevalı Çori: 'cult building', phase III (after* Hauptmann 1993.49, Fig. 9*).

Dimensions of buildings

That a dwelling has a larger ground plan does not necessarily mean it has a different function; its greater dimensions could have had other reasons, such as more occupants. The ascription of two buildings in Parţa as sanctuaries is supposedly proven by their dimensions ('Sanctuary 1': 12.6 x 7m; 'Sanctuary 2': 11.6 x 6m) and architecture (*Lazarovici 1989.149; Lazarovici* et al. *2001.204*). However, other buildings in Parţa are identical in construction (*Lazarovici* et al. *2001; Lazarovici, Lazarovici 2006.217*). A similar argument was made for the 'shrine' in Nea Nikomedia (*Rutkowski 1986.155–157*). With dimensions of 11.8 x 13.6m, this structure was relatively larger than the surrounding buildings ('structure 1+2'; *Pyke 1996.45, Tab. 3.1*); it stood out among the other houses mainly because of its fully revealed ground plan. However, the context of the ground plans of 'structure 1+2' (*Pyke 1996.22*) was rather unclear. The construction and layout of the 12 x 12m dwelling at Vrbjanska Čuka (*Kitanovski* et al. *1990*) still awaits publication.

Hence, if another, different purpose is assumed for the building, religious use would become merely one possibility among others. For instance, a building with a bigger surface area could also have served as an assembly hall or chief's house.

The classification of a building as a cult structure on the basis of its dimensions is hardly acceptable as a criterion. The supposed 'temple' in Madžari (*Sanev 1988.29*) does not differ in size from other structures; the same applies to house 4 designated as sanctuary in Zorlenţu Mare (*Lazarovici, Lazarovici 2006.155*). In Kormadin, Jovanović (*1991.120*) confirms that there is no evidence for any special construction or a larger size of the 'sanctuary'.

Interior furnishings and inventory

In most cases, these buildings could not be distinguished from other houses in the settlement on the basis of their architecture. Their identification as a 'sanctuary' is based exclusively upon the finds (Fig. 8).

Various aspects of the interior furnishings or the inventory were interpreted by the excavators as indicative of cult practices inside the building:

- clay boxes with incised decoration have been interpreted as 'cult' or 'libation' tables (House 1 in Kormadin; 'Sanctuary 2' in Parţa);
- the finds of several figurines (the 'shrine' in Nea Nikomedia). The Precucuteni 'sanctuaries' from Isaiia, Poduri and Sabatinovka (*Lazarovici, Lazarovici 2006.561–566*). This kind of argument has been produced equally for the 'shrine' of Höyücek/SW-Turkey (*Duru, Umurtak 2005*);
- models of a house found within the building (*e.g.*, in Căscioarele; Madžari; Vésztő–Mágor);
- the existence of bull-skulls and -horns (*e.g.*, in Kormadin; Parţa). In Parţa, raised applications of a stylised human face and a bull skull as well as a sickle-shaped clay application around a hole in the wall led the excavator to assume that this building served as a temple (*Lazarovici 1998; Lazarovici* et al. *2001.204–241*). The head of a large figurine is mentioned from Zorlenţu Mare house 4 (*Lazarovici, Lazarovici 2006.153*).

The examples listed above elucidate the problems of identifying cult buildings through the inventory. In this regard, the terminology employed is worth noting: pedestals are termed 'altars' or 'offering tables' (Parţa), and hearths are reinterpreted as 'offering tables' (Madžari). The 'offering table' found in Zelenikovo was later changed into a 'hearth', when the 'sanctuary' was rebuilt into a dwelling. A quadrangular basin (2 x 2m) in 'cult building' in Vrbjanska Čuka (*Kitanovski* et al. *1990*) has been declared an 'altar'.

'Cult objects' found upon a table or bench in a corner of the (cult)room in Nea Nikomedia are submitted as evidence of a sanctuary (*Rutkowski 1986*).

The decoration of the walls through painting or plastic applications, likewise a frequent criterion indicative of a 'cult building', is a general element of buildings in the Southeast European Neolithic and Chalcolithic periods (*Lichter 1993.48–49*). Çatal Höyük has clearly demonstrated that wall paintings or plastic applications are quite common features. One should keep in mind that the archaeological record rests mainly on the conditions of preservation and that wall paintings are documented at many sites in Europe (*Fries-Knoblach 2009*).

Burials, single human bones in buildings or graves which are associated with the erection or use of a building have also been proposed as evidence of a particular structure's cultic purpose. Yet, burials in settlements or within houses are a phenomenon attested in many prehistoric cultures and are not evidence of the special function of a building (*cf.* in general *Veit 1992*; for Southeast Europe *cf. Lichter 2001;* for Macedonia *Naumov 2007; 2013.81– 86*).

The burnt building H2b–11 in the late Neolithic layers (*c.* 4900–4800 BC) at Uivar display several peculiarities which, compared to other buildings at the site, suggest that this structure had a special function (*Schier 2006; Draşovean, Schier 2010.176*). Aside from compartments separated by approx. 0.5m high

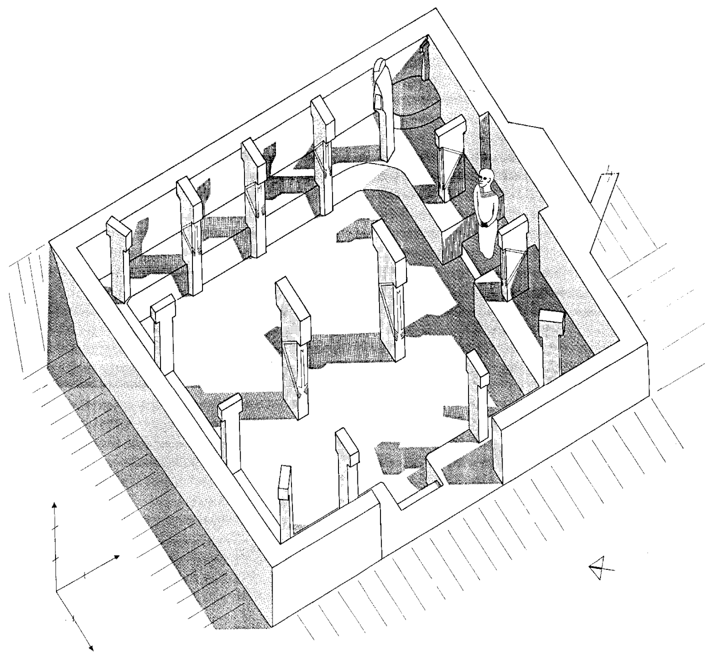

Fig. 6. Nevalı Çori: isometric reconstruction of the 'cult building' (*Badisches Landesmuseum 2007.32*).

cult objects displayed traces of use. These were not (passive) ornaments, but objects whose use lay outside food production or other aspects of daily life. It can be discerned from the countless fragments that these objects were produced in great numbers, used and then discarded. Although knowledge about Neolithic cult practices remains nonetheless relatively limited, one observation should be underscored: many of the 'cult objects' are attested in settlements, in houses, partition walls inside houses, but mostly in waste pits. This would indicate – according to Bánffy – that Neolithic cults were enacted in domestic surroundings and were not communal activities in a sanctuary (*Bánffy 2001. 209–217*). This context accords largely with the finds of clay figurines in Nevalı Çori (*Hauptmann 1993; Morsch 2002*), where almost all of the figurine fragments were found near storage structures in the spaces between houses or in the houses themselves, but always in the context of discarded material. By contrast, clay figurines are absent in the area of the cult building in Nevalı Çori, with its large-sized stone sculpture and anthropomorphic T-pillars (*Hauptmann, Schmidt 2007*). From this observation, a different function and meaning can be inferred for figurines, on one hand, and for large sculpture on the other, at least in Nevalı Çori (*Hansen 2001; 2007*). Whereas the latter was limited to so-called special buildings, obviously erected for cultic purposes, clay figurines are found in domestic settings. Similarly, numerous figurines and fragments of figurines were found in buildings in Çatal Höyük, further confirming that rituals and cult were practised solely in the domestic sphere. Special buildings meant for religious practices have not been attested there thus far. Hence, the presence of figurines is not evidence of a special building; in fact, quite the opposite.

mud walls on the eastern wall, there are several hearths/oven complexes that left little space for household activities. Peculiarities in the interior furnishings (a non-functional footed vessel, a tortoise shell, a bucranium made of clay) also distinguish this building from the others. The structure is further distinguished by a large empty space on the south side. A better evaluation of the find contexts must await the final publication on this building, which has been published hitherto only in one preliminary report. The excavator intentionally avoids addressing the building as a 'sanctuary'. As it is a two-storey structure, the confined space caused by the compartments and hearths (which might belong to different phases of use) need not be surprising, for other activities could have taken place in the upper storey.

These few examples suffice to demonstrate the difficulties at hand when argumentation is based on interior furnishings and inventory. In view of the 'cult objects' found inside them, structures have been interpreted as a 'temple' or 'cult building'. In reverse, some objects have been declared 'sacred' because they were discovered in 'cult buildings': a classic example of circular reasoning. Finally, the use of the these objects in cult practices should first be investigated and attested for every culture before the question is pursued as to whether or not a building was actually a place for cult practises (Fig. 9).

Referring to some examples from the Carpathian Basin, Eszter Bánffy (*2001*) could show that so-called

This also applies to figural vessels which appear in a domestic context (*Schwarzberg 2011*).

The situation is similar with regard to house models. Janos Makkay (*1971*) denoted some examples as models of sanctuaries, which he considered in turn were proof of the existence of these sacred structures. Makkay's line of reasoning is still followed (*Lazarovici, Lazarovici 2008; 2010*). But according to the archaeological record, this opinion can no longer be upheld (*Trenner 2010*). Goce Naumov (*2013.86*) has suggested, that anthropomorphic house models should be seen as representative of individuals buried inside or near a house.

Grind stones, storage vessels, loom weights, sling stones and ovens found in supposed 'sanctuaries' in Southeast Europe document the fact that these can hardly be differentiated from other structures. Commentaries about cultic grinding or symbolic looms cannot be followed (*Lazarovici 1989.150–151; Lazarovici, Lazarovici 2006.540–541*). 'Cult tables', figurines and bucrania found in house 2 in Kormadin imply that not only practical and economic dealings (residing, food preparation, grain storage, production of implements and textiles *etc.*), but also religious acts were performed in the domestic sphere. Some other houses of the Vinča culture sustain this interpretation (*Chapman 1981.66; Stevanović, Tringham 1997.198*) and the site at Crkvine (*Crnobrnja, Simić and Janković 2009; Crnobrnja 2010*) demonstrates once more quite clearly, that figurines and bucrania form part of the standard inventory of Vinča culture houses. Naumov stated recently (*2013.78*) that the existence of sanctuaries cannot be confirmed for the settlements in Macedonia, since unequivocal traces of ritual activity are absent.

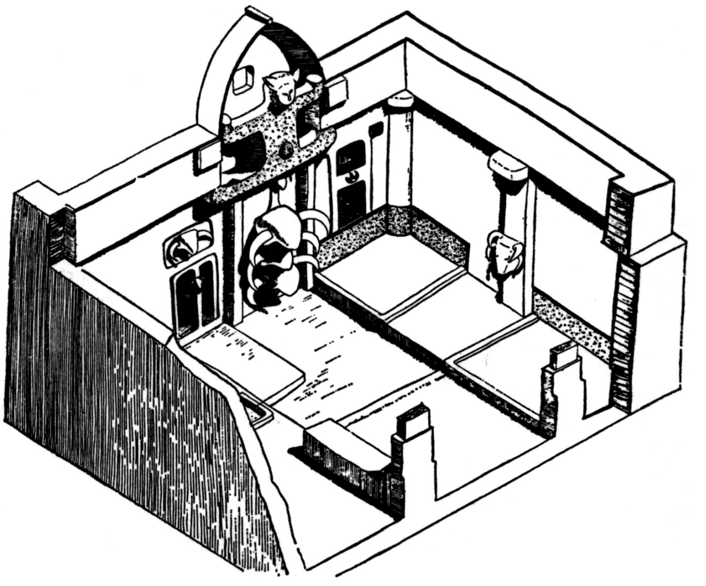

Fig. 7. Çatal Höyük: reconstruction of 'shrine' VIB 10 (after **Mellaart 1967.150, Abb. 38*).***

Burnt house remains

The severely burnt house remains often observed in tell settlements have been viewed by various authors as resulting from deliberate destruction (*Chapman 1999; Stevanović 1997; Stevanović, Tringham 1997; Tringham 2005*). According to their view, the construction, habitation and destruction of a house should be part of a constantly repeated process. Houses can catch fire for many reasons: aside from unfortunate accidents, the cause could be violent conflict or measures taken to destroy pests or fungi, among others. An interpretation that sees a deliberate symbolic act behind the burnt buildings of the Neolithic and Chalcolithic is not necessarily correct.

As evidence for this, experiments were evaluated (*e.g., Gheorghiu 2007; 2010*) in which a conflagration accidentally started in a Neolithic or Copper Age building and continued without any intensifying measures (*e.g.*, adding more combustible or flammable material, making holes in the walls or roof). The fire did not reach high temperatures nor have the disastrous effects that have often been observed in find contexts. There is some doubt about the conclusions reached through these experiments. Namely, the flammable properties of experimentally erected buildings with a relatively short duration doubtlessly differed from buildings which fell to flames only after several years or even decades. A counter-example was the documented conflagration of an Iron Age building in Lejre, Denmark (*Rasmussen 2007*), where, after approximately one hour, temperatures were measured that exceeded 1200°C. As shown by the documentation, the conflagration progressed with no additional propellants and no fuel. Furthermore, the chaff present in the building material of many Chalcolithic houses in the Balkans has not been taken into account as fuel for the fire (*Hansen, Toderaş 2010.101*).

For Okolište, it has to be considered that, in some cases after houses have been burnt a different spatial arrangement of dwellings has been recognised, but in other cases, house areas were abandoned. However, not every new spatial arrangement or abandonment can be linked to a preceding burning horizon, which strengthens the case against ritualistic razing at the end of their lifecycle (*Hofmann 2013.375*).

Furthermore, it has to be considered that identifying dwellings that are not burnt is much more difficult than identifying burnt dwellings. Therefore, dwellings that were not burnt are underrepresented in the archaeological record.

Only 5% of the buildings in Uivar were destroyed by fire, indicating that the supposed ritual of house burning was a very selective practice at most (*Schier 2006.330*). Numerous burnt houses were found in all of the layers at the tell settlement of Polgár-Csőszhalom on the remains of which new houses had been constructed. In contrast, among the 79 buildings in the flat settlement, which did not differ in size or ground plan from those on the tell site, not a single burnt house was discovered (*Raczky, Anders 2010.149*). The examples mentioned clearly demonstrate that the concept of the 'burned house horizon' (*Stevanović 1997; Tringham 2005*) does not concur with the archaeological record.

With regard to the finds, the furnishings of buildings on the tell site at Polgár-Csőszhalom were only slightly better (grind stone with hematite, miniature vessel, figurine, fragment of Spondylus), a situation that could also have been due to conflagration. Burnt mud and wood architecture can remain in an excellent state of preservation and, thus, can provide special contextual conditions, such as conserved wall decorations or a preserved house inventory. A particular feature of the 'sanctuaries' in Parţa, Madžari and Kormadin is their extraordinary preservation due to fire. Yet the attribution of a special function to these buildings does not seem justified.

Special buildings which stand out in appearance among the dwellings in Southeast Europe through their dimensions, furnishings or inventory alone and, therefore, would warrant the designation 'sanctuary', 'cult building' or 'temple', have not been observed. Instead, it has a lot to prove that within the dwellings, aside from their use as habitation and for economic purposes, cult activities were practised there as well.

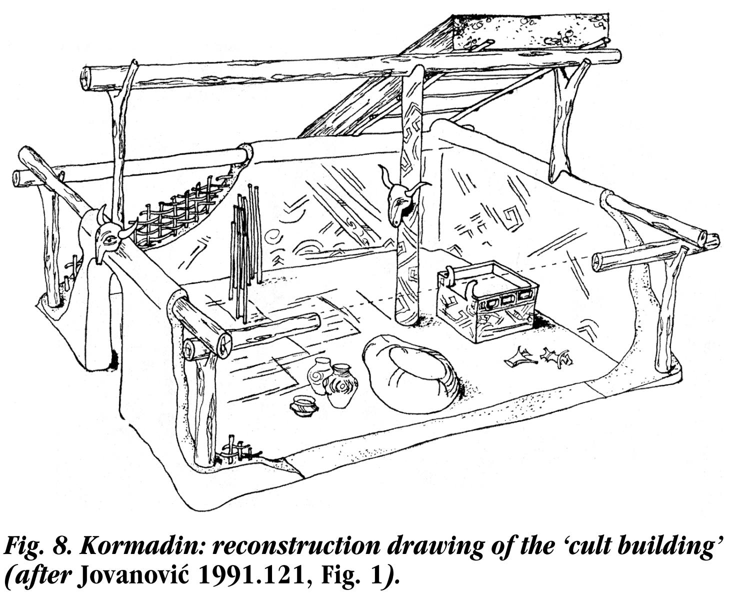

Fig. 8. Kormadin: reconstruction drawing of the 'cult building' (after* Jovanović 1991.121, Fig. 1*).

Some records from Central Europe can be explained in a similar way, such as the house wall decorated with painting and reliefs in Ludwigshafen-Seehalde (Southern Germany), dated to the 39th century BC (*Schlichtherle 2006*). With no preliminary sketching, the painting was executed in white lime in one course of the interior walls of a house dated to the 39th century BC; integrated into this were four to five pairs of breasts modelled in relief. The decorative repertoire consists of lines, dots and spaces filled with circles or semi-circular motifs, M-motifs, triangles and cross-hatching. A similar wall decoration is known, for instance, from the settlement site of Sipplingen-Osthafen. Corresponding reliefs of clay breasts are known at other sites dating from the second half of the 5th and first half of the 4th millennium BC in south-western Germany and Switzerland (*Schlichtherle 2010.273*). The brief application of the painting in Ludwigshafen-Seehalde contradicts any permanence and, therefore, should be seen instead as a sign of a temporally limited action. Preserved by a disastrous conflagration, the wall covering does not supply any arguments in favour of the building's exclusive use for religious practices.

A house of the Cortaillod culture (*c.* 3500 BC) discovered in Marin-Les-Piécettes (Lac de Neuchâtel, Switzerland) stood in the centre of the settlement on an earth platform approx. 1m high. The structure cannot be linked to any religious function, as suggested by the excavator (*Honegger 2007*).

Based on a few indications, Jens Lüning (*2009*) interprets the north-western part of the Linear Pottery Culture (LPC) houses of Central Europe (5500–4950 BC) as a space in which domestic ancestors were worshipped. The archaeological record of a house found in Nieder-Mörlen (Hessen) seems to reveal that the north-west part of the building opens onto a palisade circle (diameter 30m), which according to Lüning supposedly enclosed an earth mound in the LPC period; several thousand years later, this mound was allegedly still visible, a circumstance that led to the installation of a burial in the centre of the LPC mound during the Iron Age. This hitherto singular find context, as well as other contexts of LPC houses connected with concentric or rectangular rows of posts, were interpreted by Lüning as LPC cult structures. He further assumes – based on the rarity of such contexts – that the structure served the entire settlement and even beyond. Finally, the cultic use of the complex in Nieder-Mörlen, whose contemporaneity with the long house is hard to confirm reliably, remains conjectural, like the structure's 'responsibility' for the entire settlement.

Conclusion and outlook

Buildings that were dedicated exclusively to religious practices and which differ from the other buildings through their ground plan, construction and furnishings have not been evidenced for the Neolithic and Chalcolithic periods in Southeast Europe. Instead, there are many indications that religious ceremonies, among others, were performed in normal dwellings, which might have been decorated and arranged on certain occasions.

With the dissemination of the Neolithic in the 7th millennium BC, institutionalised cultic activities practiced in the Neolithic core area – and with them, special buildings constructed for this purpose – lost their significance. Therefore, no 'special buildings' are known yet outside the Neolithic core area; with the end of the PPN at the close of the 8th millennium BC and at the start of the 7th millennium BC, their traces even disappeared in the heartland. Evidently, the significance of clan structure for social unity had declined, and with it, the communal construction of special buildings and rituals practiced in them. In their place appeared small family units or families, for whom, as independent and separate economic units, other forms of solidarity were important. Thenceforward, not only economic, but also religious activities were practiced at the level of individual households.

Considered further, consequently, the existence or absence of special buildings reflect the different social orders and social structures of the societies inside and outside the Neolithic core area: within the core area large units existed, presumably organised in clans, whereas in areas neolithisised later (*i.e.* during the 7th millennium BC), there existed small families who were economically independent of one another.

In view of questions pertaining to the process of Neolithisation, the differences that were noted in cult practices between the origins of the Neolithic and further areas of its dissemination are of unquestionable importance. Namely, they contradict the notion of a massive immigration of Neolithic settlers from the original heartland, and can instead indicate the passing down of Neolithic traditions through exchange networks and cultural spheres. The 'arhythmic distribution model' (*Guilaine 2007*) is much more suited to these observations and can better explain the common features discernible over vast distribution areas, rather than the 'wave-of-advance' model (*Ammermann, Cavalli-Sforza 1984*).

With regard to special buildings, the somewhat evolutionist idea according to which sanctuaries are a sign of a culture of higher standing at the end of a development, and basically of a later date, should be discarded. In early times in the Near East, the core area of the Neolithic, the 'land of plenty' (*Gebauer, Price 1992.8*), it was possible for a larger community to sustain itself over a longer period of time at one location, a situation that favoured and fostered the emergence of large settlements. The cohesiveness of these large settlements was secured through, among other things, the erection and use of special buildings. Outside the Neolithic heartland, environmental conditions favouring such large settlements were not present, which consequently required other social solutions for the success of the Neolithic mode of production. Therefore, institutionalised cults in the form of communally constructed, special buildings in settlements are not attested outside the Neolithic core area. With regard to some Copper Age contexts in Southeast Europe, it appears that a few houses stood in an elevated position, but there is no evidence that these were cult buildings; perhaps these houses can be attributed to the rise of elites.

Considering developments, for instance, in the Near East as of the 5th millennium BC, then at first glance astonishing associations become perceptible. The institution of the 'temple' – institutionalised

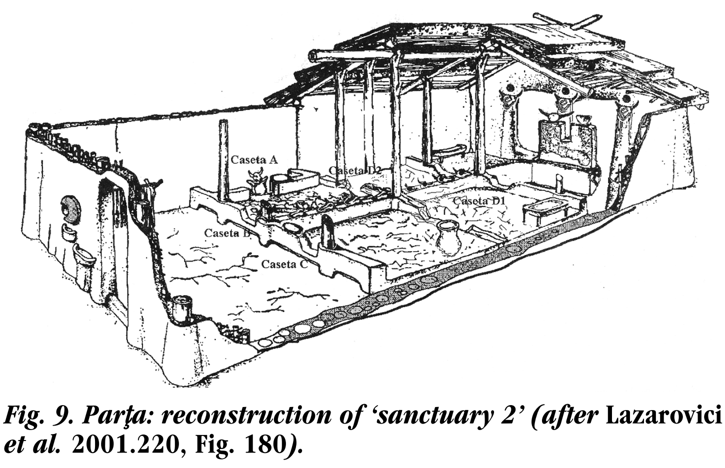

Fig. 9. Parţa: reconstruction of 'sanctuary 2' (after* Lazarovici *et al.* 2001.220, Fig. 180*).

cult – forms the core of civilisation, and with that the starting point of urban cultures in Mesopotamia or also the formation of states (*Roaf 2013*). Comparable developments took place in other areas much later. In view of these observations, one is tempted to seek the causes for this development in the differences in cultic practices that were already present in the Early Neolithic, and to view cult buildings of the Near Eastern aceramic Neolithic as forerunners of later monumental temple complexes in the Syro-Mesopotamian sphere (*Özdoğan, Özdoğan 1998*). Special buildings of the PPN might be the archaeological record for a mentality comparable with the conceptual mindscape which separates the religious from the profane (*cf.* critical remarks in *Bernbeck 2013*). This division, however, did not exist beyond the Neolithic core area at that time. In order to confirm this assumption, the gap in the contexts of special buildings that still persists between the 7th and 5th millennium BC must be filled. Also to be considered is the fact that the social structures in the background differed greatly, but that is another story.

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Simulating cultural transmission: preliminary results and their implications for the study of the formal variability of material culture in the Central Balkan Neolithic

Marko Porčić, Miloš Nešić
Department of Archaeology, Faculty of Philosophy, University of Belgrade, RS
mporcic@f.bg.ac.rs

ABSTRACT – *In this paper, we adopt the theoretical framework of evolutionary archaeology in order to model and simulate cultural transmission between hypothetical Neolithic sites in Balkans. We simulate neutral cultural transmission in order to compare the simulation results with empirically observed patterns of material culture variability such as traditional archaeological cultures. Our preliminary results show that a series of random local interactions can result in spatial groupings of typologically similar assemblages that correspond to the spatial distributions of traditional archaeological cultures, even in the absence of any other 'external' factor such as an overarching regional political structure or shared collective identity.*

IZVLEČEK – *V članku prevzemamo teoretski okvir evolucionistične arheologije, da bi modelirali in simulirali kulturni prenos med hipotetičnimi neolitskimi najdišči na Balkanu. Simuliramo nevtralen kulturni prenos, da bi primerjali rezultate simulacije z empirično ugotovljenimi vzorci spremenljivosti materialne kulture, ki jih tradicionalno imenujemo arheološke kulture. Preliminarni rezultati kažejo, da ima niz naključnih lokalnih interakcij lahko za posledico prostorsko grozdenje tipološko podobnih zbirov, ki ustrezajo prostorski razporeditvi tradicionalnih arheoloških kultur, celo v odsotnosti kakršnihkoli 'zunanjih' dejavnikov, kot so krovni okvirji regionalnih političnih struktur ali skupne kolektivne identitete.*

KEY WORDS – *evolutionary archaeology; cultural transmission: archaeological culture; Neolithic; Balkans; simulation*

Introduction

In Neolithic research, as in any other research, great effort is invested in looking for patterns. However, the search for patterns is only the first step. The final aim is to account for these patterns in terms of the historical and anthropological dynamics that produced them. The standard procedure in science is to propose an explanation (hypothesis), derive the empirical implications (expectations) from this hypothesis, and then compare these expectations to the actual empirical situation. Our hypotheses about the past are often about complex processes, and archaeological data are equally complex, so it is difficult to explore the implications of our hypotheses without the aid of some formal method. One possible approach to this problem involves attempts to 'recreate' the past by constructing a model related to some aspects of the past and then exploring the behaviour of the model and its output by computer simulation (*Lake 2014*). For example, geneticists have simulated genetic effects related to different scenarios of Neolithisation (*e.g., François* et al. *2010*) in order to see which scenario would produce contemporary genetic patterns in space as revealed by Cavalli-Sforza's seminal research (*Cavalli-Sforza 2001*). Archaeologists have simulated the demographic dynamics of the spread of the Neolithic in order to account for patterns related to radiocarbon and settlement evidence (*e.g., Fort* et al. *2012; Lemmen* et al. *2011*).

From an epistemological perspective, the simulation approach enables archaeologists to do what is gene-

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rally very difficult in social sciences and utterly impossible for historical disciplines: to approximate the experimental method by 'repeating' different versions of history and observing the outcomes (*Grüne-Yanoff, Weirich 2010; Lake 2014*).

However, what makes simulation studies possible is the theoretical framework. For example, genetic simulation models are constructed using concepts and principles of population genetics theory, and demographic simulations are based on demographic theory, which provides the conceptual framework and mathematical models of population dynamics. But what about the formal variability of material culture, which is the traditional domain of archaeology? The issue of style has been the central issue of the traditional culture-historical approach, which is still the dominant school of thought in many academic communities, especially in Southeastern Europe. In the traditional approach, variability in form was divided into entities called archaeological cultures; these entities were both patterns and explanations at the same time, because they were based on an essentialist view of archaeological cultures as direct reflections of collective identities: ethnic, linguistic, political (or even racial) (*Hodder 1982.2–12; Shennan 1994*). But regardless of the fact that such traditional culture-historical explanations are outdated, the problem remains: how can we account for the formal variability of material culture in time and space (for the most recent and thoughtful discussion of this problem, see papers in Roberts and Vander Linden (*2011*))? Just as there are genetic and demographic patterns, there are also patterns of formal variability of material culture. So, is there a theory, other than traditional culture-historical theory, that can provide a suitable framework for translating hypotheses about the workings of past societies into formal models whose properties and implications can be investigated by means of computer simulations and then compared to patterns of material culture variability observed in the archaeological record?

Evolutionary theory of culture – a new framework for an old problem

The evolutionary theory of culture or cultural transmission theory, a relatively recent development in the history of archaeological thought, is a paradigm that provides the intellectual and analytical tools to translate the patterns of formal variation of material culture in time and space into meaningful and anthropologically relevant statements about the past (*Lipo 2001; O'Brien, Lyman 2000; 2003; Shennan 2002; 2011*). It is based on an evolutionary theory of culture that views culture as an evolutionary process (*Boyd, Richerson 1985; Cavalli-Sforza, Feldman 1981; Mesoudi 2011; Mesoudi* et al. *2006; Richerson, Boyd 2005; Shennan 2002; 2011*). The evolutionary view of culture allows different classes of material culture to be treated as different hereditary systems, thus enabling the analyst to infer the nature and trajectory of cultural transmission and its underlying behavioural and social basis. This kind of analysis has the potential to tackle the most intriguing questions about the anthropological and historical reality that lies behind the archaeological record (*e.g., Bentley, Shennan 2003; Bettinger, Eerkens 1999; Gray, Atkinson 2003; Gray, Jordan 2000; Jordan, Shennan 2003; Lipo 2001; Lipo* et al. *1997; Lycett 2007; Neiman 1995; Tehrani, Collard 2002; Tehrani* et al. *2010*).

In this theory, culture is conceptualised as a population phenomenon: each domain of culture can be characterised by a frequency distribution of traits. These traits are culturally transmitted in a process that is analogous in some degree to the transfer of genes (*Henrich* et al. *2008*). Changes in frequencies of cultural traits are governed by the forces of cultural evolution, such as drift or various forms of selection (*Boyd, Richerson 1985; Richerson, Boyd 2005*). This means that attributes, types and assemblages can be thought of as the results of various cultural transmission processes operating at different scales (*cf. Clarke 1968*).

A growing number of simulation studies investigate the properties and implications of different transmission models in time and space (*e.g., Crema* et al. *2014; Lipo* et al. *1997; Premo, Scholnick 2011; White 2013*). These studies are of great theoretical and methodological importance. In this paper, we aim to make a link between abstract models from cultural transmission theory and the specific context of the Central Balkan Neolithic.

Models of cultural transmission

There are several basic transmission models in evolutionary theory of culture (*Boyd, Richerson 1985; Richerson, Boyd 2005; Shennan 2002*). These models tell us how a frequency of a trait will behave in time if it is transmitted in a certain way. One of the most important models in evolutionary archaeology is the neutral model of cultural transmission (*Bentley, Shennan 2003; Eerkens, Lipo 2005; Kohler* et al. *2004; Neiman 1995; Premo, Scholnick 2011;*

Shennan, Wilkinson 2001; Steele et al. *2010*). The neutral model assumes a random copying of cultural traits in a population. This can be illustrated, for example, by a group of potters randomly copying patterns of vessel ornamentation from one another (Fig. 1). Initially, each potter decorates a bowl with a distinctive motif. After some time, equal to the average use-life of bowls, each vessel from the set is broken and deposited, and each potter creates a new vessel by randomly deciding how to decorate each new bowl. Potters can choose a pattern of ornamentation for each new bowl from the previous generation of bowls or they can introduce a completely new motif (*i.e.* new to this community of potters) either by intention or by error of perception with an associated probability (μ), which is analogous to the mutation concept in biology. Following Neiman, the probability of mutation (μ) can be broken down into two components $\mu = \nu + m$ (*Neiman 1995.17*), where *m* is the probability that the new variant will be introduced from another community and ν is the probability that a completely new variant will be introduced.

It should be emphasised that in cultural contexts the neutral model does not have to be necessarily interpreted in such a way that individuals copy traits (*e.g.*, pottery decoration motifs) completely at random. Individual choices can be and often are idiosyncratic and have a meaning for the individual making the choice, but as long as the aggregate result of these individual choices is such that the probability of copying for each trait depends only on its current frequency in the population (*e.g.*, corresponding to the simple interpretation of the model presented above), the transmission process is effectively random (*Shennan 2011.1073*).

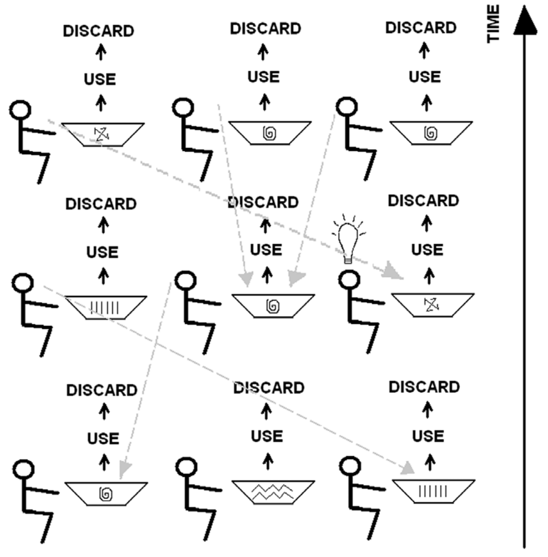

Fig. 1. Illustration of the neutral model of cultural transmission (after* Porčić in press.Fig. 1*).

In general, if the transmission is not neutral, it is biased in some manner. There are various forms of biased transmission. For example, the conformist bias is one such model; it can be illustrated by many examples where people show a tendency to conform by choosing the most common cultural trait in the population, ranging from religious beliefs to choosing a hair style or clothing style. In conformist transmission, there is an additional probability (degree of conformism) that an entity will copy the most frequent variant in the population. However, this preliminary report is limited to the simulation of the neutral model.

Research aims, questions and hypotheses

The general idea of this paper is to illustrate how cultural transmission models for the Neolithic of the Central Balkans can be translated into computer simulations. The aim is to make a simulation of cultural transmission that enables the analyst to answer theoretical, methodological and empirical questions related to the patterns of formal variability of material culture in the Central Balkans. This project is ongoing, and in this paper we present only preliminary solutions and preliminary results. Due to its incompleteness and lack of suitable empirical data for rigorous testing, this paper should be viewed only as an illustration of the potential of the simulation approach grounded in the evolutionary theory of culture. Specifically, we address two questions in this study:

❶ Can simulations produce patterns that resemble the empirical patterns of formal variability of material culture in the Central Balkan Neolithic? Our hypothesis is that the neutral model of transmission coupled with the specifics of Balkan topography is sufficient to produce patterns of typological similarity observed in the archaeological record. If correct, this hypothesis would imply that there is no need to invoke collective identity explanations (such as ethnic, linguistic or political) to explain the observed empirical patterns in the distribution of pottery styles.

❷ Should we expect the geographical distance to be strongly correlated with typological distance if the probability of interactions between sites is determined by their spatial distance? A recent empirical study of Iroquian pottery demonstrated that geographical distance had little effect on pottery similarity

(*Hart 2012*). John P. Hart (*2012*) found that the geographical distance explained a relatively small amount of inter-assemblage typological variance. We use the simulation to see whether the neutral transmission, which is often used as underlying model for the evolution of style (*Cochrane 2001; Dunnell 1978; Lipo* et al. *1997; Neiman 1995*), can produce such a result.

The simulation

Geographical set-up

The starting point for all simulations is a set of virtual sites generated on a topographical map of Central and Western Balkans (Fig. 2). We chose computer-generated site locations instead of real site locations because of the unequal and biased research history in Balkans, which makes current data about the spatial distribution of Neolithic sites unreliable. Site locations are chosen according to the most general Neolithic settlement criteria (*e.g.*, low altitude, flat terrain, proximity to water). In total, 100 sites were generated in this simulation. When site locations are chosen, the computer calculates the least cost path (LCP) distance between each pair of sites and stores these distances in the LCP distance matrix.

Sites properties and virtual material culture assemblage

The material culture assemblage for each site is modelled as a vector of integers, each element of the vector representing a certain variant of that particular material culture class. These vector elements will be referred to as entities. Entities may carry different variants (*i.e.* have different integer values); this can be interpreted as, for example, different ceramic bowl shapes or different decorative motifs. The size of the material culture assemblage (N) is 100 entities for each site. The variants which entities carry are culturally transmitted.

Modeling cultural transmission

For the purpose of this preliminary report, we simulate only the neutral model of cultural transmission. The simulation of the neutral model is based on the standard algorithm presented in the literature (*Bentley* et al. *2004; 2007; Bentley, Shennan 2003; Crema* et al. *2014; Neiman 1995*).

For each site, in each iteration, and for each entity, the computer generates a random number between 0 and 1, and based on the generated value, the entity chooses between three options:

❶ If a random number falls between μ and 1, the entity will randomly copy a variant from another entity from its own site, including itself, with the probability of a particular variant being copied equal to its current relative frequency in the assemblage.

❷ If the random number falls between 0 to ν, the entity will generate a completely new (to the entire simulation universe) variant.

❸ If the random number falls between ν and μ (being equal to $m = \mu - \nu$, see below) an entity will copy a variant from another site. The probability of each site being chosen as the source of the new variant is proportional to its LCP distance from the focal site. When the site to be copied from is chosen, a variant to be copied is chosen randomly from the cultural assemblage of that site.

Simulation procedure and output

The computer records the assemblage structure (*i.e.* the relative frequency of variants) for each site for each iteration. Each iteration corresponds to one cultural generation, because if entities are interpreted as ceramic bowls, then one simulation time step is

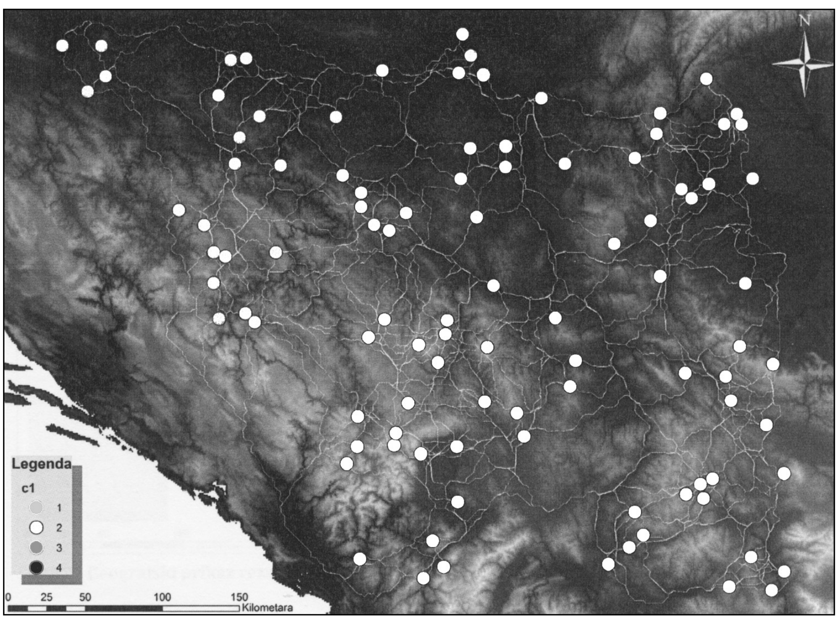

Fig. 2. Spatial distribution of virtual sites in the Central Balkans.

equal to the bowl's use-life, assuming that a broken bowl needs to be replaced with a new bowl and that the making of the new bowl involves the choice of the variant of the bowl shape or bowl decoration. For this reason, simulation iteration can be interpreted as corresponding to roughly one year, because this is close to the median use-life of serving pottery vessels, as the survey of the ethnoarchaeological literature shows (*Mills 1989; Varien, Mills 1997*). A simulation runs for 1000 iterations. Given the fact that archaeological site assemblages are not snapshots in time, but time-averaged, accumulated assemblages (*Bailey 2007*), the output of the simulation consists of matrices where sites are in rows and columns give the frequencies of variants accumulated in the last 200 iterations.

Cultural scenarios

In this paper, we present only two simple scenarios:

❶ The Low Interaction scenario. All sites start with identical assemblages with maximum diversity (each entity has a different variant). Cultural transmission is based on the neutral model with the following parameters: $m = 0.1$, $\nu = 0.01$.

❷ The High Interaction scenario. All sites start with identical assemblages with maximum diversity (each entity has a different variant). Cultural transmission is based on the neutral model with the following parameters: $m = 0.4$, $\nu = 0.01$

Methods of analysis

Comparing simulation results to the archaeological record

Ideally, we would make a direct comparison of simulation results with the archaeological record by examining a correlation between the typological distance matrix produced by the simulation and the observed typological distance matrix based on archaeological data. However, the appropriate quantitative archaeological data is not available. This would also require simulated site positions to correspond to real site positions, which is not the case here.

For this reason, we attempt to make only an indirect and very rough comparison of simulated and real-world patterns using the traditional concept of archaeological culture as defined by Gordon Childe (*1929*) and formalised by David Clarke (*1968*). Childe defined cultures in this way: "*We find certain types of remains – pots, implements, ornaments, burial rites and house forms – constantly recurring together. Such a complex of associated traits we shall call a 'cultural group' or just a 'culture'. We assume that such a complex is the material expression of what today we would call 'a people'*" (*Childe 1929.v–vi*).

Clarke gave a formal version of this definition[1]: "*A polythetic set of specific and comprehensive artefact-type categories which consistently recur together in assemblages within a limited geographical area*" (*Clarke 1968.188*).

The implication of Clarke's formalisation is that archaeological cultures are equivalent to statistical groups (*e.g.*, clusters resulting from cluster analysis). Culture historians have defined archaeological cultures as groups of sites sharing many types of material culture, with pottery usually being the most important class of material culture considered. The difference between cluster analysis and the traditional culture-historical approach is that definitions of traditional archaeological cultures are based on researchers' subjective evaluations of similarities between assemblages. However, it is not unreasonable to assume that traditional cultures, despite the informal and subjective methodology used to define them, capture some of the main trends of spatial and temporal variability of material culture. It should be emphasised that our use of archaeological cultures as proxies for the patterns of material culture variability in space does not mean that we consider archaeological cultures as real anthropological and historical phenomena; we use them only as a proxy in the absence of quantitative data on the distribution of material culture.

So, in order to make our simulation results comparable to the distribution of archaeological cultures, we performed a cluster analysis on the assemblages using variant frequencies as variables. For frequency data, Euclidean distance matrix was calculated based on variant percentages in assemblages. Ward's method was used as a clustering algorithm on variant percentage data (assemblages in rows, individual variant percentages in columns). The number of clusters is equated with the number of major archaeological cultures (4) in the study area: Vinča, Butmir, So-

1 Childe was aware of the polythetic nature of archaeological cultures but his aim was to disregard types that were associated with more than one culture (*Shennan 1994.13*).

pot-Lengyel, Tisza (Fig. 3). We have no simulated sites in the Adriatic area, so we did not anticipate the existence of clusters corresponding to the Danilo and Hvar-Lisičići cultures. Given that both scenarios start with identical assemblages, the initial conditions are broadly comparable to the Early Neolithic in the Central Balkans, where only two major cultural groups are distinguished: Starčevo-Körös-Criş and Impresso group (*Benac 1979*). Since there are no sites in an area corresponding to the Impresso culture, the fact that all virtual sites have the same assemblage crudely mimics the relative uniformity of material culture in the Early Neolithic in the Central Balkans in the first half of the 6th millenium BC. The end of the simulation occurs 1000 iterations later, accumulating the variant frequencies from the last 200 iterations. The end of the simulation would roughly correspond to the first half of the 5th millennium BC, which is the period of the Late Neolithic in Central Balkans.

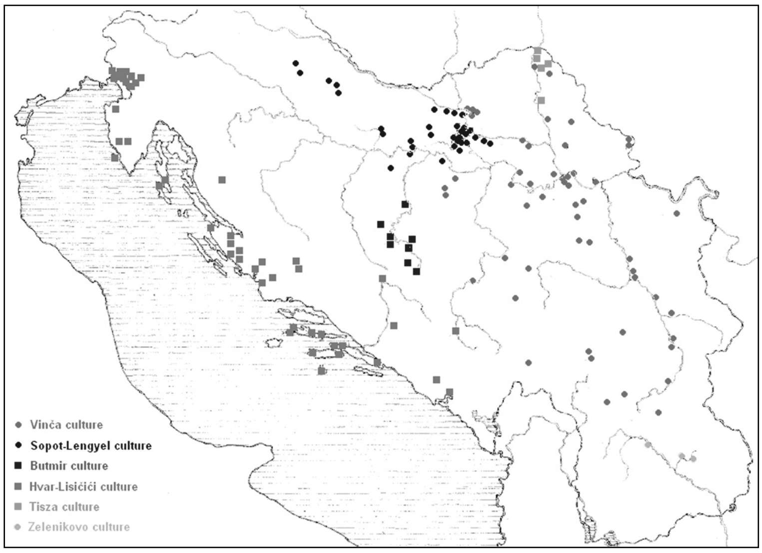

Fig. 3. Distribution of traditional archaeological cultures in the Late Neolithic of the Central Balkans (based on maps of archaeological cultures in* Benac 1979*).

The results of cluster analyses were presented visually by plotting the sites coded for the cluster membership on the study area map. In this way, we can visually explore whether clusters based on typological similarity are spatially grouped in a similar way to traditionally defined archaeological cultures.

Given that the cluster analysis may yield different solutions for different distance measures, clustering algorithms and the number of clusters, we also perform a correspondence analysis (CA) on the simulation output data matrix. CA reduces the dimensionality of the complete data matrix and the first CA axis accounts for the greatest amount of variance in the multi-dimensional data. Each site is then colour coded for its value on the first CA axis, with the colours of the spectrum corresponding to CA axis 1 score values, and the sites coded in such a way are plotted on the geographical space. In this way, we can visually explore the main trends in similarity and dissimilarity of assemblages without the intervening step of grouping them into clusters.

Is there a correlation between geographical and typological distances?

We answered this question by performing Mantel's matrix correlation test (*Mantel 1967*) on the matrix of LCP distances and the matrix of typological distances based on type frequencies. We also tested for the correlation between typological distances based on the Jaccard distance measure and LCP geographical distances. The Jaccard distance measure

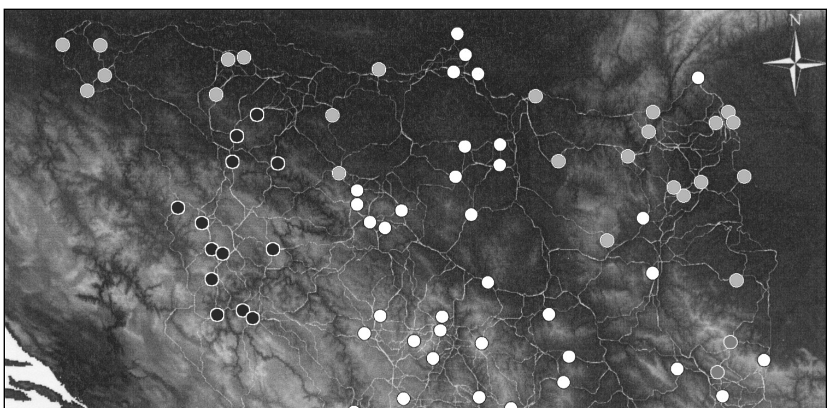

Fig. 4. Simulation results for the Low Interaction scenario.

is based on the Jaccard similarity coefficient (see below). The intensity and statistical significance of this correlation is also tested by Mantel's matrix correlation test implemented in R.

Results

Patterns of typological similarity between simulated assemblages

Figure 4 shows the results for the Low Interaction scenario cluster analysis. There is a broad correspondence between the spatial patterning of simulated assemblages and the distribution of traditional archaeological cultures. Cluster 2 roughly corresponds to Vinča, cluster 4 to Butmir, Cluster 3 to Zelenikovo (although Zelenikovo is very similar to Vinča), and cluster 1 to Sopot-Lengyel, although it seems to have a discontinuous distribution – it is interrupted by cluster 2 sites in Vojvodina and its distribution then continues in Romania.

Figure 5 shows the plot of site locations with their scores on the first CA axis, which explains 1.9% of total variance (inertia) in the data[2]. There is a gradient of CA axis 1 scores along the southeast-northwest axis. The similarity/dissimilarity pattern in space resembles the distribution of archaeological

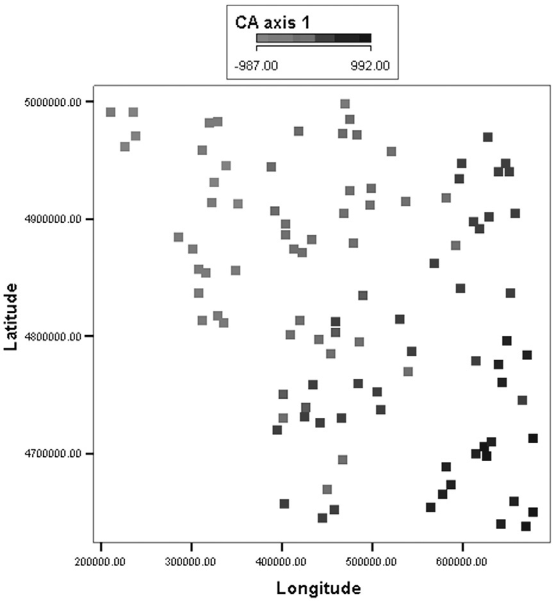

Fig. 5. Plot of simulated assemblages for the Low Interaction scenario in geographical space coded for their score on the first CA axis.

cultures. The group in Romania is clearly different from the group in Eastern Croatia. Bulgarian sites also form a clear group (shown in blue). The differences between Croatian and Bosnian sites are not as pronounced as the cluster analysis would suggest.

Figure 6 shows the results of the High Interaction scenario. In this plot, we recognise only a cluster of sites (Cluster 1) vaguely resembling Vinča culture, but the spatial distribution of other clusters is not that similar to the distribution of archaeological cultures.

Figure 7 shows the plot of site locations with their scores on the first CA axis, which explains 2.05% of total variance (inertia) in the data. Again, there is a gradient of CA axis 1 scores along the southeast-northwest axis.

Correlation of typological and geographical distances

Figure 8 shows the plot of LCP geographical distances and Euclidean typological distances, while Figure 9 shows the plot of LCP and Jaccard typological distances for the Low Interaction scenario; there is a curvilinear relationship between geographical and typological distances. Therefore, we transformed the data by calculating the logarithms of both variables. The correlation is higher for Jaccard distances (Pearson's $r = 0.767$, Mantel test $p < 0.001$) than for Euclidean distances (Pearson's $r = 0.265$, Mantel's test $p < 0.001$).

Figure 10 shows the plot of LCP geographical distances and Euclidean typological distances, while Figure 11 shows the plot of LCP and Jaccard typological distances for the High Interaction scenario. Again, the correlation for log-transformed data is higher for Jaccard distances (Pearson's $r = 0.839$, Mantel test $p < 0.001$) than for Euclidean distances (Pearson's $r = 0.522$, Mantel test $p < 0.001$).

Discussion and conclusions

We have shown that a very simple model of interactions conditioned by distance can produce patterns similar to the spatial distribution of traditionally defined archaeological cultures. This does not mean that the neutral model is the correct model. It only

2 Even though this seems extremely small, it actually does summarize the patterns of covariation of main variants. There are around 20 000 variants in the accumulated assemblage, most of which are mutations with very low frequencies. Since they appear in very low frequency for a short time (usually being lost after the iterations in which they are introduced) they are mostly independent of the high frequency variants. Therefore, many of these variants are accounted by different CA axes thus reducing the percent of inertia explained by the first axis which accounts for a relatively small number of highly frequent variants.

means that this simple model is sufficient as it is to produce patterns that are visually similar to the observed ones, so we do not necessarily need to invoke ethnic identity or some other form of collective identity to account for the observed patterns. It is interesting that the gradient in typological similarity appears to be running in the NW-SE direction, although there is no directional movement or transmission.

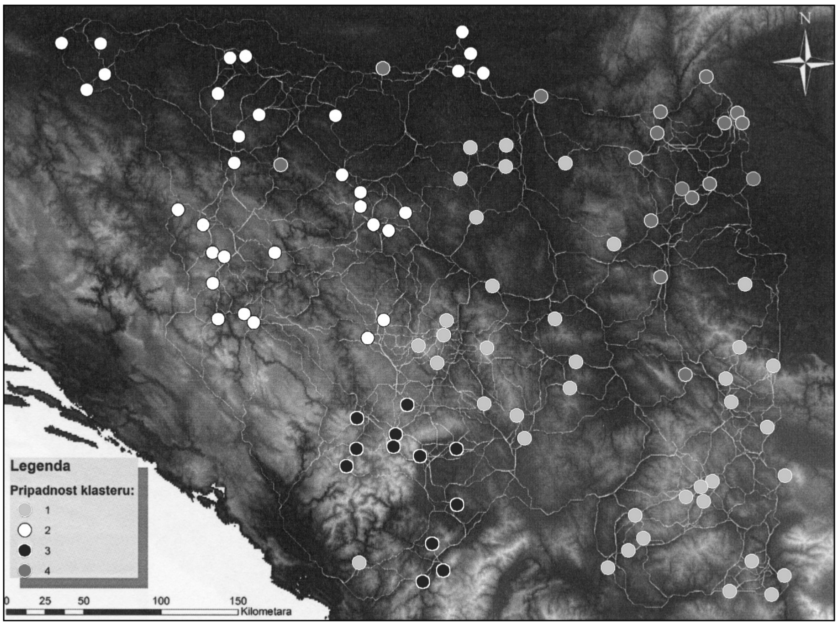

Fig. 6. Simulation results for the High Interaction scenario.

The correlation between geographical and typological distances predictably differs between the High and the Low Interaction scenarios. The High Interaction scenario shows a stronger correlation than the Low Interaction scenario. However, in both scenarios a great amount of typological variance is not accounted for by distance, although the interaction is affected by distance. This means that we should not expect to find a perfect correlation between typological and geographical distances, even if the transmission is affected by distance (*cf. Hart 2012*), because the transmission process also occurs within sites.

It is interesting that the choice of the typological distance measure influences the strength of the correlation between geographical and typological distances. At present, we can only speculate about the reasons for this effect. Our first hypothesis was that this result could be explained by the fact that the Jaccard coefficient is predominantly influenced by joint presences of types. Given that joint presences are dependent primarily on the degree of interaction, which is conditioned by geographical distance, a typological distance measure based only on joint presences will capture mostly variation correlated with geographical distance. This is not the case for Euclidean distance measure which is based on all types: *e.g.*, frequencies of types which are present only in one assemblage and not in the other, such as random innovations, will also enter into the calculation and act as random noise in relation to the signal created by interaction by geographical distance. However, we are not certain that this is the correct explanation, because when the 'city-block' distance metric is used, which is a distance analogue of the Brainerd-Robinson similarity coefficient (*Brainerd 1951; Robinson 1951*), the correlation between typological distances based on the city-block metric and geographical LCP distances for log transformed data are higher than for Euclidean typological distances, but not as high as for the Jaccard coefficient (*e.g.*, for the Low Interactions scenario with city-block distance used: Pearson's $r = 0.556$, $p < 0.001$). As Euclidean distance, the city-block distance also takes into account the frequencies of all types, regardless of whether they are jointly present or absent.

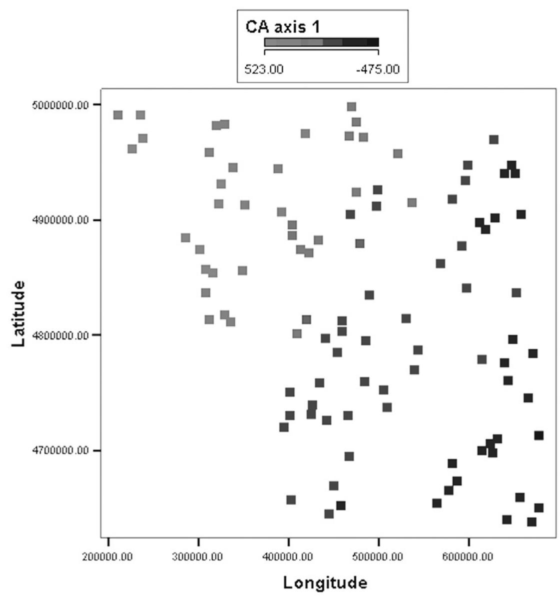

Fig. 7. Plot of simulated assemblages for the High Interaction scenario in geographical space coded for their score on the first CA axis.

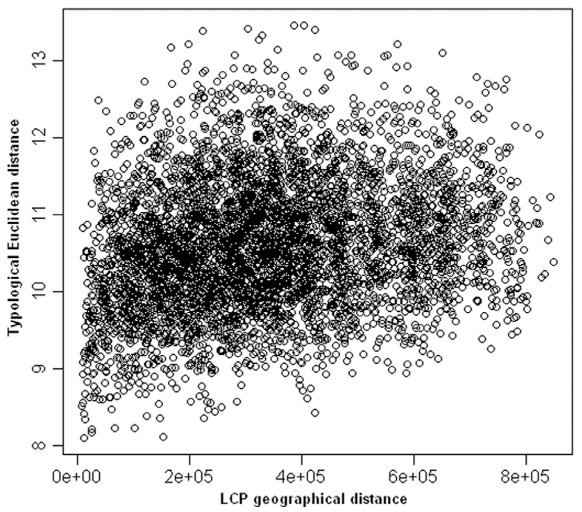

Fig. 8. LCP and typological distances based on Euclidean distance for the Low Interaction scenario.

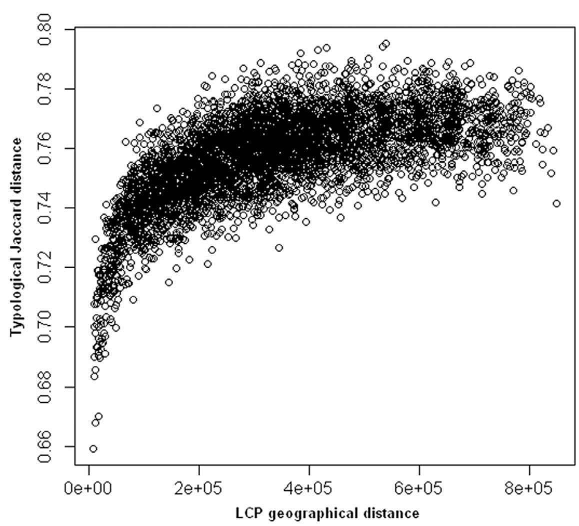

Fig. 9. LCP and typological distances based on the Jaccard distance for the Low Interaction scenario.

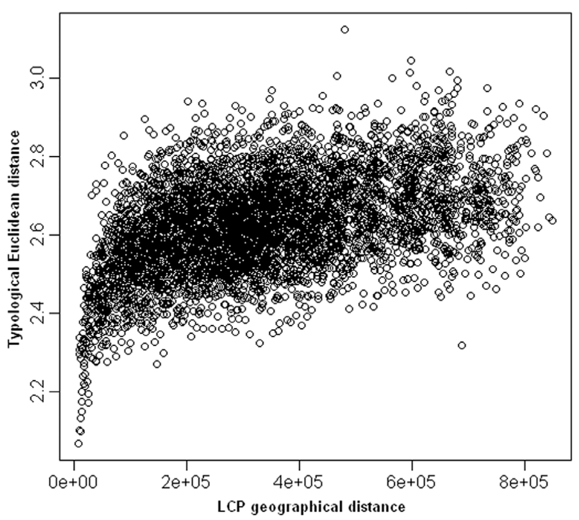

Fig. 10. LCP and typological distances based on Euclidean distance for the High Interaction scenario.

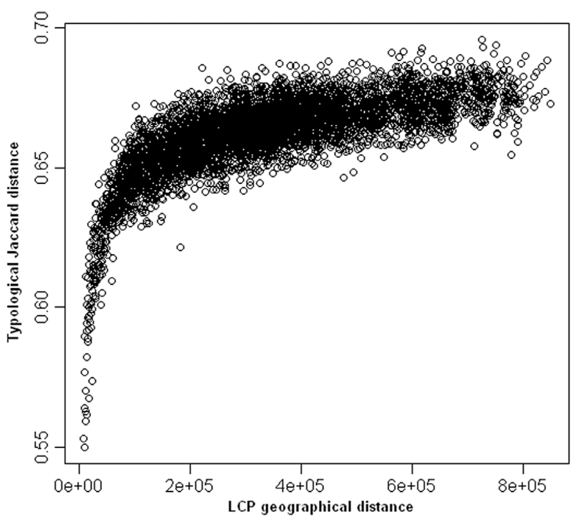

Fig. 11. LCP and typological distances based on the Jaccard distance for the High Interaction scenario.

While the results seem interesting, this project is still 'under construction', so there are many issues that need to be addressed and corrected before the simulation results can be considered relevant. One of the greatest weaknesses of the simulations described above is the lack of demographic dynamics. Demography is a key factor in the process of cultural evolution, as both theoretical work and empirical studies show (*Collard* et al. *2013; Henrich 2004; Shennan 2001; 2013*). So, demographic dynamics needs to be built into the simulation framework – work that is currently in progress.

We simulated only a very simple and general (semi-abstract) model, so our results are interesting only as a methodological exercise at this point. The simulation approach is potentially useful because it allows for more complex and realistic models to be simulated. For example, the model can be made more complex by letting the current similarity between sites affect transmission choices in addition to distance (*cf. Axelrod 1997*), or we could run simulations with several classes of 'material culture' coevolving and interacting. Additionally, spatial interaction can be modeled more flexibly (see *Crema* et al. *2014.292*).

Needless to say, the full potential of simulations will not be fulfilled until empirical work has been done. Typological data from existing archaeological assemblages need to be collected in a systematic way in a form which is compatible with the simulation results. Only then will we be able to test different models and scenarios rigorously.

ACKNOWLEDGEMENTS

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Neolithic and Eneolithic activities inferred from organic residue analysis of pottery from Mala Triglavca, Moverna vas and Ajdovska jama, Slovenia

Lucija Šoberl[1*], Milena Horvat[2], Andreja Žibrat Gašparič[2], Marko Sraka[2], Richard Evershed[1] and Mihael Budja[2]

1 Organic Geochemistry Unit, School of Chemistry, University of Bristol, UK
lucija.soberl@gmail.com
2 Department of Archaeology, Faculty of Arts, University of Ljubljana, SI

ABSTRACT – *The research discussed in this paper focused on the analysis and identification of organic residues either preserved as visible or absorbed organic remains on Neolithic and Eneolithic pottery from various archaeological and geographical contexts. These are connected with various food preparation strategies and past human activities,* i.e. *cave burials in Ajdovska jama (food as a grave good/offering), the rock shelter at Mala Triglavca (meat and dairy animal husbandry practices) and Moverna vas, which had a long occupation sequence (complex farming and animal management). The preservation of biomarkers mirrored past human activities and different pottery uses at various types of sites. The carbon stable isotope ratios of primary fatty acids in lipid pottery extracts confirmed the presence of adipose and dairy fats as well as biomarkers of plant fats, beeswax and birch bark tar.*

IZVLEČEK – *Predstavljeno raziskovalno delo se je osredotočalo na analizo in identifikacijo organskih ostankov na površini neolitske in eneolitske keramike ter ostankov lipidov absorbiranih v keramično matrico vzorcev iz različnih arheoloških in geografskih kontekstov. Ti so povezani z različnimi strategijami priprave hrane in preteklimi človeškimi aktivnostmi – pokopi v Ajdovski jami (hrana kot grobni pridatek), skalni previs Mala Triglavca (mesna in mlekarska živinoreja) ter naselbina Moverna vas z dolgo stratigrafsko sekvenco (kompleksno poljedelstvo in živinoreja). Različne tipe najdišč je bilo mogoče povezati z raznolikimi dejavnostmi in raznoliko uporabo keramičnih posod prek ohranjenih biomarkerjev. Analiza razmerja stabilnih izotopov glavnih maščobnih kislin v keramičnih ekstraktih je potrdila prisotnost mesnih in mlečnih maščob glavnih domestikatov kakor tudi navzočnost lipidnih biomarkerjev rastlinskega izvora, ostanke čebeljega voska in smole.*

KEY WORDS – *Neolithic; Eneolithic; lipid residue analysis; pottery; stable isotopes; birch bark tar; beeswax*

Introduction

Archaeological research has benefited greatly in the past twenty years from an exponential increase in interdisciplinary studies incorporating analytical sciences. Two major fields of archaeological investigation, predominantly in prehistoric periods, have been trying to understand past diets and the mobility of populations by analysing osteological material and ceramics. The porous surface of these two commonly found archaeological artefacts enables organic molecules such as lipids, proteins and nucleic acids to become entrapped and preserved through millennia.

Unglazed pottery has proved to be an ideal analytical medium: on the one hand, it readily absorbs organic compounds during cooking, food storage and consumption, while it also serves as an indicator of past lifestyles, kinship, animal husbandry practices,

* author for correspondence

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agriculture, trade or ritual practices (*Boast 2002; Gibson 2002*). Although organic molecules are prone to degradation processes during pottery use or during the post-depositional period, it has been found that adequate concentrations of lipids can be preserved either as absorbed residues or visible food crusts and retrieved through organic solvent extraction (*Heron, Evershed 1993; Evershed 2008; Craig 2004; Saul* et al. *2013*).

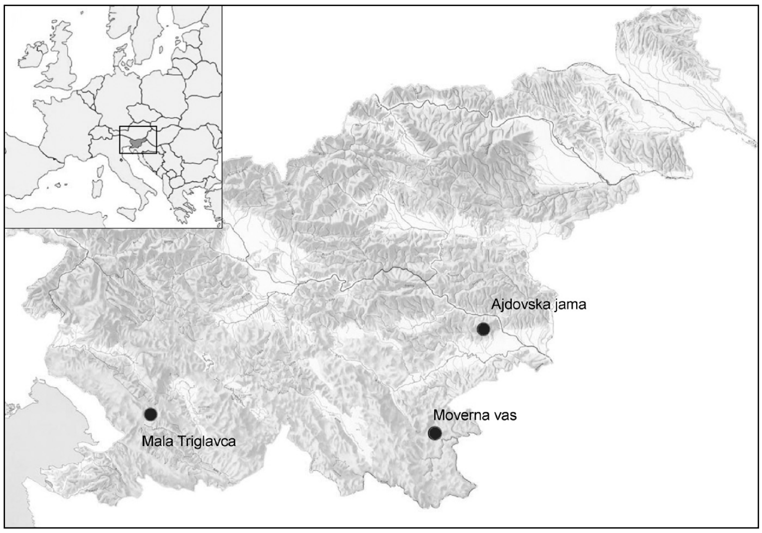


Fig. 1. A map of Slovenia showing the locations of archaeological sites investigated (adapted from National Museum of Slovenia).

Sites selection

Among the various Slovenian Neolithic and Eneolithic sites available, three were chosen for lipids analyses (Fig. 1). The two with the longest settlement sequence, *i.e.* Mala Triglavca and Moverna vas, are embedded in different environmental and cultural contexts. The third, Ajdovska jama, is a burial site with strong evidence of burial ceremonies and rituals.

The Mala Triglavca rock shelter is located on the Dinaric Karst in south-western Slovenia, 15km from the Northern Adriatic coast. The AMS ^{14}C dates show a long sequence of human activities from the 8^{th} to the 3^{rd} millennium calBC, combined with natural and geomorphological post-depositional disturbances. The Moverna vas open-air site is situated in the karstified Bela Krajina region in the south-eastern part of Slovenia. The settlement sequence spans approximately two millennia from the 5^{th} to the 3^{rd} millennium calBC. The Ajdovska jama cave site lies within the catchment of the Sava River in south-eastern Slovenia. The site is well known for its burials. The human remains at the site occurred as distinct clusters of mainly disarticulated bones belonging to at least 31 individuals. The cave was used for burial and related ritual practices in the late 5^{th} and early 4^{th} millennium calBC.

Moverna vas

The Neolithic and Eneolithic settlement sequence at Moverna vas consists of nine settlement phases. Phases 2 to 6 were recognised as Neolithic, and phases 7 to 9 as Eneolithic (*Budja 1989; 1994*). Bayesian modelling (Fig. 2) shows that the sequence spans approximately two millennia, with continuous occupation from 4945–4810 calBC to 4270–4135 calBC and discontinuous occupation until 2905–2800 calBC (at 68.2% probability) with possibly centuries-long breaks in occupation (*Budja 1994; Sraka 2013*). The chronology is largely based on AMS ^{14}C dates from carbonised organic residues adhering to interior pottery surfaces. Chemical analyses of these residues show that they are either charred remains of food

Sample Name	Material	Context	Phase	Lab code	^{14}C Conventional age (BP)	Calibrated age acc. to 68.2% prob. (calBC)	Calibrated age acc. to 95.4% prob. (calBC)	$\Delta^{13}C$ (meas. on AMS)	Reference
23MV	food crust	053.1	3	Poz-21396	5750±40	4450–4350	4460–4335	–24.9±0.5	Sraka 2013.App.
24MV	birch bark tar	050.2	4	Poz-21398	5550±40	4540–4455	4615–4370	–20.6±0.3	Sraka 2013.App.
25MV	birch bark tar	050.1	4	Poz-21399	5630±40	4715–4605	4770–4540	–24.2±0.2	Sraka 2013.App.
26MV	birch bark tar	022.1	5	Poz-21400	5610±40	4940–4805	4995–4785	–24.2±0.6	Sraka 2013.App.
27MV	birch bark tar	050.1	4	Poz-21401	5620±40	4495–4370	4530–4360	–20±0.4	Sraka 2013.App.
28MV	birch bark tar	050.2/056	2	Poz-21402	5990±40	4490–4365	4520–4355	–22.3±0.7	Sraka 2013.App.
29MV	food crust	planum 7	2	Poz-21403	5800±40	4505–4370	4540–4365	–21.6±1.8	Sraka 2013.App.
151MV	birch bark tar	031.4	6	Poz-21404	5670±40	4450–4350	4460–4335	–19.1±0.5	Sraka 2013.App.
152MV	birch bark tar	050.2	4	Poz-21420	5550±40	4680–4545	4705–4500	–22.9±0.5	Sraka 2013.App.

Tab. 1. ^{14}C dates obtained from organic remains on pottery for Moverna vas (see also Fig. 10).

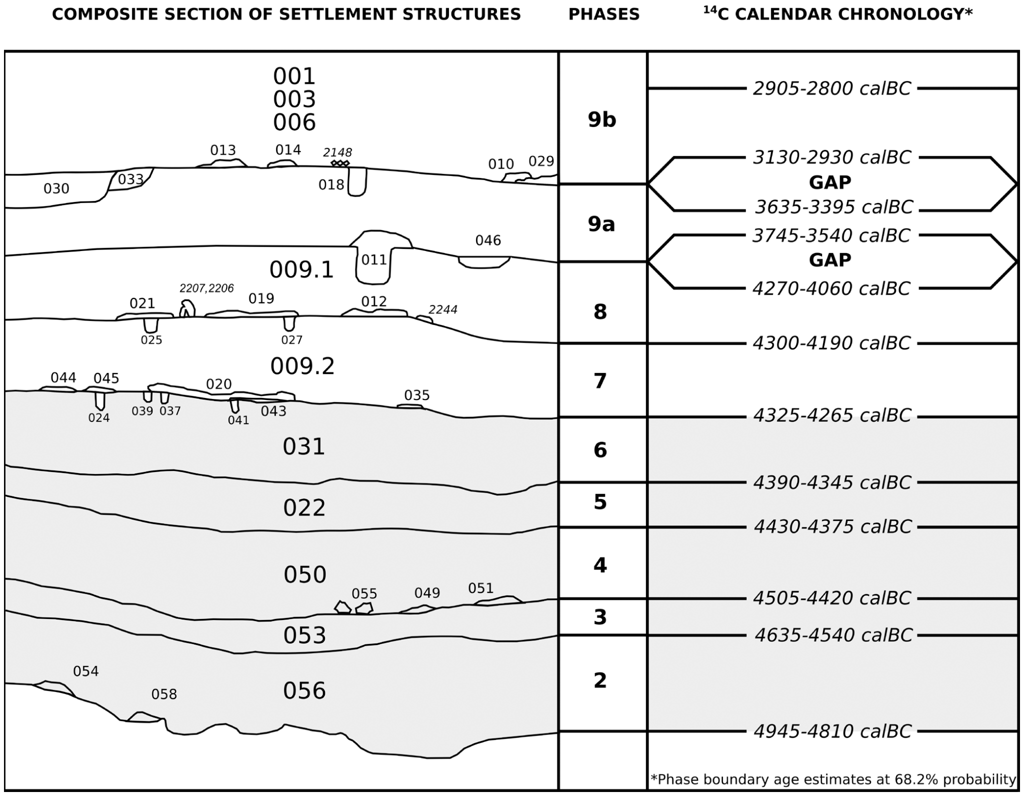


Fig. 2. Moverna vas stratigraphical sequence with Bayesian statistical modelling of radiocarbon dates.

(23MV, 29MV; App. 1; Tab. 1) or birch bark tar (24MV-28MV, 151MV, 152MV; App. 2; Tab. 1; Fig. 10). According to the results of chemical analyses, no freshwater reservoir effect is to be expected for these dates. Both the food crust and birch bark tar samples are considered as reliable samples with minimal inbuilt age (*Hedges* et al. *1992; Oinonen* et al. *2010*).

During the continuous occupation in the 5th millennium, two related changes in 4325–4265 calBC (at 68.2% probability) have been observed. While the transition from Neolithic to Eneolithic vessel types and pottery fabrics was observed in the pottery assemblages (*Tomaž 1997*), the changes in settlement pattern relate to settlement fragmentation and settlement extension within the site-catchment areas, as well as in previously uninhabited areas (*Budja 1995*).

The pottery samples selected for lipid analysis were embedded in Neolithic settlement phases 2 to 6 (*c.* 4945–4265 calBC) (Figs. 2, 4). The ceramic vessels of these settlement phases include various types of pot (Fig. 3.type 4, 5, 6, 8, 9), dishes with spouts (Fig. 3.type 1), pedestal dishes (Fig. 3.type 7), small pots (Fig. 3.type 3), bowls (Fig. 3.type 2), and ladles (Fig. 3.type 10). Most of the pottery was fired in an oxidising atmosphere and well made, with burnished surfaces and red or brown slips applied to the surface. The vessels were made with homogenous clay fabrics and abundant quartz grain inclusions, which in some samples can even be interpreted as added temper (*Tomaž 1997; 1999; Žibrat Gašparič 2008*).

Mala Triglavca

The Neolithic and Eneolithic sequence at the Mala Triglavca rock shelter consists of 23 occupational levels, ranging from *c.* 5600 to 3500 calBC. The lipid analyses of the pottery assemblage, which is comprised mainly of various types of bowls, beakers, dishes and pots have been published (*Šoberl* et al. *2008; Budja* et al. *2013*) and will be used here mainly in relation to other sites in the discussion. The pottery samples were taken from Neolithic occupational levels and can be linked according to their morphology and technology to the Vlaška pottery group (*Barfield 1972; Žibrat Gašparič 2004*). The oldest pottery fragments appear as early as 5616–5525 calBC. For the lipid analysis, we sampled 65 vessels from contexts that range from 5480 to 4261 calBC (68.2% probability). The results indicate an extensive mixing of ruminant and non-ruminant, and ruminant adipose and ruminant dairy fats in individual vessels. In some vessels, the presence of molluscs, crustaceans and freshwater fish was detected. Thirty per cent of the sampled pottery contained lipids characteristic of dairy fats, indicating

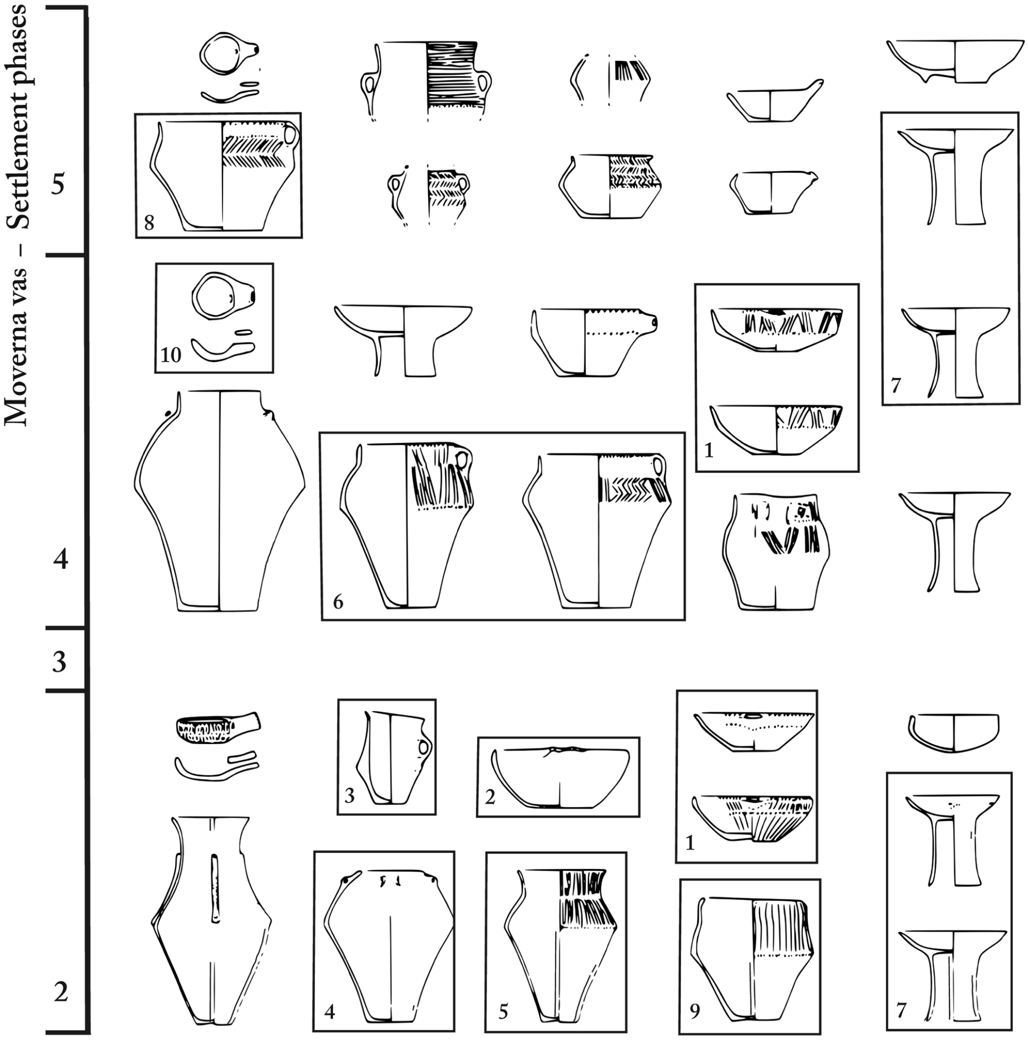


Fig. 3. Moverna vas pottery types represented within the different settlement phases. Types 1–10 were analysed for organic residues. See Appendix 1.

that the processing of dairy products in pottery vessels was quite extensive. The use of dairy products at Mala Triglavca is embedded in the time span between 5467–5227 calBC (for details see *Budja* et al. *2013*).

Ajdovska jama

Excavations in Ajdovska jama proved that the cave was an eminent site at the end of the Neolithic period, with traces of temporary human activity until the High Middle Ages. Ajdovska jama is the funerary site with the oldest excavated burials in Slovenia, and a place where the remains of the dead were worshipped. The cave is also a natural karstic phenomenon, which might have had a symbolic meaning for prehistoric people.

The most typical grave goods of individual groups of burials that were excavated in the central hall and the left corridor included pottery (*i.e.* pot, dish, jug and ladle), jewellery (*i.e.* necklace or bracelet), and tools or weapons (*i.e.* axe, awl). The grave goods were found alongside the bodies of the deceased and prove that rituals were performed at the time of subsequent burials and visits to the cave. Food and meat were also placed beside the bodies as offerings. Analyses of plant and animal remains from the burials showed that cereals (*e.g.*, wheat, barley and a type of bean) and the meat of domestic animals (*i.e.* ovicaprids, cattle) as well as wild animals (*i.e.* rabbit, wild boar, red deer, fox) were cooked (*Horvat 1989*). Additional information on diet came from the analyses of carbon (^{13}C) and nitrogen (^{15}N) isotopes in collagen obtained from human and animal bones. The results show that the people of this community consumed mostly meat and plant protein coming from C_3 dietary source (*Ogrinc, Budja 2005; Bonsall* et al. *2007*). Bayesian chronological modelling of ^{14}C dates provided by Clive Bonsall *et al.* (*2007*) shows that the burials belong to a relatively

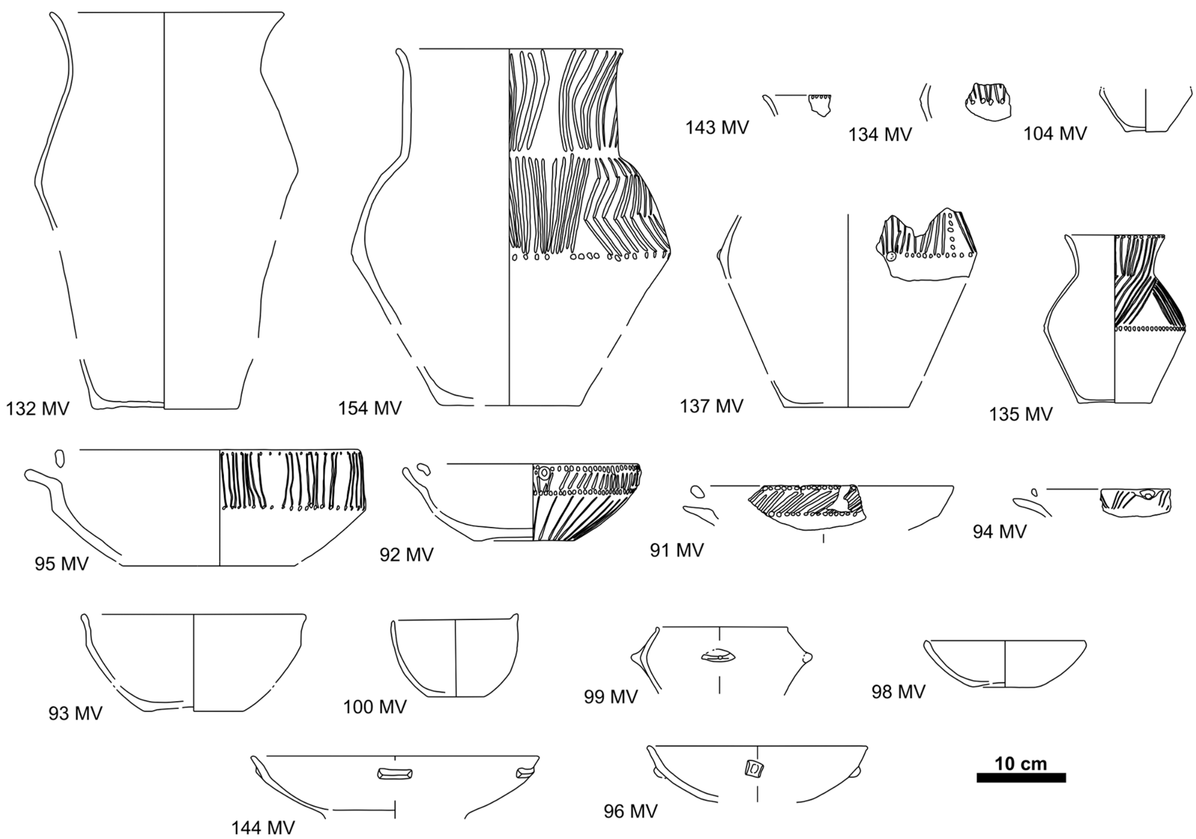


Fig. 4. Vessels from Moverna vas that were analysed for organic residues.

short time interval of a few human generations from 4340–4290 to 4295–4235 calBC (at 68.2% probability).

A collection of 52 pottery samples was selected for lipid residue analysis, including various types of pots, dishes, dishes with spouts, pedestalled vessels, bowls and jugs (Fig. 5). Most of the vessels were fired in an oxidising atmosphere and were made with various fine-grained quartz fabrics (*Horvat 1989; Osterc 1986*).

Organic residue analysis

Cooking and processing organic commodities enables insoluble lipid residues to be absorbed into porous ceramic matrix and preserved for several thousand of years in the form of surface or/and absorbed residues. Cooking vessels have proved to be the most convenient for analysing organic residues due to their constant everyday use and exposure to high temperatures during cooking. However, non-culinary related vessel use can also absorb lipids when fatty commodities are stored: from the use of various sealants to reduce the permeability of the unglazed ceramic surface (resin, tar, pitch, milk and beeswax) and from the use of adhesives to repair broken vessels (*Charters* et al. *1993a; Regert, Rolando 2002; Regert 2004*).

When determining the functionality of pottery, numerous archaeological methods can be employed, including written and pictorial evidence, the use of archaeological contexts, information obtained via ethnographical comparisons, pollen analysis of visible organic remains, use wear analysis and the analysis of preserved contents (*Orton* et al. *1993; Rice 1987; Tite 2008; Skibo, Feinman 1999*). Prudence Rice (*1987*) divided the principle functions of pottery into three categories: (i) storing dry substances; (ii) carrying liquids; and (iii) heating the contents over fire. Direct evidence for storage vessels apart from their larger size is not readily available, cooking pots offer some additional indices, *i.e.* carbonised visible remains adhering to outer or inner pot surfaces and signs of sooting.

Chemistry offers interpretative tools for use in cases with a complete absence or selective preservation of organic and biological remains, such as osteological assemblages or plant remains; or for activities that are archaeologically difficult to trace, such as beekeeping. The primary focus of lipid research in the past 20 years has been to identify various biomar-

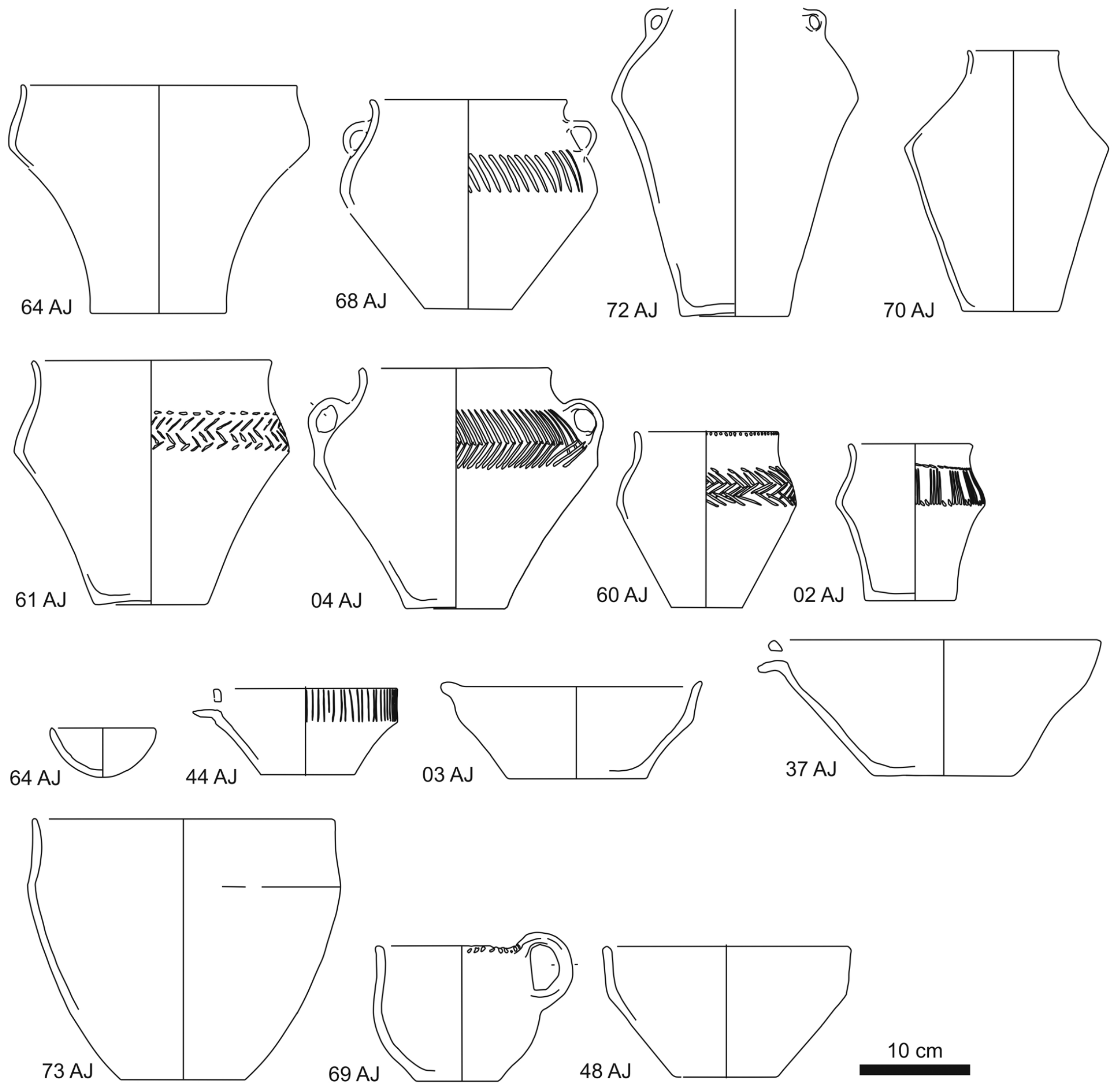


Fig. 5. Vessels from Ajdovska jama that were analysed for organic residues.

kers connected to specific domestic activities and ancient diets, and above all, identifying landmark transitions in ancient economies. These transitions include examples such as horse domestication (*Outram* et al. *2009*), the earliest dairying practices in Europe, the Near East and Africa (*Copley* et al. *2005c; Craig* et al. *2005; Evershed* et al. *2008b; Dunne* et al. *2012; Salque* et al. *2013; Cramp* et al. *2014*); the chronologically and typologically diverse importance of pig exploitation (*Mukherjee* et al. *2007*) and the evidence of geographical dependence on marine food sources (*Copley* et al. *2004b; Hansel* et al. *2004; Evershed* et al. *2008d; Craig* et al. *2011; Cramp* et al. *2014; Cramp, Evershed 2014*).

The components of the lipid extracts of such residues can be identified and quantified by solvent extraction and a combination of analytical techniques that can achieve molecular level resolution, *i.e.* high temperature-gas chromatography (HTGC), GC/mass spectrometry (GC/MS; *Evershed* et al. *1990*) and GC-combustion-isotope ratio MS (GC-C-IRMS; *Evershed* et al. *1994; 1999*).

Furthermore, modern cooking experiments have helped to understand the accumulation of lipids caused by different cooking practices, vessel use and preservation. If we take into consideration that an average concentration of preserved lipids in archaeological pottery is around 100μg g^{-1}, it is quite clear that only 1% or less of the original concentration survives post-depositional degradation (*Evershed 2008*). The initial lipid absorption also depends on the lipid content of processed food (animal *vs*. plant products) and modes of food preparation or storage. Variations in long-term lipid preservation can also occur due to differences in fabric types. Animal fats are by far the most common class of residue identified from archaeological pottery with compound-specific stable carbon isotope analysis, allowing the identification of different animal fats, *e.g.*, ruminant and non-ruminant adipose fats and dairy fats (*Dudd, Evershed 1998*), as well as the identification of the mixing of commodities (*Charters* et al. *1995; Evershed* et al. *1999*).

Materials and methods

Lipid analyses were performed with established protocols that are described in detail in earlier publications (*Evershed* et al. *1990; Charters* et al. *1993b*). The identification of individual compounds was based upon eluting order, a comparison of retention times to standards and by comparing the mass spectra with known fragmentation patters and NIST spectra library. In summary, after cleaning the potsherd surface, a 2g fragment was ground to a fine powder and extracted using a mixture of chloroform and methanol (2:1 v/v). An aliquot of the obtained total lipid extract (TLE) was trimethylsilylated and analysed directly by HTGC. Structure elucidation and molecular identification was achieved by GC-MS and HTGC-MS analyses. Fatty acid methyl esters were prepared by saponification of a TLE aliquot with BF_3/methanol to enable compound-specific stable isotopic determination by GC-C-IRMS. The addition of an internal standard of known concentration (n-tetratriacontane, 1mg mL^{-1}) enabled the calculation of extracted lipid concentration. The discussion of recovery rates refers to the proportional number of pottery extracts with an appreciable preserved lipid concentration (>5μg g^{-1}), which was determined as the lowest acceptable lipid concentration that can be reliably attributed to and interpreted as remnants of ancient food processing rather than modern contamination (*Evershed* et al. *1999; Evershed 2008a*).

Visible surface residues were scraped from the ceramic surface with a clean scalpel, ground to a fine powder and extracted as described above; again an internal standard was added for lipid quantification.

A total of 179 potsherds and visible residues were selected for organic residue analysis: 52 samples from Ajdovska jama, 36 samples from Mala Triglavca and 91 samples from Moverna vas site. Potsherds were selected to represent different occupational phases and human activities at each site. Visible residues were sampled and analysed separately. To avoid duplication, where visible residues were present they were labelled with the number 1, while the originating potsherd extract was labelled with the number 2.

Results

Neolithic and Eneolithic pottery from Ajdovska jama, Mala Triglavca and Moverna vas showed a very good lipid preservation, with an overall 53.6% of potsherds analysed yielding an appreciable lipid concentration. The preservation of lipids in pottery is heavily influenced by the alterations that may occur during vessel use or due to post-burial conditions in the soil, as well as the use of ceramic vessels during their lifetime (*Evershed* et al. *1999; Evershed 2008a*). These factors could explain the variations observed in average lipid concentrations and recovery rates between sites: the pottery assemblage from Mala Triglavca yielded the least TLE extracts, with appreciable lipid concentrations (30.6%), followed by 48% of pottery from Ajdovska jama yielding lipids, while 65.9% of the analysed pottery from the Moverna vas site showed preserved organic residues. This trend is also repeated in observed median lipid concentrations from potsherd extracts as well as lipid concentration ranges. For a better demonstration of different concentration ranges, these are plotted as box-and-whiskers plots in Figure 5. Since, generally, only lipid concentrations higher than 5μg g^{-1} are considered as appreciable and can therefore be interpreted as archaeological, lipid concentrations below this threshold were ignored in the following comparisons (see Fig. 6 and Tab. 2).

The observed lipid concentration ranges are considerably narrower in the ceramic assemblages of Mala Triglavca and Ajdovska jama than those from Moverna vas. Since the latter site was a fully developed, permanent settlement, in contrast to the occasionally used rock shelter and burial cave, higher lipid concentrations could indicate frequent daily use of ceramic vessels resulting in an accumulation of residues.

The organic residues in the investigated pottery showed compound distributions typical of animal fats and plant material degraded to various degrees. The parent triacylgycerols (TAGs) present in fresh adipose fats and plant oils quickly degrade into their constituent fatty acids, with the palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) fatty acids persisting in highest abundance, and with minor contributions from shorter chain saturated fatty acid components. Many vessels yielded only free fatty acids, indicating that complete hydrolysis of the precursor TAG components had taken place. Two gas chromatograms representing differing degrees of degradation and compounds most commonly identified in the Neolithic and Eneolithic residues analysed can be seen in Figure 7.

Fatty acids are usually present in the greatest abundance in archaeological lipid extracts with even rather than odd carbon number preference, dominated by palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) fatty acids. While animal fats generally display a greater abundance of stearic acid, the plant derived lipids show a predominance of palmitic acid (*Dudd 1999; Copley* et al. *2005a; Romanus* et al. *2007*). The presence of odd carbon number free fatty acids (*e.g.*, $C_{15:0}$, $C_{17:0}$, $C_{19:0}$) together with their iso- and anteiso-branched variations may indicate ruminant animal sources, as these compounds are biosynthesised by the bacteria living in the rumen (*Mottram* et al. *1999; Evershed* et al. *2002*).

Despite their predominance, the $C_{16:0}$ and $C_{18:0}$ fatty acids possess only limited biomarker potential. Broad groups of commodities can be alluded to only by investigating the $C_{16:0}$ *vs*. $C_{18:0}$ fatty acid ratio (P/S ratio). Previous investigations of P/S ratios in modern reference materials have provided some additional proxies; however, interpretations of these have to be applied with great caution and only in combination with other data, *i.e.* TAG distributions and $\delta^{13}C$ values. Calculated P/S ratios for pottery extracts from investigated sites are shown in Figure 8.

Previous studies have reported a P/S ratio <1.3 as indicative of ruminant adipose fats; a P/S ratio of approx. 2.2–2.9 and 4.9 indicative of dairy fats or non-ruminant adipose fats, while a P/S ratio between 4.0 and 9.4 has been reported for commercial olive oils (*Dudd 1999; Copley* et al. *2005a; Romanus* et al. *2007*). P/S ratios calculated for TLEs of Slovenian pottery (Fig. 8) show a large proportion of 53 lipid extracts (68%) falling below the 1.3 mark, indicative of ruminant adipose fat; 24 extracts (31%) displaying the range 1.3–4.0, attributed to either ruminant dairy or non-ruminant adipose fats; only 1 extract (1%) displays a P/S ratio higher than 4.0, indicative of olive/plant oils.

Labels	Ajdovska jama	Mala Triglavca	Moverna vas
Min	5.02	5.53	5.25
Q1	8.26	10.81	18.03
Median	32.45	21.93	118.18
Q3	79.25	65.95	503.45
Max	557.13	173.35	3308.10
IQR	70.99	55.14	485.42
Upper Outliers	3	1	7

Tab. 2. Details of absorbed lipid concentration ranges in analysed pottery.

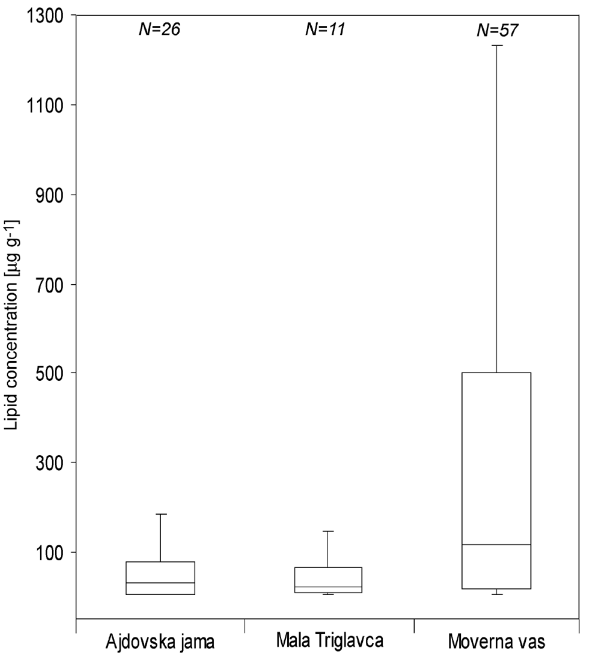


Fig. 6. Box-and-whisker plots showing the range of preserved appreciable lipid concentrations in pottery from Ajdovska jama, Mala Triglavca and Moverna vas. Only concentrations higher than >5µg g^{-1} were used.

The presence of ruminant-derived lipids has also been confirmed by observed distributions of odd carbon number saturated fatty acids with their branched iso- and anteiso- homologues ($C_{15:0}$, $C_{15:0br}$, $C_{17:0}$, $C_{17:0br}$), biosynthesised by the bacteria living in the rumen (*Dudd* et al. *1998; Mottram* et al. *1999; Vlaemnick* et al. *2006*). These branched fatty acid biomarkers were found in ten potsherd extracts: 08MT, 18MT, 75MT, 87MT, 23MV-2, 98MV, 134MV, 149MV, 153MV and 154MV.

Apart from $C_{16:0}$ and $C_{18:0}$ fatty acids, a series of saturated long-chain fatty acids (LCFA) with a carbon number range between C_{20} and C_{30} has also been identified in fifteen potsherd extracts, representing 8% of the total assemblage: 03AJ, 37AJ, 69AJ, 70AJ, 18MT, 29MV-2, 91MV, 99MV, 102MV, 111MV, 114MV, 121MV, 147MV, 149MV AND 154MV. Such a series of LCFA has previously been associated with two potential sources, depending on the accompanying compounds. If found in combination with isoprenoid fatty acids such as phytanic or pristanic acid, 4,8,12-trimethyltridecanoic acid or ω-(*o*-alkylphenyl)-alkanoic acids, preserved lipids are most likely derived from marine organisms (*Copley* et al. *2004b;*

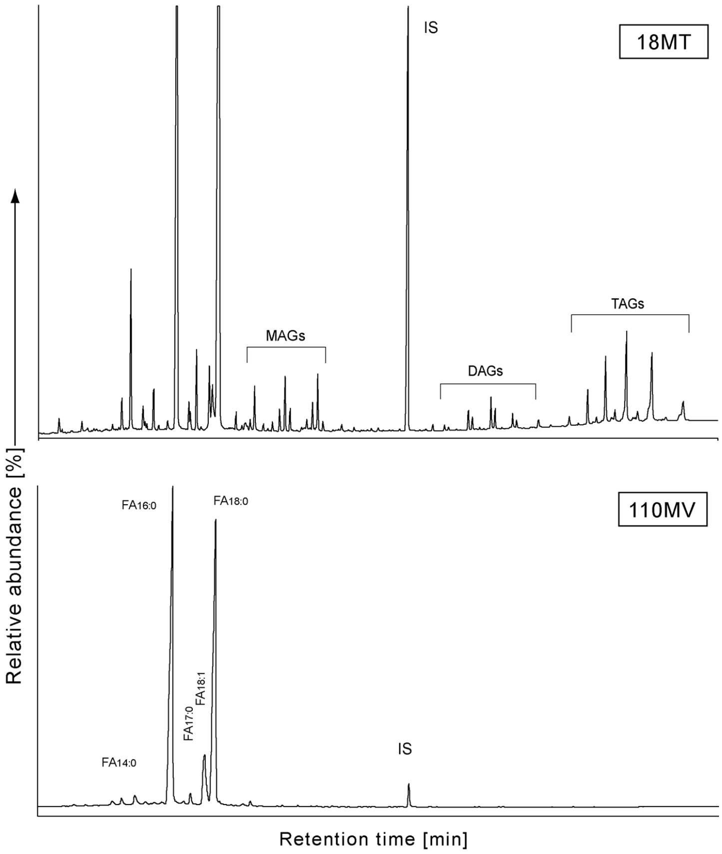


Fig. 7. Partial HTGC profile of the trimethylsilylated total lipid extract from potsherds 18MT (Mala Triglavca) and 110MV (Moverna vas) illustrating the contrasting distribution of compounds characteristic of partially and fully degraded animal fat. Key: FAX:Y are saturated free fatty acids of carbon length x and degree of unsaturation y. IS is the added internal standard; MAGs are monoacylglycerols; DAGs are diacylglycerols; TAGs are triacylglycerols.

Hansel et al. *2004; Evershed* et al. *2008c*). LCFA extracted from Slovenian Neolithic and Eneolithic pottery, however, occur in high frequency together with long-chain n-alcohols of C_{22} to C_{32} even-carbon number series and analogous odd-carbon number n-alkane series of C_{23} to C_{33} chain length, which are more characteristic of degraded plant waxes (*Tulloch 1976; Bianchi 1995*).

Mid-chain ketones have been identified in six residues derived from five body sherds and one rim sherd (02AJ, 04AJ, 72AJ, 29MV-2, 91MV, and 133MV), most frequently displaying a narrow distribution with C_{29}, C_{31}, C_{33} and C_{35} homologues. These biomarker compounds are known to form by the condensation of fatty acids, involving decarboxylation and dehydration reactions occurring at high temperatures, typically in excess of 300°C (*Evershed* et al. *1995; Raven* et al. *1997*). The carbon chain length of ketones previously found in pottery extracts usually ranges between C_{27} and C_{35}, which reflects the length of the precursor fatty acids. These compounds have also been reported as components of the epicuticular leaf waxes of higher plants (*Tulloch 1976; Kolattukudy* et al. *1976*). However, the presence of unsaturated ketones was identified in two lipid extracts (02AJ and 72AJ), suggesting the unsaturated fatty acid precursors common in plant oils. A similar series of ketones was also reported to be formed during vigorous pyrolysis at temperatures reaching 800°C (*Raven* et al. *1997*).

Waxes

Beeswax recovered from archaeological contexts can undergo various degrees of alteration; however, four major groups of compounds provide biomarkers for its presence: (i) long-chain alcohols (C_{24} to C_{32}); (ii) odd-carbon number n-alkanes (C_{25} to C_{33}); (iii) a series of palmitic wax esters (C_{40} to C_{54}); and (iv) hydroxy palmitic wax esters (C_{42} to C_{54}). Similarly, plant waxes contain a mixture of compounds, including odd-carbon number n-alkanes (C_{21} to C_{37}), monoesters ranging in chain length from C_{32} to C_{64} and long-chain alcohols with a chain length range between C_{22} to C_{34} (*Tulloch 1976; Heron* et al. *1994; Mills, White 1994; Charters* et al. *1995; Regert* et al. *2001*). A relatively large proportion of preserved lipid residues (27%) showed traces of wax esters with chain lengths of C_{40} to C_{48}, together with even-carbon number long chain alcohols (C_{22}–C_{32}) and odd-carbon number straight chain alkanes (C_{23}–A_{33}), which could either derive from diagenetically altered beeswax or degraded epicuticular plant waxes (Fig. 9).

Wax esters in these potsherd extracts were predominantly found together with free fatty acids and their acylglycerol moities, suggesting that the vessels were used to process both leafy plants and animal products; whether they were processed simultaneously or separately cannot be elucidated from this data. Interestingly, a beeswax residue was identified in cup extract 125MV without any contributions from animal fats or plant waxes. A further seven potsherd extracts from three vessels (25MV, 26MV and 28MV) contained birch-bark tar biomarkers in conjunction with wax esters, indicating mixing of commodities.

Recent experimental work reported by Dana Millson (*2011*) and Merryn Dineley (*2000; 2011*) has addressed the question of applying beeswax as a sealant, concluding that, although it is an effective waterproofing agent, it is not appropriate for use on cooking pots, causing the pot fabric to spall and flake off. Based on this, as honey would have been the earliest available natural sweetener, the beeswax residues identified in archaeological pottery could be interpreted as the remains of food processing that involved the addition of honey.

Birch bark tar

An unusual set of triterpenoid compounds was identified in 16 potsherd extracts from Moverna vas, representing seven vessels (24MV, 25MV, 26MV, 27MV, 28MV, 151MV and 152 MV) which had visible residues present on either the interior or exterior surface (Fig. 10). Visible residues are a common find on archaeological pottery, and routinely used for radiocarbon dating. It has been previously assumed/assessed that the exposed nature and structure of visible residues are usually not a good medium for preserving organic molecules (*Evershed* et al. *1992; Evershed 2008*). It was possible to assess this variation, because visible residues were sampled and extracted separately. Lipid concentration values differ quite significantly, with values for visible residues averaging at 1537.04μg g^{-1}, while absorbed residues displayed an average lipid concentration of 25.5μg g^{-1}. The two sets of residues were also differentiated by the biomarkers extracted: visible residues showed the presence of lupa-2,20(29)-dien-28-ol, allobetul-2-ene, lupenone, lupeol, betulone and betulin, which are characteristic of birch-bark tar. While betulin and lupeol are the predominant biomarkers present in birch-bark tar, other compounds are formed by degradation reactions, particularly the heating processes needed to produce the pitch. In particular, betulin is partly transformed into lupa-2,20(29)-dien-28-ol by dehydration, whereas lupeol leads to the formation of a triterpenoid hydrocarbon identified as lupa-2,2-(29)-diene (*Charters* et al. *1993; Pollard, Heron 1996; Regert, Rolando 2002; Regert* et al. *2003a: 2003b*).

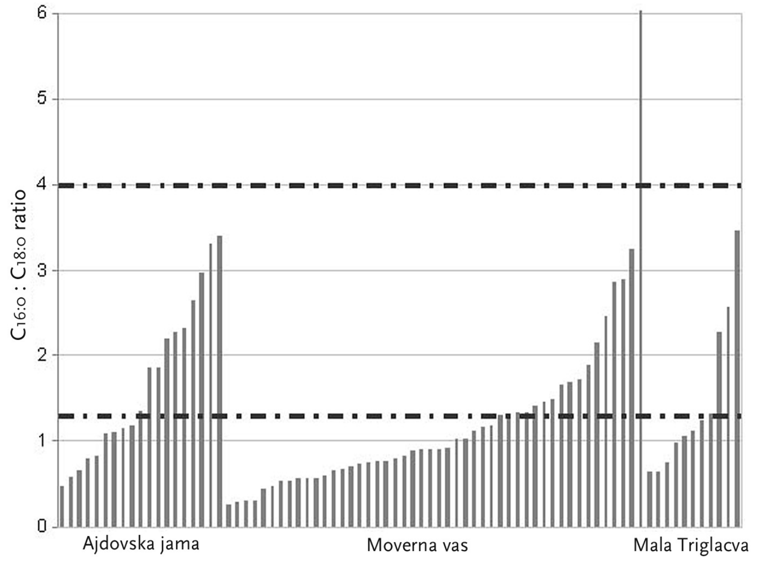


Fig. 8. Histograms representing the relative abundance ratios of palmitic ($C_{16:0}$) vs. stearic ($C_{18:0}$) fatty acid as detected in analysed potsherds. The dotted lines (set at 1.3 and 4) represent criteria as reported in the literature and used to separate ruminant adipose fats from non-ruminant, ruminant dairy fats and plant oils (**Dudd 1999; Copley *et al.* 2005a; Romanus *et al.* 2007*)**.*

Triacylglycerols

Triacylglycerols, as the most abundant components of fresh animal fats and plant oils, can be useful indicators of lipid preservation and the extent of degradation. A comparison of TAG distributions with those of modern reference fats has shown that specific distributions can be linked to different lipid sources and enable the preliminary differentiation of their origins from the two major classes of domestic animals (ruminant and non-ruminant/porcine) and between ruminant dairy and adipose fats. Ruminant animals show a characteristic distribution of TAGs, with carbon numbers ranging from C_{44} to C_{54} with a maximum concentration at C_{52}, whereas non-ruminant animals display a slightly shorter distribution with carbon numbers between C_{46} and C_{54} with a low concentration at C_{46} and C_{54} and a maximum again at C_{52}. Dairy fats show the widest TAG distribution, with carbon numbers ranging from C_{42} to C_{54}, usually with two maxima at C_{50} and C_{52} (*Evershed* et al. *1997; Dudd, Evershed 1998; Mottram* et al. *1999*). Triacylglycerol remains (including samples with only trace amounts preserved) were identified in thirty pottery lipid extracts, representing 17% of the total assemblage investigated. Quantifiable TAG distributions as detected in lipid extracts from Slovenian potsherds are represented in Figure 11.

TAG distributions detected in potsherd extracts seem to be predominantly derived from ruminant adipose fats, with only 5 extracts (18MT, 79MT, 159MT, 96MV, 143MV) possibly deriving from ruminant dairy

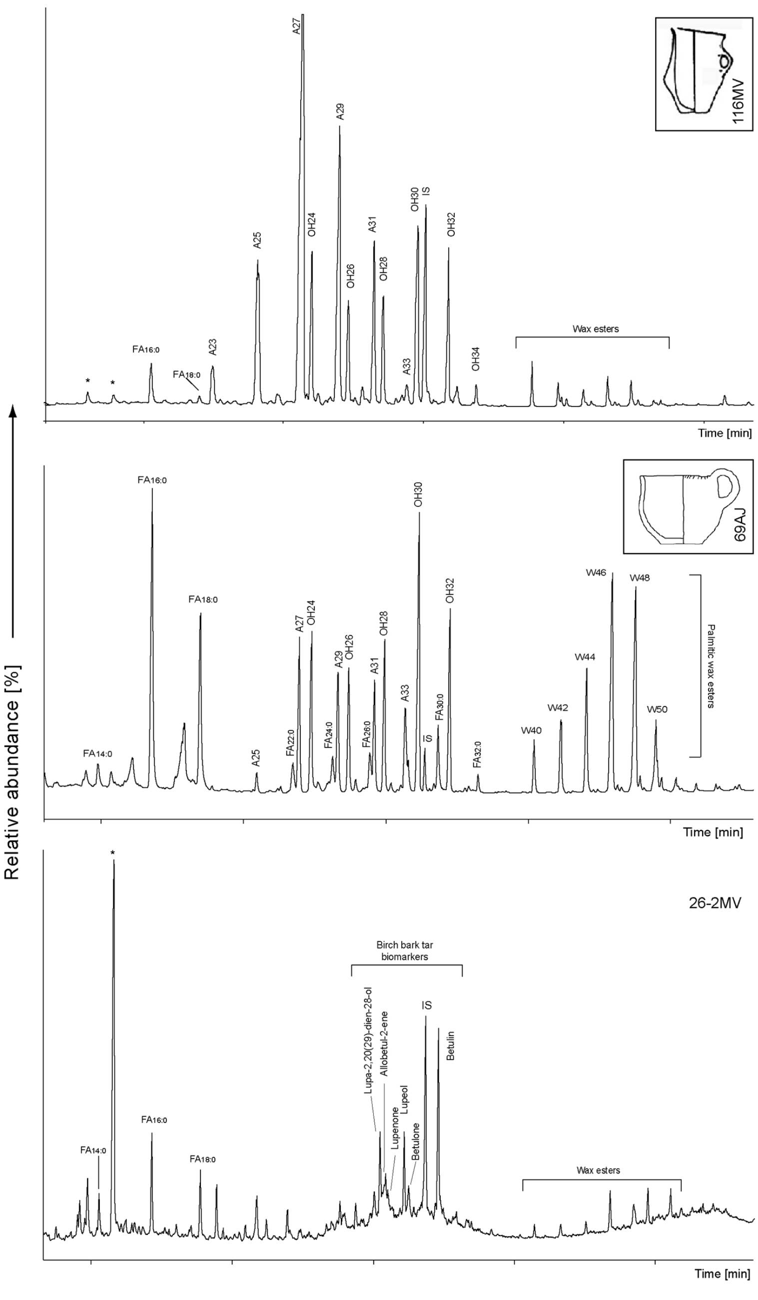


Fig. 9. Partial gas chromatograms of the trimethylsilylated TLEs from pottery showing the various biomarkers detected: 116MV epicuticular waxes residue; 69AJ a mixture of beeswax and plant residue; 26-2MV mixture of birch bark tar and plant residue. Key: FAx:y are fatty acids where x is the carbon chain length and y is the degree of unsaturation; OHx are long-chain alcohols of carbon chain length x; Ax are aliphatic alkanes of carbon chain length x; Wx are wax esters with carbon chain length x; IS is internal standard; * are plasticisers.

tion of compounds with lower carbon numbers, and thus come to resemble the narrower distribution seen in ruminant adipose fat TAGs distribution (*Dudd, Evershed 1998; Aillaud 2001*). Conclusions from TAG distributions have to be drawn with caution and serve only as preliminary results, complemented with compound-specific carbon isotope ratio measurements.

Compound-specific stable carbon isotope analysis

Compound-specific stable carbon isotope values ($\delta^{13}C$) were obtained for the palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) fatty acid methyl ester derivatives (FAMEs) from 52 Neolithic and Eneolithic potsherd residues with sufficient lipid concentrations. In order to elucidate the origin of preserved lipids accurately, archaeological $\delta^{13}C$ values were compared with modern reference fats from animals reared on isotopically similar diets to those of animals in prehistory. To eliminate any isotopic variations occurring in animals through differences in dietary intake or environmental factors, the difference between $\delta^{13}C_{18:0}$ – $\delta^{13}C_{16:0}$ values ($\Delta^{13}C$) is plotted in Figure 12. $\Delta^{13}C$ values ranging from –3.3 to –6.3‰ indicate ruminant dairy fats; values from 1.0 to 2.8‰ represent ruminant adipose fats, while values from –0.7 to + 1.9‰ indicate porcine adipose fats (*Dudd, Evershed 1998; Evershed* et al. *2008; Craig* et al. *2011; Dunne* et al. *2012; Salque* et al. *2013*).

Distributions of stable carbon isotopic values of lipids preserved in Neolithic and Eneolithic pottery show differences between individual archaeological sites: the residues recovered from Ajdovska jama pottery were predominantly of ruminant adipose (5 extracts) and ruminant dairy origin (4 extracts), while those from the Moverna vas pottery assemblage were mainly of ruminant adipose origin (17 extracts). The ubiquitous presence of dairy lipid residues in vessels from Mala Triglavca has already been reported, with 63% and

residues and with no TAG distribution indicating the presence of porcine fats. However, laboratory experiments have shown that TAG distributions can be skewed by degradation occurring during use or post-deposition, causing the wide TAG distribution characteristic of fresh ruminant dairy fat to become considerably narrowed due to the preferential degrada-

17% of vessels being used to process or store dairy products, respectively (*Šoberl* et al. *2008; Budja* et al. *2013*). The lowest occurrences were of porcine derived lipids, being found on only one potsherd from Ajdovska jama and three potsherds from Moverna vas. The mixing of various commodities throughout the life of vessels can also be seen by $\delta^{13}C$ values plotting close to, or between, the ranges of modern reference fats. It has been assumed that the pottery extracts with minor concentrations of leaf waxes or beeswax components present still reflect the isotopic signature of predominant fatty acids present in the residues.

Discussion

Pottery use in different contexts

Pottery has been traditionally regarded as a passive bearer of culture; however, with the rise of contextual archaeology, pottery has come to be seen more as an active factor, brought about by human agency and used in the construction of social identity (*Boast 2002; Gibson 2002*). Ceramic vessels could be used for many primary functions, such as the preparation, storage and cooking of food, brewing, tanning, dairying, dyeing, fulling, textile washing, transporting and salt preparation.

Whatever pottery was used for, it was an important artefact, as demonstrated by its appearance at domestic sites, as well as within ritually structured deposits. Pottery deposited in funerary settings could consist of previously used vessels or one made deliberately for that purpose. Although pottery is very robust and able to survive, it is also very sensitive and responsive to cultural, social, economic and ideological changes. These can be mirrored in a variety of ways: decoration, design, typology, modes of use and deposition.

Ajdovska jama

The ceramic vessels recovered from the Ajdovska jama site formed part of Neolithic burial rituals, acting as grave goods or simply containers for food offerings. Lipid preservation in ceramic vessels was good, with almost half of the potsherds (48%) yielding an appreciable amount of organic residue. The variety of animal remains deposited with the burials is well reflected in preserved fatty acid composition and isotopic signatures, indicating that ceramic vessels predominantly contained ruminant animal products (meat and dairy), while only one vessel showed the presence of porcine fat. The presence of mid-chain ketones in three pots (02AJ, 04AJ, 72AJ), formed by the condensation of precursor fatty acids at high temperatures in the presence of clay, suggests these vessels were used as cooking pots (Fig. 5). The extraction of uncommon unsaturated mid-chain homologues in 02AJ pot could be the result of processing plant material which contains high concentrations of unsaturated fatty acids. This was also suggested by the extracted organic residues, which in combination with the excavated plant remains (burnt, scattered cereal grains and pulses), show a high contribution of a plant-based diet, with approx. 25% of vessels containing some plant biomarkers. A mixed diet of plants and animals was also attested in bulk stable isotopic determinations ($\delta^{13}C$ and $\delta^{15}N$) of collagen extracted from osteological remains recovered from the burials (*Ogrinc, Budja 2005; Bonsall* et al. *2007*). However, enriched $\delta^{13}C$ values of palmitic acid extracted from lipid residues in ceramics (Fig. 12) could indicate a C_4 or marine component in the animal-based diet, as they are strongly diet-dependent (*Copley* et al. *2003*). Since a marine dietary contribution seems unlikely in the case of Ajdovska jama, enriched $\delta^{13}C_{16:0}$ values could have been introduced via animals eating plants from a waterlogged environment (*Salque* et al. *2012*). This observed difference between Ajdovska jama, Mala Triglavca and Moverna vas isotopic values

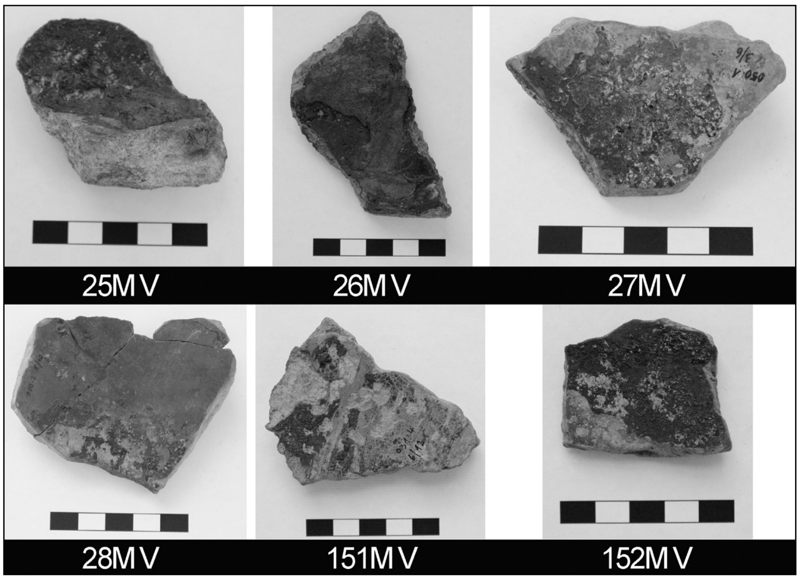


Fig. 10. Potsherds from Moverna vas with visible residues, remnants of birch bark tar application or production.

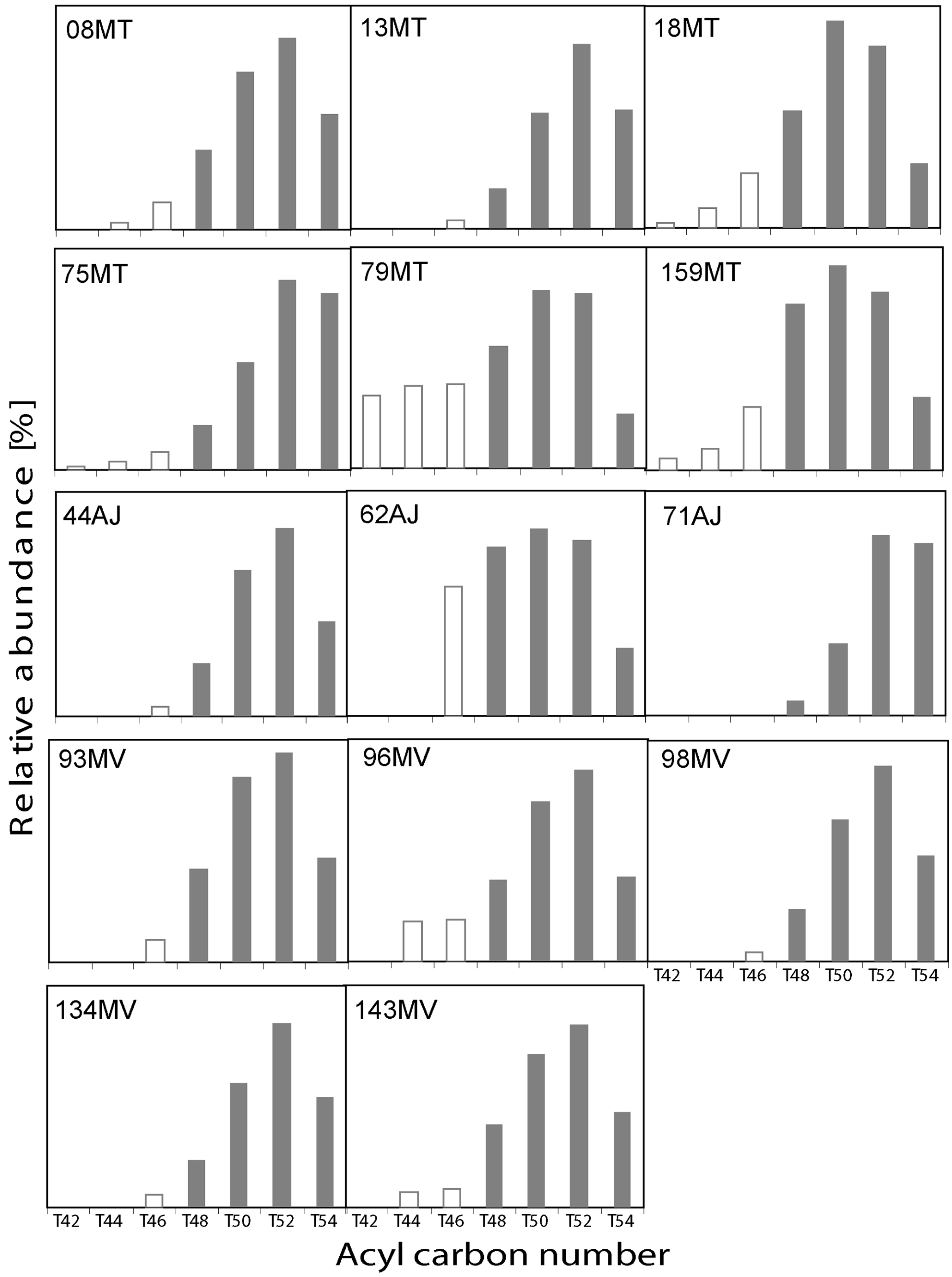
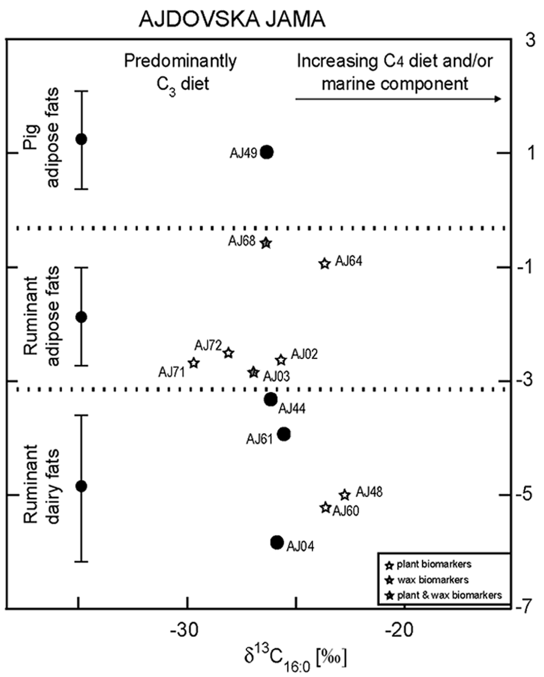


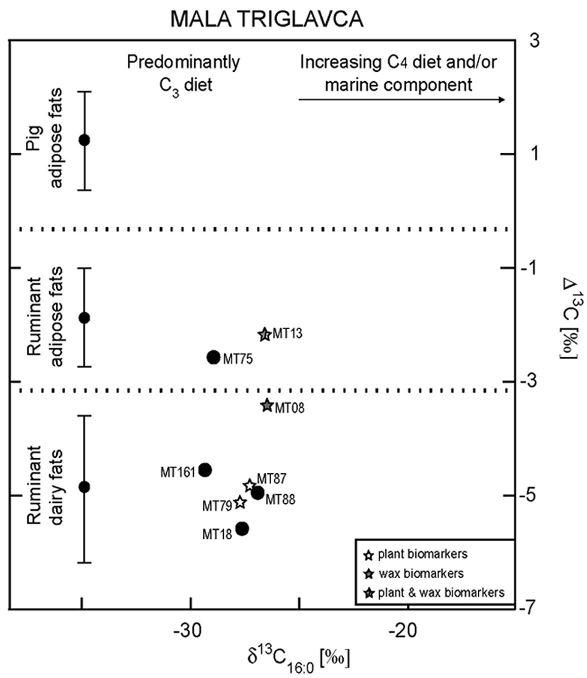
Fig. 11. Histograms showing triacylglycerol (TAG) distributions detected in pottery lipid extracts from Ajdovska jama, Mala Triglavca and Moverna vas. TX denotes the number of acyl carbon atoms in individual TAGs, grey bars represent TAGs identified in modern adipose and dairy fats while those in white are usually found only in dairy fats.

was also confirmed statistically with a two-tailed student's T-test which returned probability values of 0.003 and 0.016.

Mala Triglavca

Rock-shelters such as Mala Triglavca were used as gathering places for Mesolithic populations, and some could have been subsequently transformed into shelters and pens for domestic animals during the Neolithic. An analysis of herd structure and mortality on faunal remains (sex and age of animals) can be used to produce 'kill-off curves' in order to distinguish between meat or dairy animal exploitation (*Payne 1973*). Kill-off curves from Neolithic sites in the Northern Adriatic region have been interpreted in two ways: while Preston Miracle, Stašo Forenbaher and Laura Pugsley believe herds of domestic animals were kept predominantly for dairying, Dimitrij Mlekuž suggests simple, non-optimised animal husbandry (*Miracle, Forenbaher 2005; Miracle, Pugsley, 2006; Mlekuž 2005; 2006; Bonsall* et al. *2013; Rowley-Conwy* et al. *2013*).





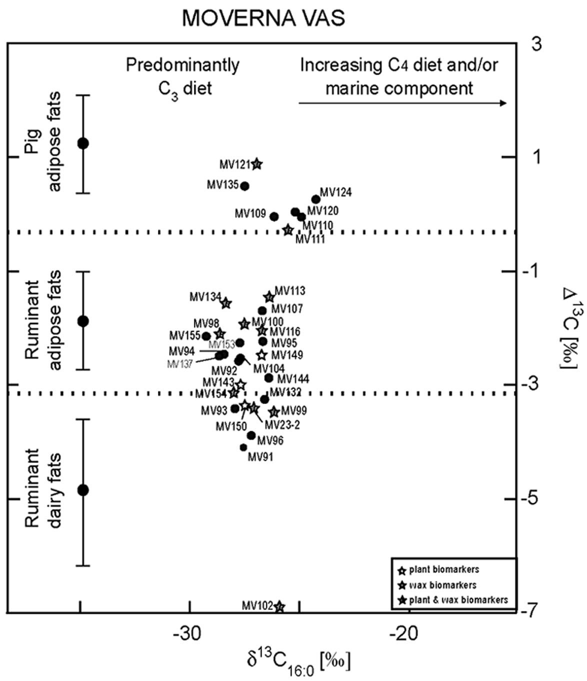


Fig. 12. Scatter plots showing Δ^{13}C values (δ$^{13}C_{18:0}$ – δ$^{13}C_{16:0}$) and δ^{13}C values of $C_{16:0}$ fatty acids extracted from Neolithic and Eneolithic pottery from sites Ajdovska jama, Mala Triglavca and Moverna vas. The ranges for the modern reference fats obtained from Europe, Africa, Kazakhstan and the Near East are plotted to the left of the diagram with mean ±1 s.d. (*Salque *et al.* 2013*). The δ^{13}C values obtained for modern reference animal fats have been adjusted for the post-Industrial Revolution effects of fossil fuel burning, by the addition of 1.2‰.

The findings of absorbed organic residues from Mala Triglavca rock-shelter pottery have been discussed elsewhere (*Šoberl* et al. *2008*) together with a more recent analysis of another pottery assemblage from the same site (*Budja* et al. *2013*). Both studies show lipid biomarkers of a mixed animal and plant economic model. Domesticates were simultaneously exploited for meat and milk. The question of the contribution of game to the diet of the Neolithic occupants of this rock-shelter, as attested in zoological remains, has yet to be addressed and investigated. Ceramic vessels displayed the lowest concentration range of preserved lipids, as well as an absence of mid-chain ketones, suggesting perhaps less intense food processing (no heat involved) or a faster turnover in pottery use. While porcine fats were completely absent, the δ^{13}C values of most abundant fatty acids ($C_{16:0}$ and $C_{18:0}$) fall within a range expected for ruminant dairy (75%) and ruminant adipose fats (25%; Fig. 12). Traces of odd-carbon number aliphatic alkanes, even carbon number long-chain alcohols and wax esters were detected in three potsherds (08MT, 13MT, 79MT), indicating a degree of mixed commodities (meat as well as vegetables) being processed within these vessels.

Moverna vas

The Neo-Eneolithic settlement of Moverna vas had fully developed animal husbandry with agriculture, as well as diverse pottery production. The complexity of this settlement was mirrored perfectly in the lipid biomarkers extracted from the ceramic vessels. The 99 potsherds analysed covered a diverse vessel typology, from large cooking and storage pots to small 'drinking' cups and highly specialised pedestal dishes. Intensive use of ceramic vessels in food preparation and storage is reflected in the highest lipid concentration range (Fig. 6) and the presence of mid-chain ketones identified in three potsherds (29MV-2, 91MV, 133MV) (Fig. 4). Extensive mixing of commodities (meat and plants) is apparent from extracted lipid biomarkers, in which not only free fatty acids were identified together with their parent acylglycerol moieties, but also a suite of other compounds, *i.e.* aliphatic alkanes, long-chain fatty acids, long-chain alcohols, triterpenoids and wax esters. In the absence of faunal remains, compound specific stable isotope analysis of palmitic and stearic fatty acid enabled us to approximately reconstruct animal husbandry practices. While $\delta^{13}C$ values for $C_{16:0}$ and $C_{18:0}$ extracted from ceramic vessels found at Ajdovska jama and Mala Triglavca sites showed the ubiquitous presence of ruminant meat and dairy products, the potsherds from Moverna vas settlement contained predominantly ruminant and porcine adipose lipids (Fig. 12). Only seven potsherds revealed the presence of milk residues (23-2MV, 91MV, 93MV, 96MV, 99MV, 102MV, 150MV) (Fig. 4). An elusive association of porcine products with prehistoric pottery has been observed in the past, especially in British Neolithic pottery (*Mukherjee* et al. *2007*) as well as two recently investigated Slovenian Neolithic pottery assemblages from Maharski prekop and Resnikov prekop. While porcine derived lipids were detected in extracted residues at Resnikov prekop, the same class of foodstuff was completely absent from Maharski prekop (*Ogrinc* et al. *2012; Mlekuž* et al. *2012; 2013*). The discrepancy in preserved porcine lipids and faunal statistics may be the result of alternative ways of preparing porcine meat that did not necessarily involve pottery, but perhaps spit-roasting, as suggested by Umberto Albarella and Dale Serjeantson (*2002*).

Pottery use within typology

The ubiquity of pottery finds in all archaeological sites shows indirectly that this was a commodity produced en masse and used daily, not simply made for display or burials. From the perspective of pottery typology, it is only assumed which vessels were used for storing and/or cooking food.

Investigations of British Neolithic and Bronze Age pottery revealed correlations between specific commodity groups and three main differential criteria: (a) pottery size/rim diameter; (b) pottery typology, and (c) various household activities (*Copley* et al. *2005c; 2005d*). Similarly, biomarkers for a specific commodity, dairy products in this case, were detected in Neolithic ceramic sieves in Europe, which were in turn interpreted as cheese strainers (*Salque* et al. *2013*). Lipid residue analyses of pottery from Ajdovska jama, Mala Triglavca and Moverna vas have shown some correlations between lipid concentrations and pottery typology (Figs. 4, 5 and 13), while only two correlations between specific commodities and vessel types have been observed. Mid-chain ketones, which are used as biomarkers for exposure to high temperature (cooking), were observed in only three vessel types, all characterised either by larger volumes or openness of rims: pots, bowls and dishes. Pots and pedestal dishes were also unique ceramic types associated with birch-bark tar biomarkers.

Rice (*1987*) divided the principle functions of pottery into three categories: (i) storing dry substances; (ii) carrying liquids; and (iii) heating contents over fire. The investigation of potsherd samples taken from different parts along the profile of the same ceramic vessel compared to laboratory cooking simulation experiments has shown correlations between concentrations of absorbed lipids, their spatial distribution and different modes of pottery use.

The hydrophobic nature of lipids and their lower density results in the highest lipid concentrations to be absorbed near the top of the vessel, where the original water line would have been (*Charters* et al. *1997*). Other lipid distributions observed in the bases of vessels are thought to indicate an analogous preparation of food, namely roasting, or the application of surface sealing treatments (*Charters* et al. *1993b; 1997*).

The average lipid concentration profiles in Figure 13 were divided into rim, body and base sherds to assess potential variations in distinguishing pottery use. Investigated pottery from Ajdovska jama, Mala Triglavca and Moverna vas shows distinct differences in vessel use: while average lipid concentration in cups peaks in the upper parts of the vessels, suggesting preferential absorption of immobilised lipids, an opposite concentration distribution was observed for pots and jugs, where the highest concentration in the lower vessel parts could indicate 'dry' cooking.

Average lipid concentration poses an interesting question as well; accepting that lipid accumulation correlates with the longevity of vessel's use, it is clear from Figure 13 that pedestal dishes, small cups and

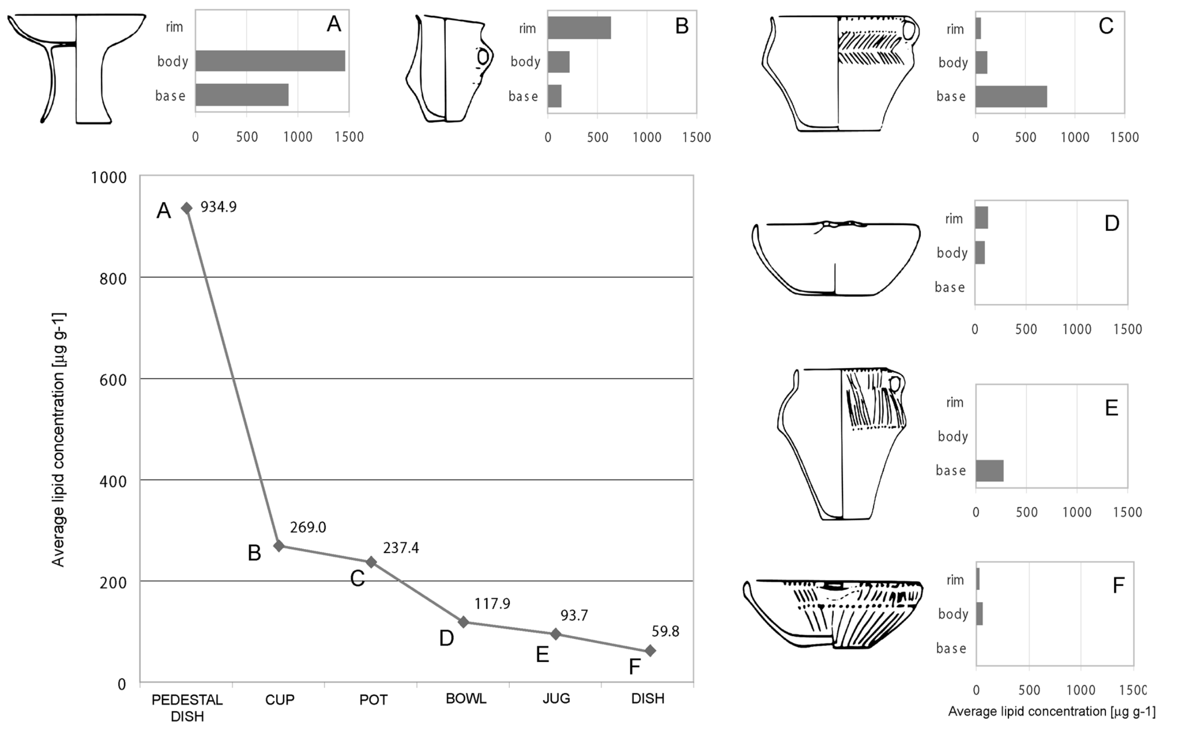


Fig. 13. Diagrams showing the mean concentration of extracted lipids according to ceramic typology and potsherd location.

pots with the highest preserved lipid concentrations (935, 269 and 237µg g-1, namely) were probably used regularly to process or store fatty foodstuffs over an extended period. On the other hand, bowls, jugs and dishes were perhaps used only as storage vessels for less fatty commodities, or were perhaps dedicated serving vessels. An estimate of the longevity of cooking pots in regular use ranges between three months, one year and even longer periods of two to ten years (*Foster 1960; David 1972; DeBoer 1974; Rice 1987; Longacre 1991*).

Birch-bark tar – a multi-purpose widespread prehistoric commodity

Similar to beeswax, resins have also been shown to have had various potential applications in prehistory: as adhesives (*Charters* et al. *1993a; Regert* et al. *2003b*), for medicinal use (*Lucquin* et al. *2006; Evans, Heron 1993*), as a waterproofing agent (*Evershed* et al. *1985; Robinson* et al. *1987; Romanus* et al. *2009*) in pitch and tar production (*Eerkens* et al. *2002*) or perhaps in wine production (*McGovern* et al. *2009*). The presence of birch-bark tar has been widely reported from various prehistoric archaeological contexts, where it was mainly used as hafting adhesive on arrowheads or as a material used to repair broken ceramic vessels as early as the Neolithic (*Pollard, Heron 1996; Regert, Rolando 2002; Regert* et al. *2003b; Regert 2004; Lucquin* et al. *2006*). Birch-bark tar is sometimes also found as free lumps in sediment or in the form of visible residues on the exterior or interior surfaces of ceramic vessels (*Charters* et al. *1993; Bosquet* et al. *2001; Urem-Kotsou* et al. *2002; Regert* et al. *2003; Lucquin* et al. *2006*). Birch-bark tar was only identified as a visible organic residue on pottery from Moverna vas, where it was linked specifically to pedestal dishes and pots. Pedestal dishes have been previously reported together with this natural product from Neolithic funerary contexts in Brittany (*Lucquin* et al. *2006*), where the authors interpreted these vessels as 'incense burners' or portable hearths. As the smell of burning tar is quite unpleasant, it has been suggested that it might have been used to mask strong odours, such as decomposing bodies in funerary contexts (*ibid.*). This theory could explain the find of a small, black, amorphous lump of tar within the burial sediments in Ajdovska jama, where burial rituals were similar to those described above (*Šercelj, Culiberg 1984*). The presence of this natural substance has also been reported from the Urnfield culture cemetery at the Slovenian Academy of Sciences and Arts in Ljubljana (*Puš 1976; Hadži, Cvek 1976; Hadži, Orel 1978*) and the Neolithic pile dwelling site at Maharski prekop (*Hadži, Orel 1978*). The availability of birch trees in prehistory has also been confirmed by palinological analysis of contemporary regional sediments, where a decline has been recorded after 6400 cal BP with the increase of 'anthropogenic indicators' (*Andrič 2007*).

Conclusions

The organic residue analysis of the Neolithic and Eneolithic pottery from Ajdovska jama, Mala Triglavca and Moverna vas showed very good lipid preservation, enabling us to reconstruct the past pottery use and address potential contextual differences. The choice of three sites with very diverse archaeological contexts has proven to be justified, as the vessels retained varying lipid concentrations, probably depending on their originating contexts.

Pottery from Mala Triglavca rock shelter yielded the lowest lipid recovery (30.6%) as well as the lowest lipid concentration range, which together with the absence of mid-chain ketones identified might suggest less intense food processing, without heating, or a faster turnover in pottery use. Lipid biomarkers confirm the archaeozoological data, *i.e.* the presence of domesticated ovicaprids, which were exploited for both meat and dairy products, occasionally mixed with plant-based foods as indicated by biomarkers.

The Ajdovska jama pottery that played a part in prehistoric funerary rituals proved to retain 48% of vessels with identifiable lipid residues. Identified biomarkers reflect the animal remains that were deposited with the deceased, suggesting a mixed plant and animal based diet. The compound specific stable isotopic analysis of primary fatty acids suggests that the lipids derive from ruminant animals (meat and dairy) and one porcine fat residue, most likely a remnant of wild boar. A high occurrence of plant biomarkers (25% of the pottery assemblage) in conjunction with recovered palaeobotanical remains suggests that a large proportion of the cave visitors' diet or food offerings were plant based.

The highest lipid recovery rate (65.9%) as well as the broadest lipid concentration range of Moverna vas settlement pottery can be interpreted as an indication that prehistoric ceramic vessels were used frequently to process or store foodstuff of animal as well as vegetable origin. The complexity of biomarkers in ceramic vessels mirrors perfectly the complexity of a fully developed Neolithic and Eneolithic settlement economy. Ceramic vessels were used to process animal products (ruminant and porcine adipose fats) and plant-based foodstuffs, as well as more rare commodities such as beeswax (perhaps indicating the presence of honey) and birch-bark tar. Pots and pedestal dishes were unique ceramic types associated with birch-bark tar biomarkers, which were identified only on pottery from Moverna vas. Other prehistoric finds of birch-bark tar from Slovenian archaeological sites include a lump of tar in sediment from Ajdovska jama, and occurrences with pottery have been reported from other Neolithic and Bronze Age sites in Slovenia.

The analysis of pottery typology and lipid residues showed that some vessels types can be linked to specific foodstuffs or food preparation techniques. Mid-chain ketones, biomarkers for exposure to high temperature, were observed only in vessel types of larger volume or openness of rim (*i.e.* pots, bowls and dishes). High lipid concentrations detected in pedestal dishes, cups and pots suggest intensive use with fatty foods, while bowls, jugs and dishes were perhaps used only as storage or serving vessels for less fatty commodities.

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Appendix

App. 1. Details of ceramic assemblages investigated.

Sample # CHEM	Sample # ARCH	Site code	SF #	SE/rel. depth	Sector/quadrant	Description
01AJ	1	Ajdovska jama 1982	129a	42	LH/tunnel 1	body of a pot, bucket- shaped
02AJ	2	Ajdovska jama 1982	684	43	CDV/XXII, group 4	body of a pot
03AJ	3	Ajdovska jama 1982	567/2	43	CDV/XXII, group 4	body of a dish
04AJ	4	Ajdovska jama 1982	660 (2519)	43	CDV/XVI, group 4	body of a pot
05AJ	5	Ajdovska jama 1982	682	43	CDV/XVI, group 4	body of a dish
06AJ	6	Ajdovska jama 1982	146	44	LH/tunnel 1	body of a pot
07AJ	7	Ajdovska jama 1982	43	43	LH/tunnel 2	body of a pot
31AJ	8	Ajdovska jama 1976	208	43	LH/group 6	body of a pedestal dish
32AJ	9	Ajdovska jama 1982	70	/	DH/33	body with base of a dish, black residue on exterior
33AJ	10	Ajdovska jama 1986/87	633	43	CDV/XVIa, group 4	body of a pedestal dish, modern glue residue
34AJ	11	Ajdovska jama 1986	640	42	CDV/XXII	upper body of a pedestal dish
35AJ	12	Ajdovska jama 1967	262	43	LH/group 6	base of a pedestal dish, traces of a red slip on exterior
36AJ	13	Ajdovska jama 1967	284	43	LH/group 6	body of a dish
37AJ	14	Ajdovska jama 1988	730	43	CDV/XXIVa, group 4	base with body of a spouted dish, yellowish residue perhaps on interior
38AJ	15	Ajdovska jama 1986	577	43	CDV/XVI, XIIa, group 4	rim of a spouted dish, black residue on interior, shiny surface – perhaps consolidant?
39AJ	16	Ajdovska jama 1986	576	42	CDV/ XXIX/XXVIII; XXVIII	rim of a dish, modern glue residue
40AJ	17	Ajdovska jama 1967	274	42	LH	body of a spouted dish, modern glue present
41AJ	18	Ajdovska jama 1985-87	575	43	CDV/XXII,XXIIa, XXIX, group 4	rim of a dish
42AJ	19	Ajdovska jama 1985/86	635	43	CDV/XXIIa, group 4	rim of a bowl, modern glue present
43AJ	20	Ajdovska jama 1986	574	42	CDV/XVI	rim of a dish, unusual surface – organic residue, limescale or consolidant?
44AJ	21	Ajdovska jama 1967	273	43	LH/group 6	body of a spouted dish
45AJ	22	Ajdovska jama 1967	245	42	LH	body of a spouted dish , modern glue present
46AJ	23	Ajdovska jama 1982	122	42	LH/tunnel 1	rim of a dish with an appliqué decoration
47AJ	24	Ajdovska jama 1982	119	44	LH/group 1	body of a dish, ribbed decoration
48AJ	25	Ajdovska jama 1986	584	42	CDV/XXIX	body of a bowl (by fireplace SE56), ribbed decoration
49AJ	26	Ajdovska jama 1985	583	43	CDV/XXII, group 4	rim of a bowl
50AJ	27	Ajdovska jama 1986	586	/	CDV/ X/IX,XV,XXIX	body of a ribbed dish
51AJ	28	Ajdovska jama 1982/83	109	42	LH/tunnel 1	body of a spouted dish
52AJ	30	Ajdovska jama 1982	126	42	LH/tunnel 1	body of a bowl, bucket-shaped
53AJ	32	Ajdovska jama 1967	258	43	LH/group 6	body with base of a spouted bowl
54AJ	33	Ajdovska jama 1985	440	43	CDV/XVI,XXII, group 4	rim of a jug
55AJ	34	Ajdovska jama 1967	267	43	LH/group 6	body of a jug with a horizontal rib and incised decoration
56AJ	35	Ajdovska jama 1967	206	43	LH/group 6	base of a jug
57AJ	36	Ajdovska jama 1967	257	43	LH/group 6	body of a jug
58AJ-1	29	Ajdovska jama 1987	739	44	CDV/XXII,XXIIa,XVIa	body of a pot, burnt residue on interior and exterior
58AJ-2	29	Ajdovska jama 1987	739	44	CDV/XXII,XXIIa,XVIa	body of a pot, burnt residue on interior and exterior
59AJ	31	Ajdovska jama 1984	116	42	LH/tunnel 1	body of a pot, bucket-shaped
60AJ	37	Ajdovska jama 1985-87	743	43	CDV/XXII,XXIIa,XVI, group 4	rim of a pot with incised decoration

Sample # CHEM	Sample # ARCH	Site code	SF #	SE/rel. depth	Sector/quadrant	Description
61AJ	38	Ajdovska jama 1986/87	756	43	CDV/XXIIa, group 4	two rims of a pot – one with a horizontal rib, one with criss-cross incisions
62AJ	39	Ajdovska jama 1985	737	43	CDV/XXII, group 4	body of a pot with horizontal incisions and a base of the handle (similar in Moverna vas assemblage)
63AJ	40	Ajdovska jama 1982	120	44	LH/group 1	three body fragments of a pot with a zoomorphic head
64AJ	41	Ajdovska jama 1984	385	83	CDV/XVIII	rim with body of a pot
65AJ	42	Ajdovska jama 1987	641	43	CDV/XXIIa, group 4	body of a pot
66AJ	43	Ajdovska jama 1985	564	43	CDV/XXII, XVI, group 4	rim of a pot with vertical incisions
67AJ	44	Ajdovska jama 1985/86	455	43	CDV/XVI,XXII,XXIIa, group 4	base of a pot, painted decoration
68AJ	45	Ajdovska jama 1982	125	44	LH/group 1	body of a pot
69AJ	46	Ajdovska jama 1982	107	42	LH/tunnel 1	body of a pot
70AJ	47	Ajdovska jama 1967/82	670	44	LH/group 1	body of a large pot (pythos)
71AJ	48	Ajdovska jama 1982	198	43	LH/group 2	body of a pot
72AJ	49	Ajdovska jama 1985-87	606	44	CDV/XXII,XVI, group 3	body of a pot, red slip on exterior, burnt interior
73AJ	50	Ajdovska jama 1982	129	43	LH/tunnel 1	body of a pot, bucket-shaped
74AJ	51	Ajdovska jama	703	?	CDV/22	body of a pot, ribbed decoration
8MT	/	Mala Triglavca 2006	PN1690	55	A/L92/a	body, unwashed, undefined type
9MT	/	Mala Triglavca 2006	PN1722	55	A/L92/a	body, unwashed, undefined type
10MT	/	Mala Triglavca 2006	PN1697	55	A/K93/c	body, undefined type
11MT	/	Mala Triglavca 2006	PN1752	55	A/K91/c	body, undefined type
12MT	/	Mala Triglavca 2006	PN1694	55	A/L93/a	body, undefined type
13MT	/	Mala Triglavca 2006	PN1714	55	A/K92/c	rim, undefined type
14MT	/	Mala Triglavca 2006	PN1748	55	A/L91/a	body, undefined type
15MT	/	Mala Triglavca 2006	PN1561	47	A/L91/d	body, undefined type
16MT	/	Mala Triglavca 2006	PN1680	55	A/L92/d	body, undefined type
17MT	/	Mala Triglavca 2006	PN1644	47/51	A/L90/a	body, undefined type
18MT	/	Mala Triglavca 2006	PN1829	61	A/L91/a	body, undefined type
75MT	78	Mala Triglavca	R043	2.90-3.05m	5,6,7	perforated rim, undefined type
76MT	81	Mala Triglavca	R044	2.90-3.05m	5,6,6	base with body, burnt interior, undefined type
77MT	85	Mala Triglavca	R045	2.90-3.05m	5,6,7	body of a pot
78MT	86	Mala Triglavca	R046	2.90-3.05m	5,6,7	body of a bowl, incised decoration
79MT	101	Mala Triglavca	R052	2.90-3.05m	5,6,7	body of a bowl, polished exterior
80MT	103	Mala Triglavca	R054	2.90-3.05m	5,6,7	rim and body (two fragments), incised decoration, undefined type
81MT	112	Mala Triglavca	R060	2.90-3.05m	5,6,7	body of a bowl, burnt interior
82MT	140	Mala Triglavca	R076	2.90-3.05m	5,6,7	base with body, undefined type
83MT	169	Mala Triglavca	R097	2.70-3.00m	4	body of a dish
84MT	335	Mala Triglavca	R178	2.70-2.90m	3	base with body, undefined type
85MT	377	Mala Triglavca	R187	2.60-2.75m	5,6,7	rim with body (two fragments) of a bowl
86MT	440	Mala Triglavca	R208	2.50-2.70m	4	rim with body, traces of a black slip, undefined type
87MT	459	Mala Triglavca	R214	2.50-2.70m	4	body of a cup, modern glue residue
88MT	503	Mala Triglavca	R230	2.60-2.80m	3	rim with body, burnt interior, undefined type
89MT	512	Mala Triglavca	R236	2.30-2.50m	4	rim with body (two fragments), undefined type
156MT	20	Mala Triglavca 1984	R016	3.05-3.25m	5	undefined type
157MT	27	Mala Triglavca 1984	R021	3.05-3.25m	5	pot
158MT	36	Mala Triglavca 1984	R024	3.05-3.25m	5,6,7	bowl
159MT	40	Mala Triglavca 1984	R027	3.05-3.25m	5,6,7	bowl
160MT	59	Mala Triglavca 1984	R034	3.05-3.25m	5,6,7	bowl
161MT	99	Mala Triglavca 1984	R050	2.90-3.05m	5,6,7	ladle
162MT	159	Mala Triglavca 1981	R090	2.70-3.00m	4	bowl
163MT	222	Mala Triglavca 1981	R123/124	2.70-3.00m	4	handle fragment

Sample # CHEM	Sample # ARCH	Site code	SF #	SE/rel. depth	Sector/quadrant	Description
164MT	238	Mala Triglavca 1981	R133	2.70-3.00m	4	cup
165MT	239	Mala Triglavca 1981	R134	2.70-3.00m	4	bowl
166MT	442	Mala Triglavca 1981	R210	2.50-2.70m	4	pot
23MV-1	/	Moverna vas 1988	1238	053.1	5/13	visible black, charred residue, inside
23MV-2	/	Moverna vas 1988	1238	053.1	5/13	small bowl
24MV-1	/	Moverna vas 1988	2478	050.2	4/3	visible black, charred residue, inside
24MV-2	/	Moverna vas 1988	2478	050.2	4/3	base with body of a pot, organic residue on interior
25MV-1A	/	Moverna vas 1988	/	050.1	6/1-116	visible black, compact residue, inside
25MV-1B	/	Moverna vas 1988	/	050.1	6/1-116	visible brown, compact residue, inside
25MV-2	/	Moverna vas 1988	/	050.1	6/1-116	base with body of a pot, organic residue on interior
26MV-1	/	Moverna vas 1988	/	022.1	4/15	dark brown, compact residue, inside
26MV-2	/	Moverna vas 1988	/	022.1	4/15	base with body of a pot, organic residue on interior
27MV-1A	/	Moverna vas 1988	6	050.1	5/6	black, compact residue, inside - only spots
27MV-1B	/	Moverna vas 1988	6	050.1	5/6	black, compact residue on section
27MV-1C	/	Moverna vas 1988	6	050.1	5/6	black, compact residue outside - only spots
27MV-2	/	Moverna vas 1988	6	050.1	5/6	foot of a pedestal dish with red slip, organic residue on the foot
28MV-1A	/	Moverna vas 1988	5	050.2	5/10	black, compact residue, inside - only spots
28MV-1B	/	Moverna vas 1988	5	050.2	5/10	black, compact residue on section
28MV-1C	/	Moverna vas 1988	5	050.2	5/10	black, compact residue outside - only spots
28MV-2	/	Moverna vas 1988	5	050.2	5/10	foot of a pedestal dish with red slip, organic residue on the foot
29MV-1A	/	Moverna vas 1984	212	323-332cm	2/1-8/7, N-profile	pale brown residue on various parts, mixed with black residue - possibly soil, outside
29MV-1B	/	Moverna vas 1984	212	323-332cm	2/1-8/7, N-profile	"black, compact residue in form of a lump, located just below the rim and running over the rib; looks charred and visible fibres, outside"
29MV-2	/	Moverna vas 1984	212	323-332cm	2/1-8/7, N-profile	rim of a biconical cup, organic residue on exterior
30MV-1	/	Moverna vas 1984	/	/	2/9/7, T8-7/7	white, compact residue in spots, inside
30MV-2	/	Moverna vas 1984	/	/	2/9/7, T8-7/7	base of a miniature bottle with incised decoration, whiteish residue on interior
90MV	1	Moverna vas 1988	R6	056.3	5/7	body of a spouted dish, type 1
91MV	2	Moverna vas 1988	R17	056	4/11	body of spouted dish (two fragments), type 1, burnt interior
92MV	3	Moverna vas 1988	R 174	056.3	3/10-14	rim with body of a spouted dish, type 1, impressed and combed decoration
93MV	4	Moverna vas 1988	R176	056.3	3/7	body of a spouted dish, type 1, appliqué decoration on exterior
94MV	5	Moverna vas 1988	R226	056.1	6/13	body of a spouted dish, type 1
95MV	6	Moverna vas 1988	R 467	050.2	?	body of a spouted dish, type 1, horizontal rib and combed decoration
96MV	7	Moverna vas 1988	R8	056.2	3/13	body of a bowl with red slip, traces of residue on exterior, type 2
97MV	8	Moverna vas 1988	R19	056.2	4/3	body of a bowl (two fragments), type 2
98MV	9	Moverna vas 1988	R23	056.3	5/6	rim of a bowl (two fragments), type 2
99MV	10	Moverna vas 1988	R27	056.3	5/10	body of a bowl, type 2
100MV	11	Moverna vas 1988	R36	056.2	3/7	rim with body of a bowl (three fragments), type 2
101MV	12	Moverna vas 1988	R179	056.2	3/5,9	body of a bowl, type 2
102MV	?	Moverna vas 1988	?	056.3	3/7	rim of a bowl, type 2
103MV	13	Moverna vas 1988	R20	056.3	4/13	body of a small pot with red slip, type 3
104MV	14	Moverna vas 1988	R239	056.3	5/13	body of a small pot (two fragments), type 3
105MV	15	Moverna vas 1988	sample 99	050.1-2	3/7	body of a small pot (three fragments), type 3, horizontal rib

Sample # CHEM	Sample # ARCH	Site code	SF #	SE/rel. depth	Sector/ quadrant	Description
106MV	16	Moverna vas 1988	sample 103	056.2	3/14	body of a small pot (three fragments), type 3 horizontal rib
107MV	17	Moverna vas 1988	sample 104	056.2	3/9	body of a small pot with red slip, type 3
108MV	18	Moverna vas 1988	sample 105	056.2	3/3	base of a small pot with red slip, type 3
109MV	19	Moverna vas 1988	sample 106	056.2	3/3	body of a small pot, horizontal rib, type 3
110MV	20	Moverna vas 1988	sample 107	056.2	3/6	rim with body of a small pot with red slip, type 3
111MV	21	Moverna vas 1988	sample 108	056.2	3/6	base of a small pot with red slip, type 3
112MV	22	Moverna vas 1988	sample 109	056.2	3/8	rim of a small pot with red slip, type 3
113MV	23	Moverna vas 1988	sample 110	056.2	3/2	whole profile of a small pot with red slip, type 3
114MV	24	Moverna vas 1988	sample 111	056.2	3/2	base of a small pot, type 3
115MV	25	Moverna vas 1988	sample 112	056.2	3/7	body of a small pot with red slip, type 3
116MV	26	Moverna vas 1988	sample 113	056.2	3/1-16	body of a small pot with fragmented handle, type 3
117MV	27	Moverna vas 1988	sample 114	056.2	3/14	body of a small pot with red slip (two fragments), horizontal rib, type 3
118MV	28	Moverna vas 1988	sample 115	056.2	3/14	body of a small pot with red slip, type 3
119MV	29	Moverna vas 1988	sample 116	056.2	3/14	body of a small pot with red slip, horizontal rib, type 3
120MV	30	Moverna vas 1988	sample 117	056.2	3/14	body of a small pot with red slip, type 3
121MV	31	Moverna vas 1988	sample 118	056.2	3/14	body of a small pot, incides decoration on interior, type 3
122MV	32	Moverna vas 1988	sample 119	056.2	?	rim and base of a small pot with grey slip, type 3
123MV	33	Moverna vas 1988	sample 120	056.2	3/15	body of a small pot with red slip, type 3
124MV	34	Moverna vas 1988	sample 121	056.2	3/5	body and base of a small pot with red slip, type 3
125MV	35	Moverna vas 1988	sample 132	056.3	5/5	body of a small pot, horizontal rib, type 3
126MV	36	Moverna vas 1988	sample 133	056.3	5/5	rim of a small pot with red slip, type 3
127MV	37	Moverna vas 1988	sample 134	056.3	5/10	body of a small pot with red slip, type 3
128MV	38	Moverna vas 1988	sample 183	056.2	4/7.3/3	body of a pot (two fragments), type 4
129MV	39	Moverna vas 1988	sample 225	056.3	3/12	body of a pot (two fragments), type 4
130MV	40	Moverna vas 1988	sample 102	056.3	5/11	body of a pot, type 5, combed decoration on exterior
131MV-1	41	Moverna vas 1988	sample 128	056.2	3/5	brown visible residue on exterior
131MV-2	41	Moverna vas 1988	sample 128	056.2	3/5	body of a pot, type 5, horizontal rib and combed decoration on exterior, organic residue on exterior
132MV	42	Moverna vas 1988	R38	056.3	3/7	body of a pot, type 5,
133MV	43	Moverna vas 1988	R130	056.2	3/3	rim of a pot, type 5,
134MV	44	Moverna vas 1988	R131	056.2	3/3	rim and body of a pot, type 5, horizontal rib and combed decoration on exterior
135MV	45	Moverna vas 1988	R181	056.3	5/1	body of a pot (two fragments), type 5, combed decoration on exterior
136MV	46	Moverna vas 1984	R222	1/8/7	1/5-8	body of a pot, type 5, incised decoration on exterior
137MV	47	Moverna vas 1984	R 262	2/5/7	2/9	body of a pot (two fragments), type 5, impressed and combed decoration on exterior
138MV	48	Moverna vas 1988	R212	050.1	5/11	body of a pot (three fragments), type 6
139MV	49	Moverna vas 1988	sample 101	056.3	3/14	body of a pot, type 6, horizontal rib and combed decoration on exterior
140MV	50	Moverna vas 1988	R8	056.3	3/10	body of a pedestal dish with red slip, type 7
141MV	51	Moverna vas 1988	R122	056.2	3/2	rim of a pedestal dish with red slip, type 7
142MV	52	Moverna vas 1988	R124	056.2	3/11	base with foot of a pedestal dish, type 7, red slip
143MV	53	Moverna vas 1988	R127	056.2	3/5	rim and body of a pedestal dish, type 7, red slip
144MV	54	Moverna vas 1988	R224	056.3	3/5	base with foot of a pedestal dish, type 7, red slip
145MV	55	Moverna vas 1988	R264	050.1.2	3/3	body of a pedestal dish, type 7, red slip
146MV	56	Moverna vas 1984	R56	1/8/7	1/5-6	base and foot of a pedestal dish, type 7, red slip
147MV	57	Moverna vas 1988	sample 100	056.2	3/7	base and foot of a pedestal dish, type 7, red slip
148MV	58	Moverna vas 1988	sample 123	056.2	3/2	rim and body of a pedestal dish (two fragments), type 7, red slip
149MV	59	Moverna vas 1988	sample 125	056.2	3/10	rim and body of a pedestal dish (two fragments), type 7, red slip
150MV	60	Moverna vas 1988	sample 126	056.2	3/5	rim of a pedestal dish, type 7, red slip
151MV-1	61	Moverna vas 1988	sample 135	031.4	6/12	black, compact residue, inside

Sample # CHEM	Sample # ARCH	Site code	SF #	SE/rel. depth	Sector/ quadrant	Description
151MV-2	61	Moverna vas 1988	sample 135	031.4	6/12	body of a pedestal dish, type 7, red slip, organic residue on interior
152MV-1	62	Moverna vas 1988	sample 136	050.2	5/3	black, compact visible residue, covering interior surface uniformly
152MV-2	62	Moverna vas 1988	sample 136	050.2	5/3	body of a pedestal dish, type 7, red slip, organic residue on interior
153MV	63	Moverna vas 1988	R232	022	5/11	body of a pot, horizontal rib and incised decoration, type 8
154MV	64	Moverna vas 1984	R115	1/8/7	1/0-5	body of a pot (two fragments), combed decoration, type 9
155MV	65	Moverna vas 1988	sample 129	056.2	3/5	rim of a ladle, type 10

App. 2. Summary of lipid residue analysis and their interpretations

Sample # CHEM	Vessel part	Biomarkers detected	Lipid concentration [μg g⁻¹]	P/S ratio	$\delta^{13}C_{16:0}$ [‰]	$\delta^{13}C_{18:0}$ [‰]	Interpretation
01AJ	body	/	2.38	/	/	/	n/a
02AJ	body	FA14, FA16, FA17, FA18, K29-K35, K33:1, K35:1	198.63	1.19	-25.26	-27.88	mixed animal fat, plant residue, cooking
03AJ	body	FA14, FA16, FA17, FA18, FA20-FA28; OH24-OH34; A27-A31, traces of WE	83.19	0.46	-26.44	-29.27	ruminant adipose fat, plant residue, waxes
04AJ	body	FA14, FA15, FA16, FA17, FA18, K27-K35	161.18	1.15	-25.45	-31.25	ruminant dairy fat, cooking
05AJ	body	/	0		/	/	n/a
06AJ	body	/	11.86	1.35	/	/	n/a
07AJ	body	FA14, FA16, FA18, OH24-OH32	7.9	1.10	/	/	plant residue
31AJ	body	/	4.43		/	/	n/a
32AJ	body	/	0		/	/	n/a
33AJ	body	/	2.16		/	/	n/a
34AJ	body	/	0		/	/	n/a
35AJ	base	FA16, A25-A31; OH24-OH32, traces of WE	12.94		/	/	plant residue
36AJ	body	/	2.66		/	/	n/a
37AJ	body	FA16, FA22-34; A25-A33; OH22-OH34, WE	99.93	3.30	/	/	plant residue, waxes
38AJ	rim	/	0		/	/	n/a
39AJ	rim	/	2.73		/	/	n/a
40AJ	body	/	3.97		/	/	n/a
41AJ	rim	/	2.79		/	/	n/a
42AJ	rim	/	3.89		/	/	n/a
43AJ	rim	/	0		/	/	n/a
44AJ	body	FA14, FA16, FA17,FA 18, DAGs, TAGs	80.45	0.59	-25.71	-28.99	mixed ruminant fat
45AJ	rim	/	1.08		/	/	n/a
46AJ	rim	/	0		/	/	n/a
47AJ	body	/	4.03		/	/	n/a
48AJ	body	FA14, FA16, FA18:1, FA18, FA20	7.05	3.40	-22.41	-27.40	ruminant dairy fat, plant residue
49AJ	rim	FA16, FA18, FA20	48	2.32	-25.91	-24.88	porcine fat
50AJ	body	/	5.15		/	/	n/a
51AJ	body	/	0		/	/	n/a
52AJ	body	/	0		/	/	n/a
53AJ	body	/	4.16		/	/	n/a
54AJ	rim	/	1.76		/	/	n/a
55AJ	body	/	7.34		/	/	n/a
56AJ	body	/	6.72		/	/	n/a
57AJ	base	A25-A33, OH24-OH34, FA22-FA30	267.04		/	/	plant residue, waxes
58AJ-1	body	/	0		/	/	n/a
58AJ-2	body	/	0		/	/	n/a
59AJ	body	/	4.66		/	/	n/a
60AJ	rim	FA14, FA16, FA18	21.96	2.27	-23.25	-28.47	ruminant dairy fat, plant residue
61AJ	rim	FA16, FA17, FA18, FA20, MAGs, DAGs, TAGs	47.46	0.65	-25.15	-29.05	ruminant dairy fat
62AJ	body	FA14, FA16, FA17, FA18, MAGs, A27-A33, OH24-OH32, DAGs, WE, TAGs	73.65	1.09	/	/	animal fat, waxes
63AJ	body	/	0		/	/	n/a
64AJ	rim	FA16, FA18	9.36	1.85	-23.29	-24.24	ruminant adipose fat
65AJ	body	FA16, FA18, DAGs, traces TAGs	13.37	2.64	/	/	mixed animal fat
66AJ	rim	/	0		/	/	n/a
67AJ	base	/	5.02		/	/	n/a

Sample # CHEM	Vessel part	Biomarkers detected	Lipid concentration [μg g⁻¹]	P/S ratio	$\delta^{13}C_{16:0}$ [‰]	$\delta^{13}C_{18:0}$ [‰]	Interpretation
68AJ	body	FA16, FA18:1, FA18, traces WE	11.39	2.96	-25.91	-26.47	porcine fat, plant residue
69AJ	body	FA14, FA15, FA16, FA17, FA18, A25-A33, OH24-OH32, FA22-FA32, WE, DWE	557.13	2.20	/	/	plant residue, waxes
70AJ	body	FA14, FA16, FA18, A25-A33, OH24-OH34, FA22-FA30, WE, traces DWE	75.66	1.85	/	/	plant residue, waxes
71AJ	body	FA16, FA18:1, FA18, OH, DAGs, TAGs	42.94	0.82	-29.11	-31.78	ruminant adipose fat, plant residue
72AJ	body	FA16, FA18, K29-K35, K33:1, K35:1	47.37	0.80	-27.59	-30.08	mixed ruminant fat, plant residue, cooking
73AJ	body	/	1.46		/	/	n/a
74AJ	body	/	0		/	/	n/a
08MT	body	FA14, FA15br, FA15, FA16, FA17br, FA17, FA18:1, FA18, MAGs, DAGs, TAGs, traces of WE	173.35	0.99	-26.51	-29.91	ruminant dairy fat, plant residue
09MT	body	traces of FA16 & FA18, K31-K35	1.9		/	/	n/a
11MT	body	traces of FA16 & FA18, K31-K35	0.81		/	/	n/a
12MT	body	/	0.42		/	/	n/a
13MT	rim	FA16, FA18, MAGs, DAGs, TAGs, traces of WE, A and OH	11.56	0.63	-26.68	-28.85	ruminant adipose fat, plant residue
14MT	body	/	0.24		/	/	n/a
15MT	body	/	0		/	/	n/a
16MT	body	/	0		/	/	n/a
17MT	body	/	1.01		/	/	n/a
18MT	body	FA14, FA15br, FA15, FA16, FA17br, FA17, FA18:1, FA18, FA20-FA24, MAGs, DAGs, TAGs	88.09	0.75	-27.68	-33.26	ruminant dairy fat
75MT	rim	FA14, FA15, FA16:1, FA16, FA17, FA17br, FA18:1, FA18, FA20, MAGs, DAGs, TAGs	90.54	0.64	-28.96	-31.52	ruminant adipose fat
76MT	base	/	2.92		/	/	n/a
77MT	body	/	0		/	/	n/a
78MT	body	/	2.58		/	/	n/a
79MT	body	FA14, FA16, FA17, FA18:1, FA18, FA20, traces of A & OH, DAGs, TAGs	27.23	1.24	-27.80	-32.91	ruminant dairy fat, plant residue
80MT	rim	/	3.45		/	/	n/a
81MT	body	/	1.34		/	/	n/a
82MT	base	/	0		/	/	n/a
83MT	body	/	3.12		/	/	n/a
84MT	base	/	1.1		/	/	n/a
85MT	rim	/	1.34		/	/	n/a
86MT	rim	/	1.38		/	/	n/a
87MT	body	FA14, FA16, FA17br, FA17, FA18:1, FA18, FA20, MAGs, traces of A & OH, traces of DAGs & TAGs	21.93	1.05	-27.35	-32.18	ruminant dairy fat, plant residue
88MT	rim	FA14, FA16, FA18, FA20	9.93	2.56	-26.97	-31.91	ruminant dairy fat
89MT	rim	/	0		/	/	n/a
156MT	rim	FA16, FA18:1, FA18, traces of MAGs & DAGs	10.06	2.27	/	/	n/a
157MT	rim	/	4.06		/	/	n/a
158MT	rim	/	0.98		/	/	n/a
159MT	rim	FA16, FA18, MAGs, DAGs, TAGs	12.65	1.32	/	/	mixed animal fat
160MT	complete	FA16, FA18, traces of MAGs, DAGs & TAGs	5.53	3.46	/	/	n/a
161MT	rim	FA16, FA18:1, FA18, MAGs, traces of DAGs	43.81	1.11	-29.38	-33.95	ruminant dairy fat
162MT	n/a	/	2.77		/	/	n/a
163MT	body	FA16, FA18	4.02		/	/	n/a
164MT	rim	FA16, FA18	2.47		/	/	n/a
165MT	rim	/	1.53		/	/	n/a
166MT	rim	/	4.67		/	/	n/a
23MV-1	rim	FA16, FA18, traces OH	361.4	0.30	/	/	animal fat
23MV-2	rim	FA14, FA16, FA17br, FA17, FA18, FA20, OH24-OH34, A29-A35, WE	434.99	0.25	-26.99	-30.46	mixed fat, waxes
24MV-1	base	pitch markers	1789.97		/	/	birch bark tar

Sample # CHEM	Vessel part	Biomarkers detected	Lipid concentration [μg g-1]	P/S ratio	$\delta^{13}C_{16:0}$ [‰]	$\delta^{13}C_{18:0}$ [‰]	Interpretation
24MV-2	base	traces of pitch markers	0.77		/	/	n/a
25MV-1A	base	pitch markers, traces of WE	720.94		/	/	birch bark tar, waxes
25MV-1B	base	pitch markers, traces of WE	911.02		/	/	birch bark tar, waxes
25MV-2	base	pitch markers, traces of WE	31.06		/	/	birch bark tar, waxes
26MV-1	base	pitch markers	1539.77		/	/	birch bark tar
26MV-2	base	FA10, FA12, FA14, FA16, FA18, pitch markers, WE	24.3	1.48	/	/	birch bark tar, waxes
27MV-1A	base	FA16, FA18, pitch markers	3308.1	1.33	/	/	birch bark tar
27MV-1B	base	FA16, FA18, pitch markers	118.18	1.34	/	/	birch bark tar
27MV-1C	base	FA16, FA17, FA18:1, FA18, pitch markers	740.32	1.71	/	/	birch bark tar, plant residue
27MV-2	base	/	0		/	/	n/a
28MV-1A	base	FA16, FA18, pitch markers, WE	3056.3	1.32	/	/	birch bark tar, plant residue, waxes
28MV-1B	base	FA16, FA18, pitch markers, WE	542.58	1.30	/	/	birch bark tar, plant residue, waxes
28MV-1C	base	FA16, FA18, pitch markers, WE	1261.79	1.68	/	/	birch bark tar, plant residue, waxes
28MV-2	base	FA16, A, OH, traces of WE	5.25		/	/	plant residue
29MV-1A	rim	/	18.03		/	/	n/a
29MV-1B	rim	FA16:1, FA16, FA18:1, FA18	8.06	1.89	/	/	plant residue
29MV-2	rim	FA14, FA16:1, FA16, FA17, FA18:1, FA18, FA20-FA24, K31-K35	27.57	1.02	/	/	mixed animal and plant residue, cooking
30MV-1	base	/	0		/	/	n/a
30MV-2	base	FA16, MAG16, DAG32, TAG54	17.69		/	/	plant residue
90MV	body	/	0		/	/	n/a
91MV	body	FA16, FA17, FA18-FA24, K29-K35	156.62	0.31	-27.53	-31.65	ruminant dairy fat, cooking
92MV	rim	FA14, FA16, FA18, FA20, MAGs, traces of DAGs and TAGs	29.41	1.02	-27.75	-30.35	mixed ruminant fat
93MV	body	FA14, FA16, FA17, FA18:1, FA18, MAGs, DAGs, TAGs	119.17	0.77	-27.92	-31.36	mixed ruminant fat
94MV	body	FA16, FA18, FA20	15.2	0.57	-28.41	-30.89	ruminant adipose fat
95MV	body	FA16, FA18, MAGs, traces of DAGs and TAGs	5.5	1.19	-26.65	-28.90	mixed animal fat
96MV	body	FA14, FA16, FA18, FA20, MAGs, DAGs, TAGs	9.51	0.81	-27.18	-31.09	dairy fat
97MV	body	FA16,FA18	10.52	0.92	/	/	mixed animal fat
98MV	rim	FA12, FA14, FA16, FA17br, FA17, FA18, MAGs, traces of A & OH, DAGs, traces of WE, TAGs	57.85	0.69	-28.62	-30.75	ruminant adipose fat, plant residue, waxes
99MV	body	FA16, FA18, A25-A33, OH24-OH34, FA24-FA32, WE, DWE	429.65	6.20	-26.09	-29.62	dairy fat, plant residue, waxes
100MV	rim	FA16, FA18, A25-A31, MAGs, OH24-OH34, DAGs, WE, DWE	449.81	0.57	-27.47	-29.44	ruminant adipose fat, waxes
101MV	body	/	0		/	/	n/a
102MV	rim	traces of FA16 & FA18, A25-A33, OH24-OH34, FA24-FA34, WE, DWE	399.78	2.86	-26.20	-33.48	plant residue, waxes
103MV	body	FA16, FA18, MAGs, traces of A&OH, DAGs, traces of WE	4.27		/	/	plant residue
104MV	body	FA14, FA16, FA17, FA18	214.36	0.65	-27.66	-30.22	ruminant adipose fat
105MV	body	/	0		/	/	n/a
106MV	body	FA16, FA18, traces of A&OH	4.51	2.15	/	/	plant residue
107MV	body	FA16, FA18	29.38	0.67	-26.68	-28.39	mixed animal fat
108MV	base	/	0		/	/	n/a
109MV	body	FA16, FA17, FA18	126.6	0.90	-26.14	-26.19	porcine fat
110MV	rim	FA16, DA17, FA18:1, FA18, FA20	1219.85	1.17	-24.90	-24.96	porcine fat
111MV	base	FA12, FA14, FA16, FA17, FA18:1, FA18, MAG16, A27-A33, OH24-OH34, FA24-FA28, WE	177.63	2.47	-25.40	-25.73	porcine fat, plant residue, waxes
112MV	rim	traces of A&OH, traces of DAGs, WE	5.22		/	/	plant residue
113MV	rim	traces of FA16 & FA18, A23-A33, OH24-OH34, WE	47.2		-26.36	-27.85	plant residue, waxes
114MV	base	FA16, FA18, A23-A33, OH22-OH34, FA24-FA30, WE	94.85	2.89	/	/	plant residue, waxes

Sample # CHEM	Vessel part	Biomarkers detected	Lipid concentration [µg g-1]	P/S ratio	$\delta^{13}C_{16:0}$ [‰]	$\delta^{13}C_{18:0}$ [‰]	Interpretation
115MV	body	/	0		/	/	n/a
116MV	body	FA16, FA18, A23-A33, OH22-OH34, FA26, WE	145.68	3.24	-26.68	-28.75	plant residue, waxes
117MV	body	/	0		/	/	n/a
118MV	body	/	0		/	/	n/a
119MV	body	/	0		/	/	n/a
120MV	body	FA16, FA17, FA18:1, FA18, FA20	197.58	0.81	-25.18	-25.15	porcine fat
121MV	body	A25-A33, OH24-OH34, FA24-FA32, WE	970.81		-26.89	-26.03	porcine fat, plant residue, waxes
122MV	body	traces of FA16 & FA18	2.18		/	/	n/a
123MV	body	/	0		/	/	n/a
124MV	body	FA14, FA16, FA17, FA18:1, FA18, FA20	503.45	1.65	-24.24	-23.99	porcine fat
125MV	body	A23-A31, OH24-OH32, traces of WE	12.57		/	/	waxes
126MV	rim	traces of A&OH	1.4		/	/	n/a
127MV	body	traces of A&OH	1.74		/	/	n/a
128MV	body	/	0		/	/	n/a
129MV	body	/	1.07		/	/	n/a
130MV	body	/	0		/	/	n/a
131MV-1	body	/	0		/	/	n/a
131MV-2	body	/	0		/	/	n/a
132MV	body	FA16, FA17, FA18	13.45	0.60	-26.57	-29.84	mixed ruminant fat
133MV	rim	FA14, FA16, FA17br, FA17, FA18, K	17.61	0.88	/	/	mixed animal fat, cooking
134MV	rim	FA14, FA16, FA17br, FA17, FA18, MAGs, OH22-OH32, A29-A31, DAGs, WE, TAGs	289.58	0.54	-28.35	-29.94	ruminant adipose fat, plant residue, waxes
135MV	body	FA16, FA17, FA18, MAGs, traces of DAGs & TAGs	47.71	1.41	-27.47	-26.99	porcine fat
136MV	body	/	1.06		/	/	n/a
137MV	body	FA14, FA16, FA18	14.27	0.46	-28.64	-31.15	ruminant adipose fat
138MV	body	/	0		/	/	n/a
139MV	body	/	0		/	/	n/a
140MV	body	FA16, FA18, traces of A&OH; traces of DAGs&WE	4.14	1.12	/	/	mixed residue
141MV	rim	/	0		/	/	n/a
142MV	base	/	0		/	/	n/a
143MV	rim	FA16, FA18, MAGs, OH22-OH32, A27-A33, DAGs, TAGs	6.17	0.91	-27.66	-30.71	ruminant adipose fat, plant residue
144MV	base	FA16, FA18, FA20	9.76	1.45	-26.38	-29.28	ruminant adipose fat
145MV	body	traces of FA16 & FA18, A27-A31, OH22-OH32, traces of DAGs, WE & TAGs	6.82		/	/	mixed residue
146MV	base	/	0		/	/	n/a
147MV	base	FA12, FA14, FA15, FA16, FA17, FA18:1, FA18, FA20-FA30, MAGs, A25-A33, OH22-OH32, DAGs, WE	37.61	0.53	/	/	mixed animal and plant residue, waxes
148MV	rim	/	0		/	/	n/a
149MV	rim	FA14, FA16, FA17br, FA17, FA18, FA20-FA26, MAGs, A23-A33, OH22-OH32, DAGs, traces of TAGs	20.49	0.76	-26.71	-29.22	ruminant adipose fat, plant residue
150MV	rim	FA16, FA17, FA18, MAGs, A27-A33, OH24-OH32, DAGs, traces of TAGs	9.63	0.73	-27.42	-30.82	ruminant fat, plant residue
151MV-1	body	traces of FA16 & FA18, pitch markers	2918.51		/	/	birch bark tar
151MV-2	body	FA16, FA18, pitch markers	91.85	0.44	/	/	animal fat, birch bark tar
152MV-1	body	traces of FA16 & FA18, pitch markers, traces of TAGs	2818.76	0.91	/	/	mixed animal fat, birch bark tar
152MV-2	body	/	0		/	/	n/a
153MV	body	FA14, FA15, FA16, FA17br, FA17, FA18:1, FA18, FA20, MAGs, DAGs, traces of TAGs	55.01	0.76	-27.70	-29.97	ruminant adipose fat
154MV	body	FA14, FA15br, FA15, FA16, FA17br, FA17, FA18, FA20-FA28, MAGs, A23-A33, OH22-OH32, traces of DAGs & TAGs, WE	607.11	0.29	-27.96	-31.10	ruminant fat, plant residue, waxes
155MV	rim	FA14, FA16, FA17, FA18:1, FA18, traces of DAGs & TAGs	7.15	0.56	-29.17	-31.37	ruminant adipose fat

Lipids, pots and food processing at Hočevarica, Ljubljansko barje, Slovenia

Nives Ogrinc [1], Mihael Budja [2], Doris Potočnik [1], Andreja Žibrat Gašparič [2] and Dimitrij Mlekuž [2]
[1]Department of Environmental Sciences, Jožef Stefan Institute, Ljubljana, SI
nives.ogrinc@ijs.si; doris.potocnik@ijs.si
[2]Department of Archaeology, Faculty of Arts, University of Ljubljana, SI

ABSTRACT – *The paper presents the results of lipid analyses of pottery samples from Hočevarica (Ljubljansko barje, Slovenia). Total lipid extracts were subjected to high temperature gas chromatography (HT-GC), gas chromatography- mass spectrometry (GC-MS) and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS). The results show that some vessels were used for preparing ruminant meat and vegetable, but also the remains of aquatic food were identified. The processing of non-ruminant meat was detected in a few samples. A high number of pottery samples yielded the presence of beeswax lipids. The charred residual on pottery was AMS ^{14}C dated.*

IZVLEČEK – *V članku predstavljamo rezultate analiz lipidov ohranjenih v keramičnem zbiru s Hočevarice. Lipide, ekstrahirane iz ostankov keramičnih posod, smo analizirali s pomočjo plinske kromatografije pri visokih temperaturah (HT-GC), plinske kromatografije sklopljene z masno spektrometrijo (GC-MS) in plinske kromatografije sklopljene z masnim pektrometrom za analizo stabilnih izotopov lahkih elementov preko sežigne enote (GC-C-IRMS). Rezultati kažejo, da so v posodah pripravljali hrano iz mesa prežvekovalcev in zelenjave; redko iz mesa neprežvekovalcev. V drugih so pripravljali hrano iz sladkovodnih rib. V številnih posodah je bil odkrit čebelji vosek. Karbonizirani ostanki na posodah so bili AMS ^{14}C datirani.*

KEY WORDS – *lipid analysis; ^{14}C dates; pottery; Eneolithic; Ljubljansko barje*

Introduction

Hočevarica is located at the outfall of Hočevarica drainage channel into the Ljubljanica River between Blatna Brezovica and Verd on the western part of the Ljubljansko barje area (Fig. 1). A small trench (8m^2) was excavated in 1998 (*Veluščček 2004a*). The site was recognised as a pile-dwelling settlement embedded in the time span 3650–3520 calBC (for wood samples) (*Čufar, Kromer 2004.283*) and 3640–3530 calBC (for short-lived seed and carbonised grain samples) (*Jeraj 2004.59*).

The site stratigraphy consists of ten layers (Fig. 2). While some are of geological provenance, layers 4–8 relate to settling and can be associated with two settlement phases (*Veluščček 2004b.37–40; 2004c.213–217*). Patches of burnt clay and daub (*e.g.*, house remains) are deposited in well-defined stratigraphic superposition; they correlate with the distribution of vertical wooden piles, and depositions of pottery, stone and wooden tools within the stratified settlements' layers (*ibid. 40–47*).

Palaeobotany and archaeozoology

More than 30000 remains of seeds and fruits of cultivated and gathered wild plants have been found in both settlement contexts. While cereal grains were carbonised, most of the remaining plant remains were unburned. The grains of cultivated *Hordeum vulgare* (six-rowed barley), *Triticum monococcum*

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(einkorn wheat) and *Triticum dicoccum* (*T. turgidum ssp. Dicoccum*, emmer wheat) were identified; the most abundant cereal at Hočevarica is barley.

However, the remains of wild nuts, fruits and seeds predominated in the archaeobotanical assemblage, comprising *Quercus sp. Cupulae* (acorn), *Corylus avellana* (hazelnut), *Malus sylvestris* (crab apple), *Prunus avium* (wild cherry), *Cornus mas* (Cornelian cherry), *Cornus sanguinea* (common dogwood), *Prunus spinosa* (blackthorn), *Rubus fruticosus* (blackberry), *Fragaria vesca* (wild strawberry), *Physalis alkekengi* (winter cherry), and *Trapa natans* (water chestnut). Along with *Papaver somniferum* (opium poppy) seeds, the only remains of an oily plant, *Chenopodium album* (goosefoot), which has seeds rich in oil and starch, were also gathered. Pulses such as *Lathyrus sativus* (grass pea) and *Vicia sp.* (*Vitis vinifera ssp. Sylvestris*, wild grapevine) were found in small numbers in the 1st settlement phase (*Jeraj 2004.58–59; 2009. 79–82*).

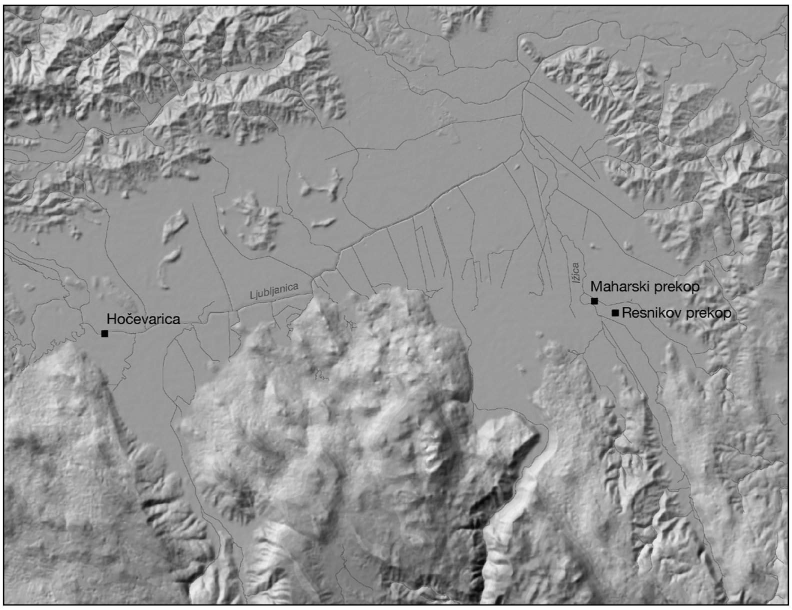

Fig. 1. Map of Ljubljansko barje region with the position of the site at Hočevarica.

It was suggested that while cereals were cultivated in fields situated on moist to damp soils close to the settlement, wild nuts, fruits and seeds were collected along the forest edges and in clearings around the settlement. The water plants were collected in small and shallow meso- to eutrophic lakes which warm up in summer. All the wild plants have been processed in settlement contexts (*Tolar* et al. *2011.216*).

Lab code	Material	Phase	^{14}C Conventional age BP	Calibrated date calBC (2σ)	Reference
Hd-18976	wood		4822±39	3695–3521	*Čufer, Kromer 2004.Tab. 6.3.2*
Hd-22139	wood		4867±26	3702–3636	*Čufar* et al. *2010.Tab. 4**
Hd-20765	wood		4748±26	3636–3382	*Čufar* et al. *2010.Tab. 4**
Hd-22305	wood		4825±25	3656–3530	*Čufar* et al. *2010.Tab. 4**
?	organic sediment		4780±40	3648–3383	*Jeraj 2004.62***
??	seed	2	4780±40	3648–3383	*Jeraj 2004.59*
???	grain	1	4810±40	3691–3518	*Jeraj 2004.59*
Beta-391181	food residue	2	4910±30	3763–3642	
Beta-391176	food residue	1	4860±30	3704–3539	
Beta-391182	food residue	2	4770±30	3641–3519	
Beta-391178	bos taurus	1	4760±30	3641–3384	
Beta-391183	ovis/capra	2	4740±30	3639–3379	
Beta-391185	*Cornus* stone	2	4720±30	3635–3376	
Beta-391180	*Cornus* stone	1	4680±30	3623–3370	
Beta-391177	food residue	1	4780±30	3635–3531	

Tab. 1. Radiocarbon dates from Hočevarica. Dates marked with an asterisk (*) are inconsistently published (Hd-22139 as 4972±25 and Hd-20765 as 4746±26 in* Čufar, Kromer 2004*). Date for organic sediment (marked by **) by Jeraj (2004) is the same age as date for seed in phase 2. Since Jeraj does not cite lab codes for dates, it is possible that both are the same sample.

The animal bone assemblage consists of 4352 animal remains. About a third of them are fishes and birds, the remainder (63.4%) are mammals. The mammal bones (2757 total) are from at least 14 species (*Toškan, Dirjec 2004.76–132*). Roe deer (*Capreolus capreolus*) remains predominate, comprising a good third of the mammalian assemblage; the second most frequent was pig/wild boar (*Sus sp.*), accounting for one third. Other species were less frequent. Only red deer (*Cervus elaphus*), beaver (*Castor fiber*), dog (*Canis familiaris*), and the remains of sheep and goat (*Ovis s. Capra*) exceeded 5% of all finds. While *Sus scrofa/domesticus* bones predominate (38.2%) in the 1st settlement phase, *Ovis s. Capra* remains are the most frequent (19.7%) in the 2nd phase (*ibid. 80*).

The evidence of animal slaughter and further meat processing at the site are weak. The proportion of bones with cut and chop marks and/or traces of boiling or roasting was below 10%. However, the analysis of tooth wear showed that most of the pigs were slaughtered in the autumn at an assessed age of 17 to 22 months, and during winter or in early spring, at a probable age of 22 to 27 months (*Toškan, Dirjec 2004.121*). The fish remains consist of five species: common carp, rudd, pike, perch and roach. The carp and rudd remains predominate (*Govedič 2004.133–151*).

Chronology

The Hočevarica radiocarbon sequence is comprised of 13 AMS radiocarbon dates. In addition to the series of four dates on wooden piles used to anchor the dendrochronological sequence and two dates obtained on short-lived botanical samples, an additional two AMS radiocarbon dates from animal bones, two AMS dates on short-lived botanical samples and four dates of carbonised food residues on pottery were obtained recently (Tab. 1).

Complementary samples allow a better understanding of the chronology of activities at the site. The radiocarbon dates of bones and carbonised food/organic residues on pottery date events relating to the preparation and disposal of food, and thus complement the dates of the wooden structures relating to building and construction events. The floating oak chronology of 139 years from Hočevarica (HOC-QUSP1) is dated between 3685 and 3547 (±10) BC, which suggests an end to building activities after around 3550 BC (*Čufar* et al. *2010*).

On the other hand, the majority of AMS dates on short-lived samples concentrate between 3630–3350 calBC (Fig. 3). The wide spread of values can be attributed to a wiggles in the calibration curve between 3620–3520 and 3480–3380 calBC. However, it seems that activities at the site reflected in the short-lived samples began well before the end of the building activities, before 3600 calBC, and continued for a few decades after building activities had ended. This long span of activities corresponds well with the two settlement phases.

Two dates on charred food residues on pottery are older than the oldest dates on the wooden piles. Lipid analysis on one sample (Beta-391176) from the first phase yielded a lipid concentration high enough (01HO; Tab. 2) to suggest that the pot was used to cook a ruminant/plant mixture. The concentration of lipids in the other sample (Beta-391181, 18HO; Tab. 2) was too low to allow a determination of foodstuffs. However, as this sample is associated with the second phase, it appears too old. At the moment, we have no dates on fish bones or food residues associated with aquatic foodstuffs that would demonstrate the presence of a reservoir effect. Therefore, both early dates could suggest earlier activities at the site or a reservoir effect.

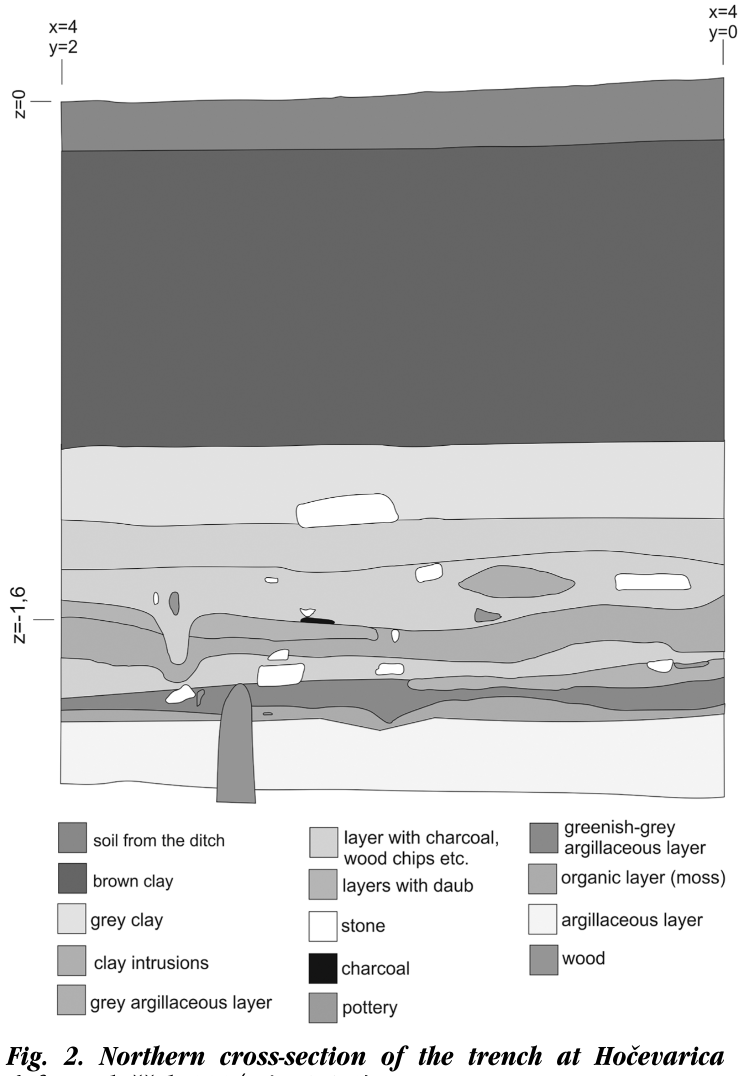

Fig. 2. Northern cross-section of the trench at Hočevarica (after* Velušček 2004.Fig. 3.1.5*).

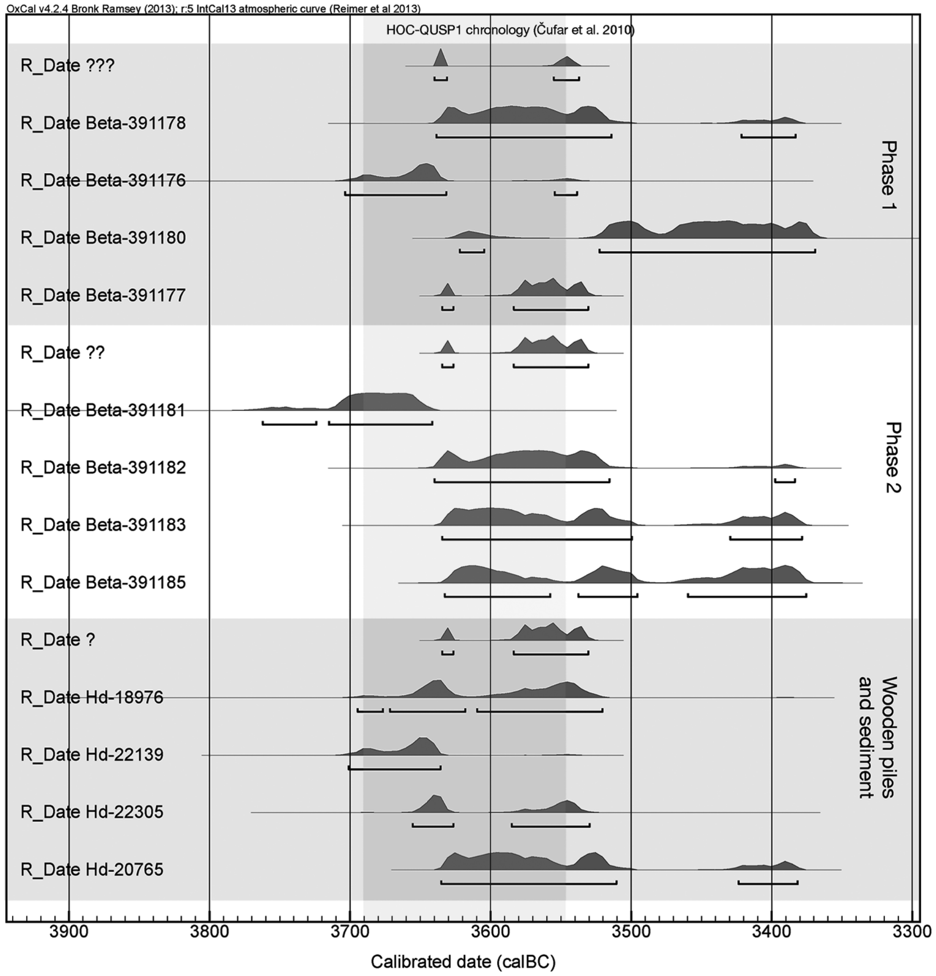

Fig. 3. Calibrated radiocarbon dates from Hočevarica in relation to the HOC-QUSP1 chronology.

These new dates suggest a long and complex chronological sequence for the Hočevarica site. It appears that the site was settled for almost 200 years, had two distinct phases of occupation, and shows possible evidence of activities before the wooden structures were built.

The pottery

For the present study, we analysed 35 pottery samples from Hočevarica by hand lens to identify inclusions, their size and frequency, and the presence of voids. The samples were chosen on the basis of typology (see *Velušček 2004d.169–212*) and on the basis of the presence of charred food remains on the interior surface of the vessels. Most of the samples came from fragments of vessel rims and walls; only 9 samples were attributed to types according to their morphology: 3 pots, 4 dishes, and 2 bowls (Fig. 4; Tab. 2).

The vessel types are similar to the pottery assemblage from the contemporary site at Maharski prekop in the south-eastern part of Ljubljansko barje (*Bregant 1974a; 1974b; 1975; Velušček 2004d. 184–212*). The majority of the vessels can be attributed to various types of pots (*Velušček 2004d.186–194*) and dishes (*ibid. 196–203*), but other forms are also present (cups, miniature vessels, hanging vessels and other special forms; *ibid. 195, 203*).

Similarly, the technological characteristics of the Hočevarica pottery assemblage are comparable to vessels from Maharski prekop (*Žibrat Gašparič 2013. 153–155*). The vessels area primarily dark grey, brown and black, and most were fired in a reducing atmosphere. Most of the pottery is poorly made and prone to mechanical decomposition; only the decorated vessels are of better quality and have polished surfaces or slips applied to the surface (*Velušček 2004d.184–185*).

We could divide the pottery samples into two technological groups according to their inclusions (descriptions after *Horvat 1999*): most of the samples have calcite/limestone inclusions (82.8%), while the

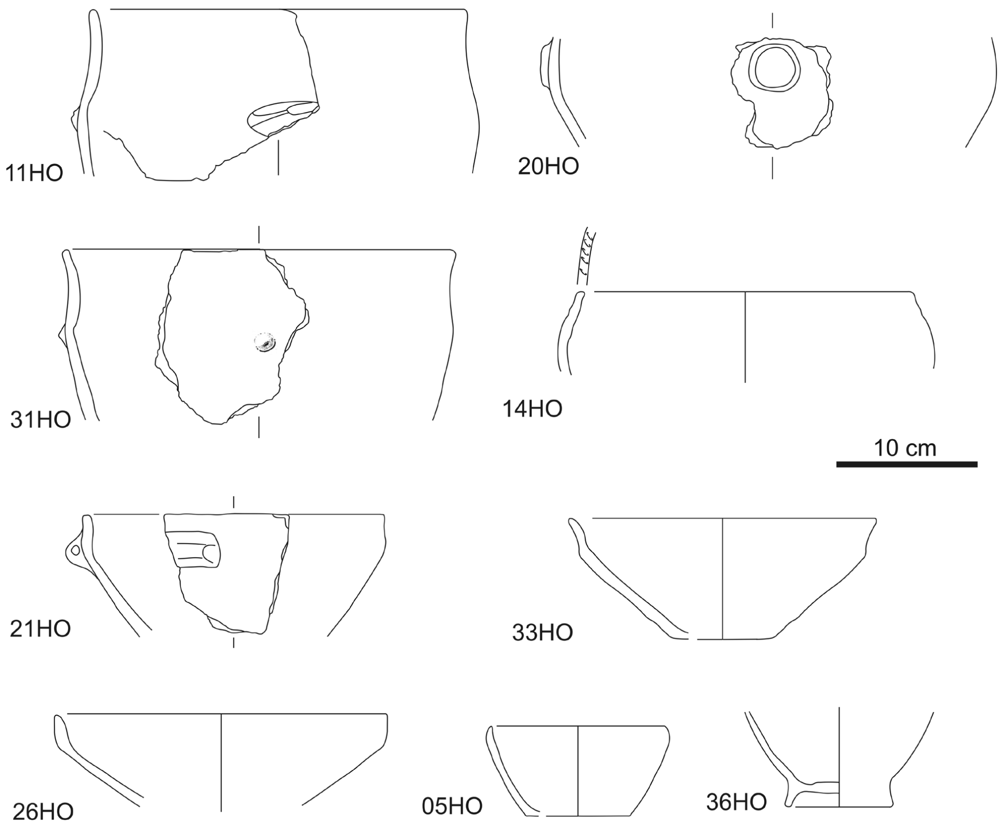

Fig. 4. Pottery samples bearing traces of ruminant fat (14HO, 33HO), mixed animal fats (05HO), mixed animal and plant fats (31HO), mixed animal fats and beeswax (21HO, 26HO, 36HO), freshwater animal oils (11HO) and a mixture of dairy fat and beeswax (20HO) (drawings after* Velušček 2004a.169–183*).

remainder are made of non-calcareous clay and have only quartz inclusions (17.2%). In the group with quartz, most of the inclusions comprise very fine (less than 0.25mm) or medium-size sand (0.25 to 0.50mm). Most of the samples with calcite/limestone have medium-size sand inclusions (0.25 to 0.50mm), but coarse sand is present (0.50 to 2.00mm) in a third of the samples.

The pottery samples from Hočevarica have voids, usually on both surfaces, in the size of medium to coarse sand fraction, and many have an angular shape similar to calcite crystals. This could be the result of calcite dissolved from the vessels. Such chemical changes in pottery are common post-depositional processes (*Rice 1987.421*). A similar situation could be observed at the contemporary site at Krašnja near Lukovica (*Žibrat Gašparič* et al. *2014*).

All the pottery samples were handmade and their surfaces burnished; smoothing and polishing were also present. One of the vessels (10HO) was decorated with a grey-black slip on both the interior and exterior surfaces. They were fired in an incomplete oxidising (51.4%) and a reducing atmosphere (34.3%), while the other samples were fired in a reducing atmosphere with an oxidising atmosphere at the end of firing.

The pottery from the calcite/limestone group at Hočevarica has characteristics very similar to fabric MP-1 from Maharski prekop, which is a non-calcareous clay with frequent calcite grains added as temper and is the most common fabric found at that site (*Žibrat Gašparič 2013.154*). On the other hand, the group with quartz inclusions from Hočevarica differs from the fabrics described at Maharski prekop and could display a new technology in the later phase of the settlement, since the samples of the quartz group all come from the 2nd settlement phase at Hočevarica. This hypothesis would have to be tested with additional pottery samples, as well as with a petrographical analysis of thin sections.

Materials and methods

A total of 36 selected pottery samples were first cleaned to remove exogenous lipids, and then ground to a fine powder. For lipid extraction, about 2g of sample were transferred to a 50ml vial and 20µl of internal standard (*n*-tetratriacontane, 1mg/mL in *n*-hexane) were added. Lipids were ultrasonically extracted with a mixture of methanol and chloroform (1:2 v/v, 24mL, 2 x 30min). The solvent extract was removed into a glass flask and reduced to a small volume by rotary evaporation. The residue of solvent extract was transferred to a 2ml glass vial and evaporated to dryness under a gentle stream of nitrogen to obtain the total lipid extract (TLE). The aliquot (500µl) of the TLE was treated with BSTFA (N, O-bis(trimethylsilyl)-trifluoroacetamide, 40µl; 70°C, 60min), evaporated to dryness and re-dissolved in *n*-hexane. The resulting trimethylsilyl derivatives were analysed using high-temperature gas chromatography (HT-GC) and, where necessary, combined GC-MS analyses were performed to identify the structure of the components (*Evershed* et al. *1990*). All HT-GC analyses were performed on Agilent Technology 6890N GC system equipment with DB-5HT capillary column (15m x 0.32m x 0.10µm). Temperature program: initial temperature 50°C (1min), increasing to 350°C (10 min) at a rate of 10°C/min. Helium was used as a carrier gas and a flame ionisation detector to monitor the column effluent.

Another aliquot (500µL) of solvent extract was used to prepare free fatty acids methyl esters (FAMEs) by adding 100µL of BF3-methanol (14% w/v, Sigma Aldrich, 70°C, 60min). The methyl derivatives were extracted with *n*-hexane and analysed by GC-MS and GC-C-IRMS using standard protocols (*Evershed* et al. *1994; Mottram* et al. *1999; Greg, Slater 2010; Ogrinc* et al. *2012*). For GC-C-IRMS (Isoprime GV system, Micromass, Manchester, UK) the accuracy of repeated measurements was ±0.3‰.

In addition, powder samples (~1mg) were analysed by elemental analysis isotope ratio mass spectrometry (IRMS) as previously reported (*Ogrinc* et al. *2012; Budja* et al. *2013*). Stable isotope results are expressed as $\delta^{13}C$ or $\delta^{15}N$ values in per mil (‰) relative to the VPDB and AIR international standard, respectively. The accuracy of measurements was ±0.2‰ for $\delta^{13}C$ and ±0.3‰ for $\delta^{15}N$.

Results and discussion

The average and standard deviations from bulk potsherd samples are –28.3±1.6‰ and +4.5±2.0‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively (Fig. 5; Tab. 2). These data fall in the range expected for C_3 plant and degraded animal tissues whose subsistence was based mainly on C_3 plants. The $\delta^{15}N$ values of terrestrial plant proteins are around +3‰, while proteins derived from terrestrial herbivores from temperate Europe should not exceed $\delta^{15}N$ values of +7.0‰ (*Richards* et al. *2003*), although protein derived from domestic animals (such as pigs) may be higher (*Privat* et al. *2002; Polet, Katzenberg 2003; Richards* et al. *2003; Ogrinc, Budja 2005*). At Hočevarica, only three samples (01HO, 03HO and 06HO) have $\delta^{15}N$ values higher than +7.0‰. Thus the variations in the carbon and nitrogen isotope ratios in our sample show that a wide diversity of animal and plant food was processed in the vessels. No sample has an $\delta^{15}N$ value greater than 9‰ consistent with processing aquatic products with a high trophic level (Fig. 5). However, data on fish species from modern and archaeological samples from lacustrine environments demonstrates a wide range of nitrogen values due to the diverse mixture of aquatic food sources. For example, the $\delta^{15}N$ values of freshwater fish in Lake Baikal range from +7.3 to +13.7‰ (*Katzenberg, Weber 1999*). And Melanie J. Miller *et al.* (*2010*) reported that the modern fish $\delta^{15}N$ values of Lake Titicaca range from +4.1 to +9.5‰, while the majority of the $\delta^{15}N$ values in archaeological fish samples ranged from +5.1 to +7.7‰.

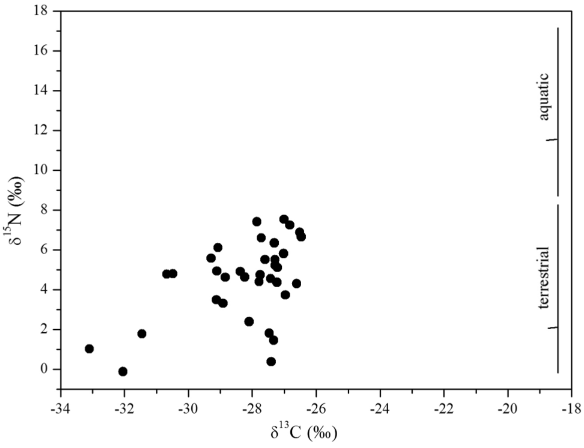

Fig. 5. Bulk stable isotope values of pottery samples from Hočevarica. The vertical bars show 95% confidence intervals and the median stable nitrogen isotope value from literature data.

In order to obtain more reliable information on the processing of different commodities in pottery vessels from Hočevarica, more specific chemical and molecular analysis, including lipid analysis, were performed. Lipid preservation in our samples was very good, with more than 75% of potsherds containing appreciable quantities of lipid (Tab. 2).

Lipid biomarkers

Even-carbon number *n*-alkanoic acids that range from $C_{12:0}$ to $C_{22:0}$ were observed in analysed sherds (Fig. 6). In addition, monounsaturated fatty acids

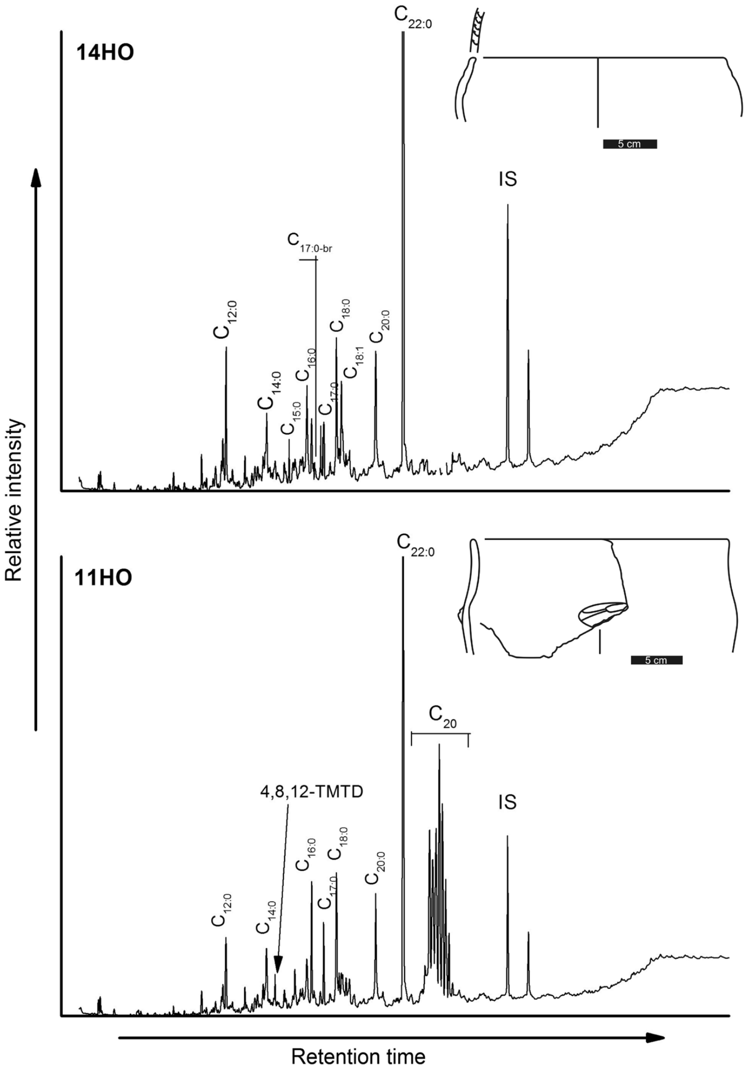

Fig. 6. The representative GC-MS total ion chromatograms of the fatty acids methylesters (FAMEs) with different $C_{16:0}$ and $C_{18:0}$ abundance extracted from the Hočevarica pottery samples 11HO and 14HO.

$C_{18:1}$ were present in the lipid extracts of all samples (Tab. 1). The presence of odd number ($C_{15:0}$ and $C_{17:0}$) and/or a low amount of branched chain of $C_{17:0}$ was determined in 50% of the pottery samples (02HO, 05HO, 14HO, 20HO, 21HO, 22HO, 25HO, 26HO, 27HO, 31HO, 33HO, 34HO, 36HO). The presence of these acids together with two double bonds positional isomers of $C_{18:1}$ indicates ruminant animal fats that have been biosynthesised in the gut and rumen (*Dudd* et al. *1999; Regert 2011*). The parallel biomarkers, *i.e.* triacylglycerols (TAGs) and their degradation products (diacylglicerols (DAGs) and monoacylglicerols (MAGs) were detected in 9 sherds (02HO, 05HO, 14HO, 20HO, 21HO, 26HO, 27HO, 34HO, 36HO), confirming the presence of degraded animal fats (Tab. 2; Fig. 7). However, the TAG distribution could be identified in three sherds (20HO, 21HO and 26HO), while in the remaining samples only traces of TAGs were observed. The narrow distribution of TAGs in these three sherds, ranging from C_{42} to C_{52}, indicates the presence of ruminant adipose or diary fats.

The presence of saturated and monosaturated fatty acids in a range from C_{20} to C_{24}, together with a high proportion of $C_{16:0}$ and minor amounts of $C_{12:0}$ and $C_{18:0}$ acids are indicative of aquatic oils and thus provide evidence that freshwater foods were processed in these vessels (*Hansel* et al. *2004; Craig* et al. *2011; 2013; Cramp* et al. *2014*). Such a lipid profile was observed in 35% of the samples (04HO, 06HO, 09HO, 10HO, 11HO, 12HO, 13HO, 17HO and 18HO). In addition, in these samples 4,8,12-trimethyltridecanoic acid (4,8,12-TMDT) at low concentrations was also identified. This component is a characteristic lipid biomarker of aquatic resources (*Hansel* et al. *2004*) (Fig. 6).

Alongside the identification of animal or aquatic fats, a high percentage of samples (81%) yielded the presence of beeswax lipids (Tab. 2). In five samples (20HO, 21HO, 25HO, 26HO, 36HO) the lipid distribution indicate the high content of degraded beeswax lipids, while in other samples only traces of wax lipids are present. Beeswax lipids may indicate the addition of honey to other foodstuffs or the application of beeswax to pottery vessels to improve impermeability (*Regert* et al. *2001; Kimpe* et al. *2002; Copley* et al. *2005*). Although in most of the samples only trace levels of this particular commodity were detected, its presence indicates that beeswax was utilised at Hočevarica in pottery vessels associated with cooking/processing foodstuffs or applied as a coating.

Long-chain ketones (C_{31}, C_{33} and C_{35}) were observed in most samples with preserved lipids, except in 05HO. Long-chain ketones have been widely reported as components of the epicuticular waxes of higher plants (*Walton 1990*), but can be also formed from the condensation of fatty acids ($C_{16:0}$ and $C_{18:0}$) during the heating of vessels to temperatures in excess of 400°C (*Evershed* et al. *1999*). The presence of long-chain ketones together with thermally pro-

Lab. sample no.	ID. No.	Context	^{14}C Lab. no.	14C conv. age BP	Fabric group	Desciption	TLE (μg g^{-1})	$\delta^{13}C$ bulk (‰)	$\delta^{15}N$ bulk (‰)	$\delta^{13}C_{16:0}$ (‰)	$\delta^{13}C_{18:0}$ (‰)
01HO	126	phase 1	Beta-391176	4860±30	calcite	vessel wall	36.5	-26.8	7.2	-29.0	-29.1
02HO	165	phase 1	Beta-391177	4780±30	calcite	vessel wall	25.3	-29.1	4.9	-28.0	-29.2
03HO	073	phase 1			calcite	vessel wall	48.3	-27.0	7.5	n/d	n/d
04HO	075	phase 1			calcite	vessel rim with wall	32.9	-27.7	6.6	-31.0	-25.7
05HO	080	phase 1			calcite	dish	39.0	-27.3	5.5	-27.8	-27.4
06HO	135	phase 1			calcite	vessel wall	96.5	-27.9	7.4	-31.1	-27.3
07HO	138	phase 1			calcite	vessel wall	42.7	-32.0	-0.1	-34.3	-29.0
08HO	174	phase 1			calcite	vessel rim with wall	40.8	-27.4	0.4	-29.8	-28.2
09HO	087	phase 1			calcite	vessel rim with wall	13.1	-31.5	1.8	-30.7	-27.1
10HO	076	phase 1			calcite	vessel rim with wall	10.9	-27.8	4.7	-32.2	-28.5
11HO	PN0081	phase 1			calcite	pot	71.3	-29.1	3.5	-29.8	-27.7
12HO	068	phase 1/2			calcite	vessel rim with wall	78.6	-26.5	6.9	-30.7	-28.5
13HO	067	phase 1/2			calcite	vessel wall	37.8	-27.0	3.7	-32.4	-27.6
14HO	PN0135	phase 1/2			calcite	pot	51.5	-27.5	1.8	-25.5	-27.9
16HO	049	phase 1/2			calcite	vessel wall	108	-27.3	1.5	-36.0	-29.9
17HO	082	phase 2			calcite	vessel base with wall	27.8	-26.6	4.3	-31.5	-28.8
18HO	088	phase 2	Beta-391181	4910±30	calcite	vessel wall	5.9	-28.4	4.9	n/d	n/d
19HO	029	phase 2			calcite	vessel wall	3.1	-27.8	4.4	n/d	n/d
20HO	032	phase 2			quartz	pot?	211	-30.7	4.8	-27.3	-33.9
21HO	PN0049	phase 2			quartz	dish	63.3	-30.5	4.8	-26.7	-28.5
22HO	035	phase 2	Beta-391182	4770±30	calcite	vessel wall	29.2	-27.3	6.3	-29.8	-29.1
23HO	020	phase 2			calcite	vessel wall	23.6	-27.0	5.8	-30.6	-26.8
24HO	017	phase 2			quartz	vessel rim with wall	2.1	-27.6	5.5	n/d	n/d
25HO	169	phase 2			quartz	vessel wall	73.9	-27.2	5.1	-26.5	-28.4
26HO	025	phase 2			quartz	dish	53.3	-27.3	5.2	-28.4	-29.2
27HO	019	phase 2			calcite	vessel wall	15.9	-27.2	4.4	-30.3	-31.4
28HO	120	phase 1			calcite	vessel wall	1.6	-28.2	4.6	n/d	n/d
29HO	121	phase 1			calcite	vessel wall	6.0	-29.3	5.6	n/d	n/d
30HO	089	phase 1			calcite	bowl	4.7	-26.5	6.7	n/d	n/d
31HO	085	phase 1			calcite	pot	26.4	-28.8	4.6	-28.6	-28.2
32HO	078	phase 1			calcite	vessel wall	18.3	-29.1	6.1	n/d	n/d
33HO	061	planum 4/4			calcite	dish	12.4	-27.4	4.6	-28.1	-29.5
34HO	008	SU 4/7			quartz	vessel wall	7.0	-28.9	3.3	-26.3	-27.2
35HO	003	SU 1/2			calcite	vessel wall	6.9	-33.1	1.0	n/d	n/d
36HO	PN0138	E cross-section			calcite	bowl?	6.2	-28.1	2.4	-28.2	-29.1

Tab. 2. A summary of the organic residues detected in pottery samples from Hočevarica, Ljubljansko barje region. Key: MAG – moniacylglycerols; DAG – diacylglycerols; TAG – triacylglycerols; A – **n*-alkanes; OH –*** **n*-alcohols; K – ketones; WE – wax esters; (tr) – trace; n/d – not detected.***

$\Delta^{13}C$ (‰)	$C_{16:0}/C_{18:0}$	Fatty Acids (FA)	Other lipids	Predominant commodity type	Reference
0.0	1.48	$C_{12:0}$, $C_{14:0}$, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE	mixture ruminant, plant	Not published
-1.2	1.45	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0\text{-br}}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE, DAG(tr), TAG(tr)	ruminant	Not published
n/d	n/d	n/d	K	n/d	Not published
5.3	1.50	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{16:0}$, $C_{17:1}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K	freshwater	Not published
0.4	0.74	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	WE, DAG, TAG	mixture ruminant, non-ruminant	*Velušček 2004.Pl. 4.1.5:7*
3.8	1.44	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{16:0}$, $C_{17:1}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	Not published
5.3	2.80	$C_{12:0}$, $C_{14:0}$, $C_{16:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	non-ruminant	Not published
1.6	0.76	$C_{12:0}$, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	non-ruminant	Not published
3.6	3.79	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	Not published
3.7	1.97	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	Not published
2.1	0.94	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	*Velušček 2004.Pl. 4.1.3:2*
2.2	1.15	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	Not published
4.8	0.74	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	Not published
-2.4	0.74	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0\text{-br}}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE, TAG(tr)	ruminant	*Velušček 2004.Pl. 4.1.6:5*
6.1	2.22	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{15:0}$, $C_{16:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	Not published
2.7	1.35	$C_{12:0}$, $C_{14:0}$, TMDT, $C_{15:0}$, $C_{15:1}$, $C_{16:0}$, $C_{16:1}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	freshwater	Not published
n/d	n/d	n/d	n/d	n/d	Not published
n/d	n/d	n/d	n/d	n/d	Not published
-6.6	1.19	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{16:1}$, $C_{17:0\text{-br}}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{21:0}$, $C_{20:0}$, $C_{22:0}$, $C_{24:0}$	A, OH, K, WE, MAG, DAG, TAG	mixture ruminant dairy fats and degraded beeswax	*Velušček 2004.Pl. 4.1.9:10*
-1.8	1.26	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$, $C_{24:0}$	A, OH, K, WE, DAG, TAG	mixture ruminant fats and degraded beeswax	*Velušček 2004.Pl. 4.1.8:1*
0.7	1.22	$C_{12:0}$, $C_{14:1}$, $C_{15:0}$, $C_{16:0}$, $C_{17:1}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K	mixture ruminant, plant	Not published
3.8	2.02	$C_{12:0}$, $C_{14:0}$, $C_{16:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K	non-ruminant	Not published
n/d	n/d	n/d	n/d	n/d	Not published
-1.9	1.93	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$, $C_{24:0}$	A, OH, K, WE	mixture ruminant fats and degraded beeswax	Not published
-0.8	2.28	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$, $C_{24:0}$	A, OH, K, WE, MAG, DAG, TAG	mixture ruminant fats and degraded beeswax	*Velušček 2004.Pl. 4.1.10:2*
-1.1	0.85	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{15:1}$, $C_{16:0}$, $C_{17:0\text{-br}}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, DAG(tr), TAG(tr)	ruminant	Not published
n/d	n/d	n/d	n/d	n/d	Not published
n/d	n/d	n/d	n/d	n/d	Not published
n/d	n/d	n/d	n/d	n/d	Not published
0.4	1.11	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{15:1}$, $C_{16:0}$, $C_{17:0}$, $C_{17:1}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K, WE(tr)	mixture ruminant, plant	*Velušček 2004.Pl. 4.1.3:3*
n/d	n/d	n/d	n/d	n/d	Not published
-1.4	1.67	$C_{12:0}$, $C_{14:0}$, $C_{16:0}$, $C_{17:0\text{-br}}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	K	ruminant	*Velušček 2004.Pl. 4.1.7:1*
-1.0	0.24	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{15:1}$, $C_{16:0}$, $C_{16:1}$, $C_{17:0\text{-br}}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{21:0}$, $C_{20:0}$, $C_{22:0}$, $C_{24:0}$	K, TAG, WE(tr)	ruminant	Not published
n/d	n/d	n/d	n/d	n/d	Not published
-0.9	0.81	$C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:1}$, $C_{18:0}$, $C_{20:0}$, $C_{22:0}$	A, OH, K, WE, DAG(tr), TAG(tr)	mixture ruminant fats and degraded beeswax	*Velušček 2004.Pl. 4.1.7:3*

duced ω-(*o*-alkylphenyl)alkanoic acids implies that their formation is mainly related to heating to high temperatures.

Stable carbon isotope composition of fatty acids

Further information regarding the source of the organic residues was obtained by measuring the stable carbon isotope ratio of saturated fatty acids $C_{16:0}$ and $C_{18:0}$ preserved in sufficient quantities in the pottery samples. The results were compared with modern reference animal data obtained from the literature presented in Figure 8 (*Evershed* et al. *2002; Copley* et al. *2005; Craig* et al. *2007; 2012*).

Twelve samples (04HO, 06HO, 07HO, 08HO, 09HO, 10HO, 11HO, 12HO, 13HO, 16HO, 17HO and 23HO) yielded $\delta^{13}C$ values closer to those of lipid extracts from modern pottery vessels used to prepare freshwater and non-ruminant animals (*Copley* et al. *2005*) (Fig. 8). Although nine of them (04HO, 06HO, 09HO, 10HO, 11HO, 12HO, 13HO, 16HO, 17HO) have aquatic biomarkers present, their use cannot be resolved more specifically. Non-ruminant, terrestrial animal contribution/origin could not be excluded, since the animal bone assemblage contains a high percentage of boar/pig (>30%) (*Toškan, Dirjec 2004*).

35% of samples (02HO, 14HO, 21HO, 25HO, 26HO, 27HO, 33HO, 34HO, 36HO) plot in the range for ruminant adipose fats (Fig. 8). The $C_{16:0}/C_{18:0}$ ratios of fatty acids for these samples range between 0.74 and 2.28 values (Tab. 2) typical of ruminant adipose fat (*Copley* et al. *2005*). The distribution of the data (Fig. 8) and $\delta^{15}N$ values of samples (average value 4.4±1.2‰) suggested that the population at Hočevarica used diverse domesticated (goat, cattle) or wild (deer) animal products in their diet. The sample 20HO plots in the region typical of ruminant dairy fats. The processing of dairy products in this pottery vessel is further supported by the distribution of lipids (Fig. 7).

A further 15% of the samples (01HO, 05HO, 22HO, 31HO) fall close to the limit value between non-ruminant and ruminant fat ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0} = 0$‰). However, not all samples could be assigned to meat mixtures exclusively. In vegetable oils, for example, the $C_{18:1}$ fatty acid is enriched in ^{13}C compared to $C_{18:0}$ (*Spangenberg, Ogrinc 2001*). A ^{13}C-enrichment of $C_{18:1}$ (up to 2.3‰) compared to $C_{18:0}$ acid was also observed in three pottery vessels (01HO, 22HO and 31HO) suggesting an admixture of plant-animal fats.

Conclusions

The results of stable isotope data and the more specific product identification based on available lipids indicate varied vessel use: pots were used to cook both aquatic and terrestrial products.

The ruminant animal fats of either domestic (cattle, goat) or wild (deer) origin were the most frequently processed products preserved in the Hočevarica pottery samples (Tab. 2; 02HO, 05HO, 14HO, 21HO, 22HO, 25HO, 26HO, 27HO, 31HO, 33HO, 34HO, 36HO). These samples come from all the analysed settlement phases at Hočevarica and display a variety of different types and technologies (both the calcite/limestone group and the quartz group). This confirms that ruminant animal fat was processed in a variety of vessels, such as pots (14HO, 31HO), dishes (21HO, 26HO, 33HO) and bowls (05HO, 36HO) (Fig. 4).

The processing of non-ruminant animal fats was detected in only three samples from Hočevarica that come from both main settlement phases, all made from the most common technological group with added calcite/limestone inclusions (Tab. 2; 07HO, 08HO, 23HO).

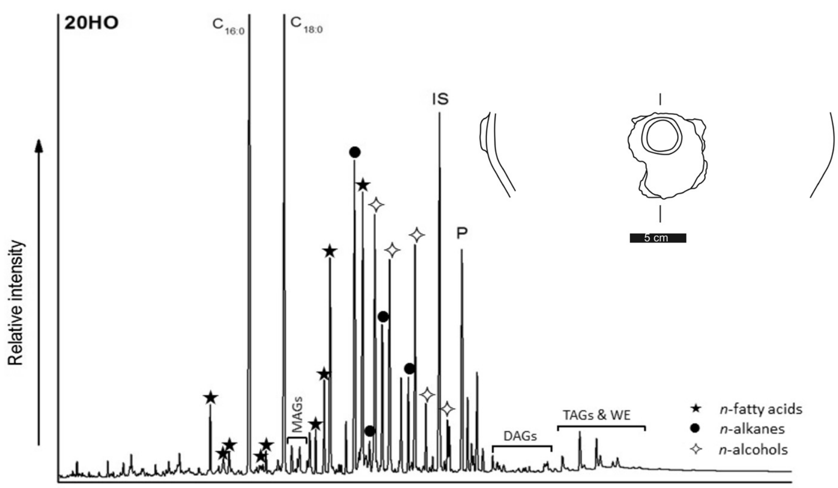

Fig. 7. Partial high-temperature gas chromatogram showing total lipid extracts from pottery sample 20HO from Hočevarica that is characteristic of a mixture of ruminant dairy fat and degraded beeswax.

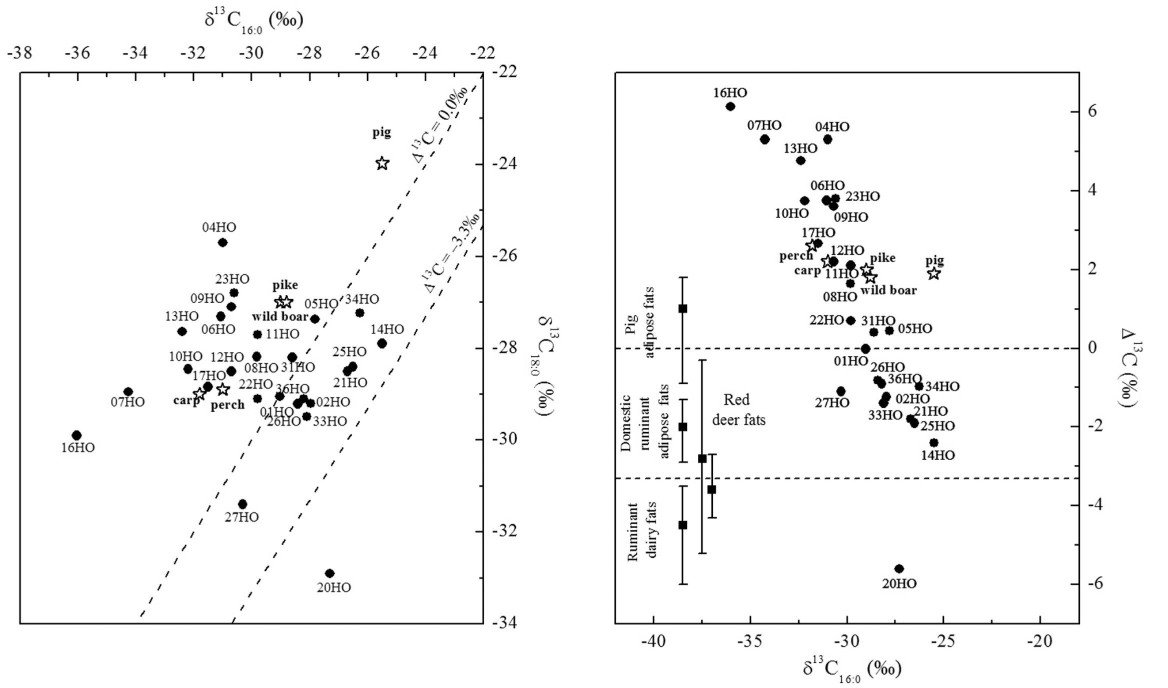

Fig. 8. Plot showing: A) the $\delta^{13}C_{18:0}$ versus $\delta^{13}C_{16:0}$ values of some modern reference animal fats and archaeological samples; B) the difference in the $\delta^{13}C$ values of $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C$) versus $\delta^{13}C_{16:0}$ recovered from pottery extracts from Hočevarica. Also shown are the data from modern reference fat: ☆ data from Craig **et al.** ***(*****2007*****) and the median and ranges of $\delta^{13}C$ from animals fed exclusively on C_3 diets. The pig adipose fats and ruminant adipose and dairy fats are from Copley*** **et al.** ***(*****2005*****), while the wild ruminants are from the UK (*****Evershed** ***et al.*** **2002*****) and red deer from Poland (*****Craig** ***et al.*** **2012*****). All isotope data have been adjusted for the effects of post-industrial carbon (*****Friedl** ***et al.*** **1986*****) in order to compare them with archaeological data.***

Only one decorated pot with an appliqué (20HO) indicates the processing of dairy fat. This pot dates to the 2nd settlement phase at Hočevarica and was made with the less common fine-grained fabric with quartz inclusions (Fig. 4; Tab. 2).

The appearance of aquatic biomarkers is associated with nine samples (04HO, 06HO, 09HO, 10HO, 11HO, 12HO, 13HO, 16HO and 17HO), indicating that these vessels were used in the preparation of aquatic resources such as fish and molluscs (Tab. 1). One of the samples with aquatic biomarkers is a pot with an appliqué (11HO; Fig. 4). Most of the samples come from the oldest settlement phase at Hočevarica and have similar technological characteristics in terms of their inclusions (calcite/limestone group), surface and firing treatment. This group of vessels also includes the only samples with a grey-black slip on the surface (10HO).

Moreover, we found that three of the pottery samples (01HO, 22HO and 31HO) were used to process both plant and animal fats. These samples also come from all the settlement phases and are made with calcite/limestone inclusions. Sample 31HO is also a pot with an appliqué and comes from the same context as pot 11HO, which showed the presence of aquatic biomarkers (Fig. 4; Tab.2).

The presence of beeswax in the vessels suggests either the storage of honey or the use of beeswax as a waterproofing agent. Beeswax was detected in five samples (Tab. 2; 20HO, 21HO, 25HO, 26HO, 36HO), of which four come from the 2nd settlement occupation phase and fall into the group with quartz inclusions. As to their morphology, the samples with preserved beeswax include two dishes (21HO, 26HO), one pot that was also used to process dairy fat (20HO), and one bowl (36HO) (Fig. 4). These results suggest that the use of beeswax as a waterproofing agent or the use of honey in the preparation of food was more common in the younger settlement phase at Hočevarica and/or connected to special types of vessels made with a different ceramic fabric.

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Neolithic pottery and the biomolecular archaeology of lipids

Mihael Budja
University of Ljubljana, Faculty of Arts, Department of Archaeology, SI
miha.budja@ff.uni-lj.si

ABSTRACT – *In this paper, we present archaeological and biochemical approaches to organic food residues, the lipids that are well preserved in ceramic matrices on prehistoric vessels. The 'archaeological biomarker revolution' concept is discussed in relation to pottery use, animal exploitation and the evolution of dietary practices in prehistory.*

IZVLEČEK – *V prispevku predstavljamo arheološke in biokemijske raziskave organskih ostankov hrane, lipidov ohranjenih v stenah keramičnih prazgodovinskih posod. Koncept 'revolucije arheoloških biomerkerjev' analiziramo v povezavi z uporabo keramičnih posod, izrabo živalskih virov in razvojem mlečnega gospodarstva v prazgodovini.*

KEY WORDS – *Neolithic; pottery; organic residues; lipids; biomarker revolution; fatty acids; stable isotopes*

Introduction

Organic residues on pottery have become broadly recognised as remnants of the original vessel contents or the accumulated remnants of its multiple uses since David Braun (*1983*) introduced the perception of 'pots as tools', in which vessels are seen as containers designed to play a set of utilitarian roles. Elizabeth F. Henrickson (*1990*) distinguishes between the terms 'use' and 'function'. While use refers to the specific utilitarian tasks of vessels, the function is defined as a broad term for the agency encompassing the way in which a vessel and pottery assemblage fit into the social, economic, and ritual contexts of a cultural system, and the roles pottery is called on to play within them. In parallel, the determination of intended use was correlated to the performance characteristics of pottery manufacture, *i.e.* fabric, shape, and firing (*Rice 1987*), accessibility, stability and transportability (*Skibo 2013*), and with shifts in diet and food in different archaeological and ethno-archaeological contexts (*Henrickson, McDonald 1983; Schiffer, Skibo 1987; Kimple* et al. *2004; Skibo 2013*).

The term organic residue covers a variety of amorphous organic remains, lipids that lack the clearly discernible morphological features that characterise other biological materials. Their identification relies on chemical and biochemical analyses. Visible and absorbed organic residues are usually regarded as remnants of the original vessel contents, the accumulated remnants of multiple uses, and one or more cooking episodes of burning of food due to overheating of vessels. These residues are "*typically chemically complex (commonly comprising hundreds of compounds of different classes, such as fatty acids and their derivatives, terpenes or polymers) and degraded (due to anthropic and natural degradation) mixtures of unknown organic compounds at low concentration*" (*Salque 2012.130*).

Visible residues can be observed as charred deposits encrusted (food-crust) on the interior and exterior of vessels (Fig. 1). Those on the outer walls may derive from soot deposited during the heating of the vessel over a fire. Resinous substances could have

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been applied during the manufacturing processes to reduce the permeability of porous fabrics. Residues on interior surfaces are highly charred and amorphous, but may provide direct and indirect evidence of their use. They are of animal or plant origin and may derive from animal fats, dairy products, beeswax, fermented beverages, resins, and tars (*Regert 2011.178;* see also *Colombini, Modugno 2009*) (Fig. 2). It has been suggested that surface residues 'are probably the result of the last, or one of the last, phases of vessel use', which increases the likelihood of identification of the original vessel content (*Oudemans, Boon 1993.222*), and that they contain 'a more intact' lipids profile because those extracted from the ceramic matrix have been thermally degraded by repetitive heating of the vessel wall (*Oudemans, Boon 2007*). Kenneth Peters, Clifford Walters and Michael Moldovan (*2005.342*) suggested on the contrary that charred food remains on the surfaces of cooking pots 'can be identified by visual inspection but provide less chemical information on their origins'. It has also been suggested that surface residues have been thermally altered, degraded and contaminated before and after deposition (*Regert* et al. *1998; Craig* et al. *2007.137*).

However, the combined archaeometrical pottery analysis, and botanical and chemical analyses of charred residues performed on Early Neolithic Swifterbant pottery show a correlation between pottery technology and function on the one hand, and between micro-fragments of partially charred foods prepared in the vessel and lipids, both identified in surface residue on the other. Thus micro-fragments of leaf tissue, roots and tubers and emmer chaff epidermis (*Triticum dicoccum*), correlate with the remains of fish scales and terrestrial animal bones, and with free fatty acids, acylglycerides, sterols and acyllipids (*Raemaekers* et al. *2013; Oudemans, Kubiak-Martens 2012*).

Lipids were successfully recovered from charred surface deposits on Incipient Jōmon pottery (*c.* 15 000 to 11 800 calBP) on Hokkaido, Honshu and Kyushu Islands. The lipids profiles in charred surface deposits show organic compounds consisting of saturated fatty acids derived from processing freshwater and marine organisms (*Craig* et al. *2013*).

In North America, the regional histories of maize utilisation have been intensively studied using bulk values of stable carbon isotopes $\delta^{13}C$, maize phytoliths and starches derived from charred cooking residues. The basic assumptions were that maize was the only C_4 resource cooked in a pot along with C_3 legumes and other plants, and that there was a linear relationship between the proportion of maize cooked in a pot relative to legumes and bulk $\delta^{13}C$ values on residues. The presence of C_4 maize in a mixture with C_3 legumes would result in higher bulk $\delta^{13}C$ values on residues. The –24‰ $\delta^{13}C$ bulk value was recognised as a proxy signature of maize presence (*Hastrof, DeNiro 1985; Morton, Schwarcz 2004*). The analytical work focused on isotope ratio mass spectrometry and was first limited to 'bulk' carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope compositions of carbonised food remains (*DeNiro 1987*). It was recognised recently as a 'very blunt analytical tool' unsuitable for

Fig. 1. A surface residue on the Neolithic pottery at Maharski prekop site (photo: M. Budja).

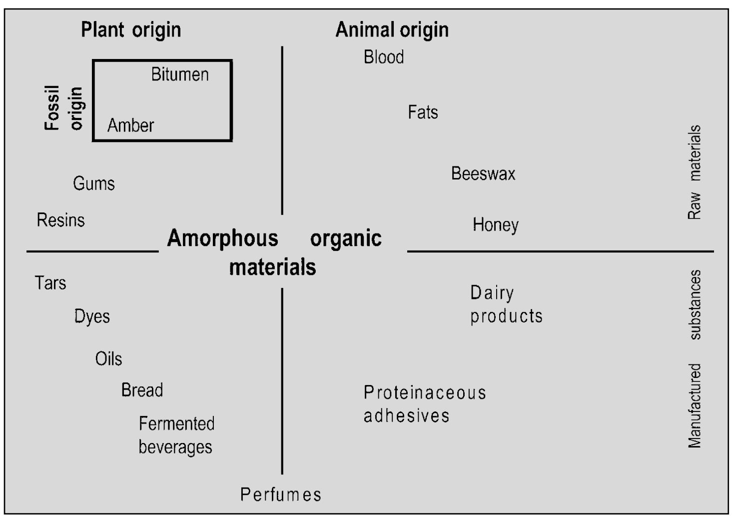

Fig. 2. Natural substances that may have been preserved as amorphous organic residues on prehistoric vessels (reprinted from* Regert 2011.Fig. 1, *copyright 2010 by Wiley Periodicals, Inc.).

distinguishing complex mixtures of biomolecules derived from a number of poorly defined origins of food constituents (*Craig 2007.137*). The experiments suggest that maize cannot be identified from bulk $\delta^{13}C$ values even when it contributed substantially to the food mix, and that different carbon mobilisation from C_3 and C_4 resources over time is an important variable in residue formation and in determining bulk values (*Hart* et al. *2007; 2009; 2012*). They even show that the decomposition of lipids was rapid, thus making maize lipids in bulk values unidentifiable. Their identification can be performed with compound-specific stable isotope analysis only (*Reber, Evershed 2004*).

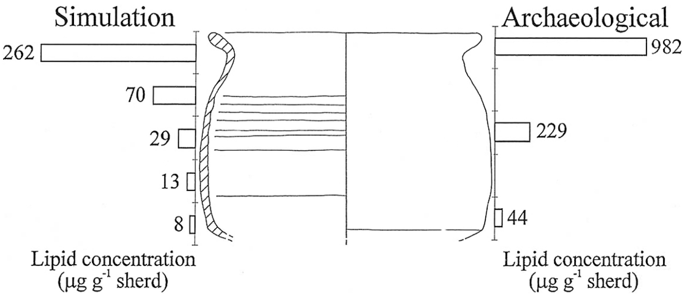

Fig. 3. **"Diagram of a replica late Saxon/Early Medieval jar showing the lipid concentrations (µg lipid g^{-1} sherd) as an average of three samples taken from cleaned ceramic at five points on the experimental vessel. On the right is a histogram showing the lipid concentrations at three points on the ancient vessel"** ***(from*** **Evershed 2008a. Fig. 2*).***

Invisible residues are absorbed by porous ceramic fabric and usually better preserved than surface deposits, because the ceramic microstructure protects them from microbial degradation. They are very common, 'probably being present in 80% or more' of all archaeological pottery assemblages (*Brown, Brown 2011.194*). It is believed that absorbed residues include compounds from the entire use of vessels, as the lipids absorbed in archaeological pottery represent an integrated signature, reflecting a number of occasions of use rather than simply the last or even later uses of a vessel (*Evershed 2008a.35*).

During boiling or roasting of food, organic compounds like lipids, proteins, carbohydrates, and other biopolymers are liberated or mobilised from foodstuffs. Different processes preserve these compounds in absorbed residues, but it seems they are hydrophilic enough to dissolve in cooking liquid and thus be absorbed into pot walls, but also hydrophobic enough not to wash out during deposition. Lipids represent the largest and most enduring portion of these residues because of their hydrophobicity and greater resistance to structural modification compared to proteins and carbohydrates. However, even the lipid components deposited in ceramic vessels are preserved in low concentrations and highly degraded. Degradation and loss of residue begin over the course of cooking and continue after discard and deposition through pyrolysis, bacterial action and autoxidation. The duration of burial is probably less important for residue survival than the prevailing conditions within the burial environment. Experimental studies have shown the variability of lipid preservation with burial environments and that anoxic conditions favour organic residue preservation. They indicate that only a small fraction of lipid originally absorbed survives burial. It was suggested that 99% of the extractable lipid missing from food residues is lost principally through microbial action. The surviving lipids – the fraction of molecules that survives is presumed to be due to their protection in molecular-sized pores within the clay fabric microstructure or strong absorption into the clay surface (*Evershed 2008a.28–29*). The latter was also suggested to be significant in the survival of protein residues as well (*Craig, Collins 2002*).

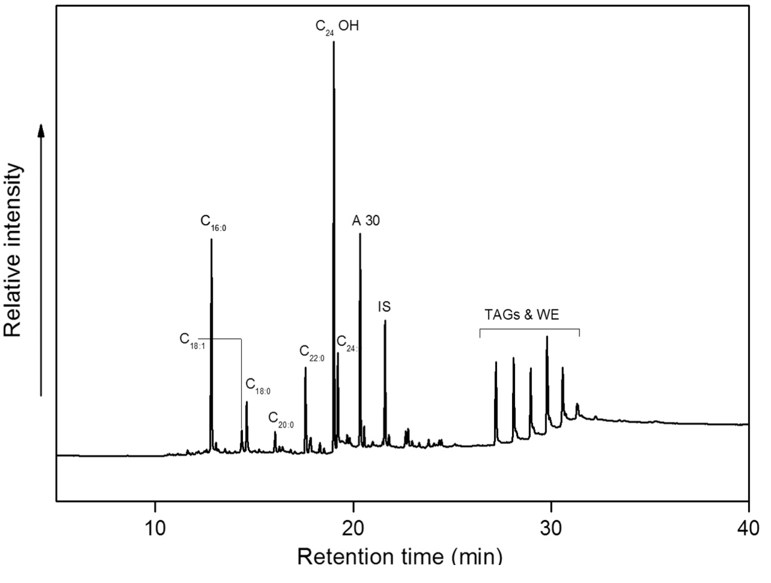

Fig. 4. Partial high temperature gas chromatogram of trimethylsilylated total lipid extracts that is characteristic of ruminant dairy fats and degraded beeswax from the Maharski prekop pottery sample MP59 (**Ogrinc** ***et al.*** **2015 in prep.*).***

Analyses show that many cooking vessels displayed greater lipid concentrations in the upper parts of vessels and much lower or negligible accumulation in their bases (Fig. 3). A notable difference appears in the absolute concentration of lipid deposited in the vessel wall in mixed residues like meat and vegetables. Meat dominates over vegetables, showing higher concentrations of triacylglycerols than of leaf wax. This difference is most strongly influenced by the lipid richness of the source foodstuff and the degradation resistance of components from different sources (*Evershed 2008a.31–35*). Since the 1990s the determination of nature and origin of lipids, which mostly derived from degraded animal fats based on the distribution of fatty acids, sterols, monoacylglycerols, diacylglycerols, and triacylglycerols, was a great challenge because they reflect a range of complex transformations and mixtures and have undergone a series of alteration processes. The introduction of biomarker concept and HTGC-MS combined with carbon isotopic analysis of individual fatty acid by GC-C-IRMS analytical tools and soft ionization techniques have offered the possibility to differentiate ruminant and nonruminant fats, and to detect dairy products (*e.g.*, goat and cow milk) in Neolithic ceramic vessels.

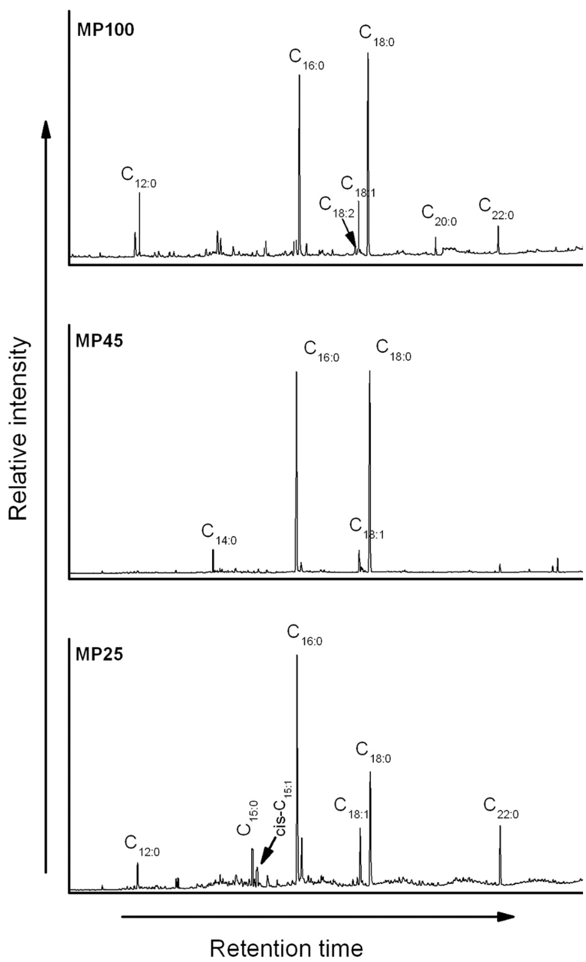

Fig. 5. The representative GC-MS total ion chromatograms of the FAs methylesters (FAMEs) with different $C_{16:0}$ and $C_{18:0}$ abundance extracted from the Maharski prekop pottery samples (from* Ogrinc *et al.* 2012.Fig. 3*).

Lipids

Lipids are a broad group of organic macromolecules produced by living organisms, which include fats, oils, waxes, steroids, and various resins. The main biological functions of lipids include storing energy and acting as structural components of cell membranes. Plants, animals, and other living organisms use fats and oils as stored forms of energy. Fats and oils are stored in the adipose cells of animals, forming adipose tissue, and in the seeds of plants. Within a wide variety of organic compounds which are categorised as lipids, the fatty (carboxylic) acids (FAs), triacylglycerols (TAGs), steroids, waxes and terpenes are recognised as useful in the analysis of prehistoric food residues. FAs rarely occur as free, isolated molecules in nature, but they most often occur as parts of TAGs, in which three fatty acids are bonded to a single glycerol molecule through ester linkages.

Lipids are relatively resistant to degradation by chemical and microbial processes and can survive with little structural change for long periods. They are recognised as 'simple' and 'complex'. The first consist of TAGs, and their derivatives derived from hydrolysis, such as diacylglycerols (DAGs) and monoacylglycerols (MAGs), free fatty acids (FAs), as well as other sterol-containing metabolites such as sterols (cholesterol), esters (waxes) and lipoproteins. The latter consist of phospholipids and glycolipids. TAGs are the main storage form of fats within the body, where their main function is to store energy. Nearly all fats and oils of animal and plant origin consist almost exclusively of TAGs.

FAs rarely occur as free molecules in nature, but are usually found as components of lipid molecules like fats and oil, and phospholipids. While FAs derive from dietary sources or produced by the metabolic breakdown of stored fats, phospholipids serve as major components of cell membranes and have an essential role in photosynthesis (*Pollard* et al. *2007; Colombini, Modugno 2009*).

Fatty acid structure is one of the most fundamental categories of lipids, and is commonly used as a build-

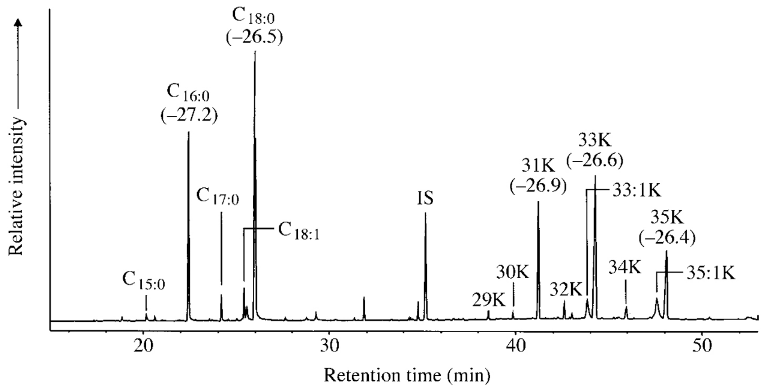

Fig. 6. Partial gas chromatogram of the total lipid extract (trimethylsilylated) of an Early Bronze Age cooking vessel, showing the presence of long-chain ketones formed by thermal free radical condensation of the FAs present in the same extract. Peak identities are $C_{16:0}$ and $C_{18:0}$, which indicate saturated fatty acids (palmitic and stearic), and $C_{18:1}$ (oleic) that indicates a monounsaturated fatty acid. K, the long mid-chain ketones with the preceding number corresponds to the number of carbon atoms in each component. IS is internal standard (5a-cholestane). Values in parentheses refer to the ^{13}C values of the individual compounds determined by GC/C-IRMS (reprinted from **Evershed *et al.* 1999.Fig. 2*).***

ing-block of more structurally complex lipids. FA is a carboxylic acid with a long aliphatic chain. The main FAs found in plant and animal foods have a chain of an even number of carbon atoms ranging from 4 to 36, which is either saturated or unsaturated. Unsaturated FAs have one or more double bonds between carbon atoms. Saturated FAs usually have between 12 and 24 carbon atoms and have no double bonds. When they are not attached to other molecules, they are known as 'free' fatty acids produced from the breakdown of TAGs. The more abundant saturated (unbonded) FAs are the palmitic ($C_{16:0}$), and stearic ($C_{18:0}$) acids, followed by lauric ($C_{12:0}$), myristic ($C_{14:0}$); the unsaturated (bonded) acids are palmitoleic ($C_{16:1}$), oleic ($C_{18:1}$), linoleic ($C_{18:2}$), and linolenic ($C_{18:3}$). These FA distributions are typical of degraded fats, and have a strong biological signature. While unsaturated FAs are more abundant in food of vegetable origin, small quantities of branched-chain fatty acids are present in many plants and animals (especially ruminants and fish), and in much larger concentrations in many bacteria (*Spangenber* et al. *2006; Eerkens 2007*).

'The archaeological biomarker revolution'[1]

Since all the organic materials processed in vessels are of biological origin, they will be complex mixtures. The complexity increases through human activities (*e.g.*, mixing biological materials in food preparation), followed then by the compositional alteration of residual matrices due to continuous vessel heating (pyrolysis), and decay during burial (diagenesis). Richard Evershed (*1993*) proposed using biomarkers as identifiers of the origin of food components in complex molecular mixtures in prehistoric vessels. The conceptualisation was embedded in the 'biomolecular archaeology of lipids', which concerns the recognition and origin of "*the properties of the individual compounds or mixtures of compounds*" in organic residues in pottery. He suggested that it is possible to identify the origin of lipids in a ceramic matrix by *"matching the structures of individual compounds, or the relative proportions of the components of a mixture of compounds, to those found in contemporary plant and animal natural products likely to have been exploited in antiquity*" (*Evershed 1993.79*).

His identification of 'lipid biomarkers' in organic residues in pottery is related to recognitions of: (i) 'sterols and sterol derivatives' in which cholesterol is the most abundant animal sterol, while campesterol and sitosterol are the two major plant sterols; (ii) 'fatty acids and acyl lipids' in which FAs, DAGs, MAGs and TAGs are detected as being associated with animal fats, dairy products, vegetable oils and fish/marine oils; and (iii) 'long chain alkyl (acyclic)' compounds that relate to beeswax and plant waxes. The main chemical characteristics that constitute

1 Evershed (*2008b.898*) introduced a syntagm recently, relating it to 'archaeological biomarker concept' that relies upon matching the structures or distributions, 'chemical fingerprints', to the compounds and mixtures known to exist in extant organisms likely to have been exploited in the past. Sometimes the structure of a single component is sufficient to define the origin of a constituent of an organic residue. Betulin is thus marking the Birck bark, Boswellic acid the Frankincense, and Moronic acid the Pistacia spp. Beeswax is further example. It can be readily recognized because of the characteristic mixture of aliphatic components that it contains. However, the fundamental aspects of the biomarker approach is ability to recognize an original constituent or source, of an organic residue based upon altered structures surviving in the residues. It requires knowledge of the chemical and biochemical mechanisms and pathways that have been involved in the processes (see below).

biomolecular markers are 'carbon skeletons, and the position, number, and stereochemistry of the double bonds' of carbon (*Ibid. 79–84*; see also *Evershed 2008b*).

The biomarkers approach focuses on the correlation of lipid molecular components preserved within organic residues in pottery with biomolecules present in modern-day plant and animal tissues. While the composition of animal and plant lipids in contemporary materials is well established, the effect of degradation, *e.g.*, chemical, microbiological or physical, on these individual lipids and their distributions during vessel use and burial (diagenesis) needs to be studied continuously (see *Spangenberg* et al. *2006; Eerkens 2007; Gregg* et al. *2009; Gregg, Slater 2010*). The complex mixtures which originate from the degradation of lipids (specifically those with unsaturated components) are difficult to interpret and can often lead to an incorrect characterisation of the origin of the residues (*Stacey 2009*).

Although the conceptualisation of 'archaeological biomolecular markers' remains unchanged, their terminology and typology have become more precisely elaborated recently (*Evershed 2008b.898; Regert 2011*). The markers are recognised as: 'biomarkers' that correspond to native molecules relating to natural sources (animal and plant fatty acids, sterols); 'anthropogenic transformation markers' that relate to chemical transformations induced by different human activities (*e.g.*, heating vessels and pyrolysis); 'natural degradation markers' formed by the natural decay of initial 'biomarkers', or 'transformation' markers during deposition by chemical or biochemical processes; and 'migration markers', known as contaminants, that relate to components migrating from sediment to archaeological organic residues (*Regert 2011.185*; see also *Erkens 2007*).

By combining the complementary data of all molecular markers, and their chemical characteristics and isotopic values, it is possible to detect animal fats in pottery and to identify their main types (body fats of ruminants and non-ruminants, dairy products, and marine and freshwater resources), their biosynthetic origins, their diagenesis through natural burial and aging, and alteration under cooking conditions. The application of the 'archaeological biomarker concept' has required analytical techniques that can achieve molecular-level resolution. While gas chromatography combined with mass spectrometry (GC-MS) is recognised as the most useful technique for lipids individual identification and distribution

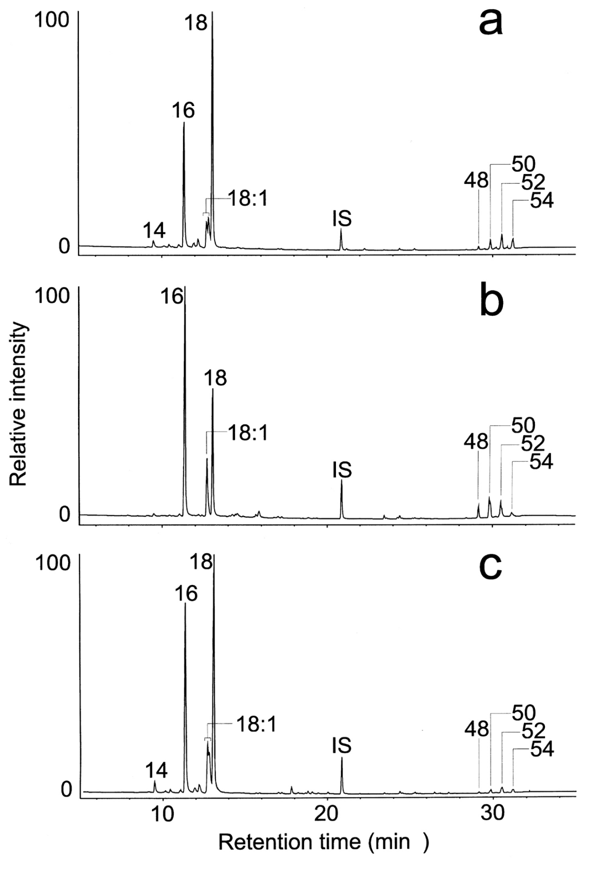

Fig. 7. High-temperature gas chromatograms of the total lipid extracts from* "Medieval pottery samples (Leicester): lamp (a), 'dripping' dish (b) and cauldron (c). Peak identities 14:0 (myristic), 16:0 (palmitic), 18:0 (stearic) are saturated fatty acids. The 18:1 is octadecenoic (oleic) acid. The IS is internal standard of n-tetratricontane. The 48, 50, 52, 54 are triacylglycerols (TAGs)*" (reprinted from* Mottram *et al.* 1999.Fig. 1, *copyright 1999, with permission from Elsevier).

within a mixture in lipids matrices, gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS) has been used to detect biomarkers isotopic structures and $\delta^{13}C$ values, and to record the biochemical history of each diagnostic components.

From 'bulk stable isotope' to 'compound-specific stable isotope' analysis

As presented above the identification of food components in organic residue in a ceramic matrix is complicated due to degradation processes that occurred during vessel use and burial. Lipids are preserved in 'low concentrations in highly degraded and complex matrices' because of chemical and micro-biological processes of degradation and alteration that include hydrolysis, oxidation, polymerization, condensation, cyclization or microbial degradation (*Evershed 2008a; Regert 2011.178*). Degrad-

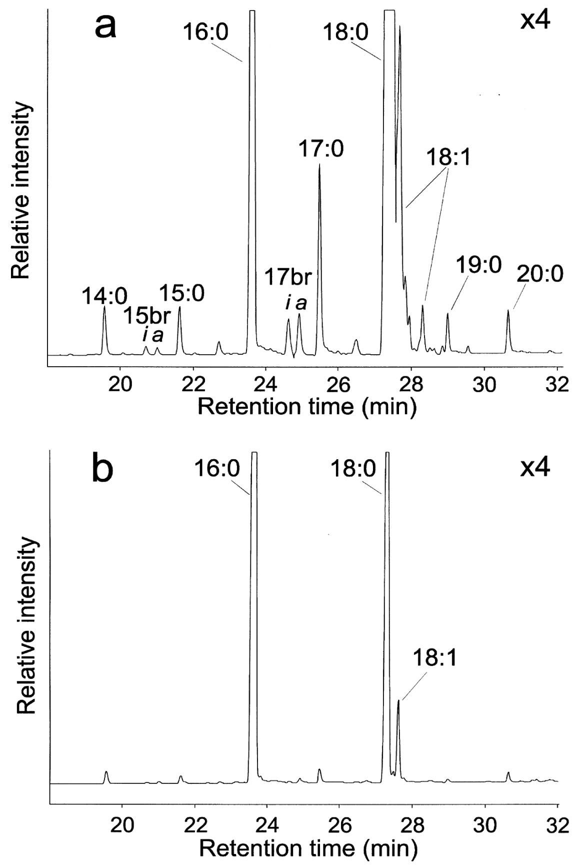

Fig. 8. Gas chromatograms of fatty acid methyl esters recovered from Medieval (Leicester) 'dripping dish' (a) and a lamp (b) (reprinted from* Mottram *et al.* 1999. Fig. 2, *copyright 1999, with permission from Elsevier).

ed animal fats, which are the most commonly identified 'biomolecular constituent', are characterised by a recognisable distribution of FAs, MAGs, DAGs and intact TAGs. Because of degradation and alteration they might exhibit great similarities in the chromatographic pattern of total lipids extract. The analytical work thus focused on the carbon isotope ($\delta^{13}C$) compositions of individual biomarkers, *e.g.*, FAs, TAGs and wax esters (*Evershed* et al. *1994; 1997a*).

Evershed (*2009.397*) suggested a number of 'compelling' reasons for an analytical and interpretative shift from bulk carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope compositions to the carbon isotope ($\delta^{13}C$) values of individual biomolecular markers, *i.e.* 'compound-specific $\delta^{13}C$ values on individual lipids'. The reasons mainly relate to the facts that structurally similar biochemical components can derive from sources exhibiting different stable isotopic signatures, and that 'complementary use of structurally diagnostic biomarkers' together with their compound-specific stable isotope values can provide information on a metabolic process (*i.e.* to distinguish adipose and milk fats). The compound-specific stable isotope analysis is thus to provide accurate stable isotope value(s) for a specific component(s) of what is likely to be a biochemically complex matrix preserved in pottery to be compared to modern reference samples.

Advances in high temperature gas chromatography (GC) analysis of total lipid extract, and the development of appropriate methodologies of lipid extraction and purification at the beginning of the 1990s made it possible to analyse the main biomarker components of animal fats, including TAGs, FAs, and sterols. Work on the assessment of transformation and degradation markers ran parallel to experimental work on animal fats from replica ceramic vessels and degradation experiments (for an overview, see *Evershed 2008a*). Evershed's team introduced an internal standard in the procedure for quantifying different components of extracts (*i.e.* molecular markers); they later became used in various laboratories, sometimes with minor modifications. However, many important components in total lipid extract (TLE) from ceramic matrices cannot be analysed directly by GC. They have to be chemically modified, or derivatised first to generate molecular markers and their isotopic signatures.

The trimethylsilylation sampling protocol (resulting in TMS derivatives) is associated with high-tem-

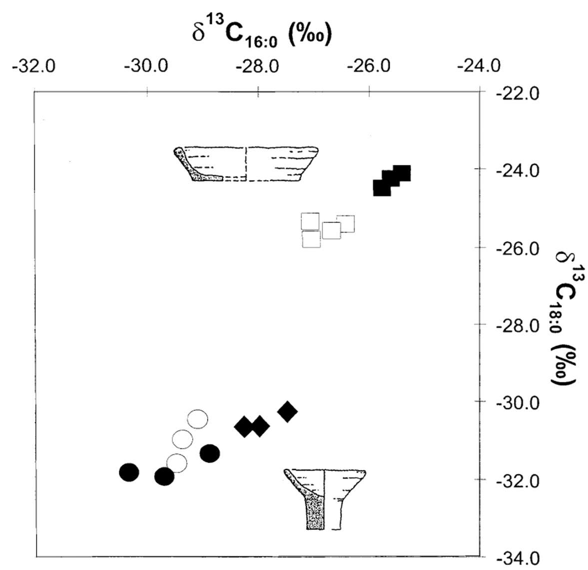

Fig. 9. Plot showing the $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ FAs* "form Medieval lamps (○) and dripping dishes (❑) and from modern reference animal fats [cattle (◆), sheep (●), and pig (■)]" *(reprinted with permission from* Evershed *et al.* 2002.Fig. 10, *copyright 2002 American Chemical Society).

perature gas chromatography (HT GC) and gas chromatography-mass spectrometry (HT GC-MS) techniques. They are basic investigative techniques focused on the initial detection of molecular markers, 'intact acyl lipids' or fatty acids like FAs, TAGs, DAGs, MAGs and wax esters that provide the partial gas chromatogram profile of the total lipid extract preserved in the ceramic matrix (*Evershed* et al. *1990; Charters* et al. *1993; 1995*) (Fig. 4).

The parallel gas chromatograph-combustion-isotope ratio mass spectrometer (GC-C-IRMS) technique enables the compound-specific isotope ($\delta^{13}C$) analysis of individual molecular markers extracted from bulk organic materials. It is necessary to transform the FAs via the chemical process of esterification to FAMEs (fatty acid methyl esters), which play a substantial role in identification of isotopic signature of individual biomarkers and to differentiate their sources (Fig. 5). GC-C-IRMS has proven especially powerful in determining and studying the $\delta^{13}C$ values of FAs as biomarkers for animal fats in pottery matrices, and in distinguishing ruminant (*e.g.*, sheep/goat and cattle) and non-ruminant (pig) body fats for the major old world domesticates (for an overview, see *Evershed 2009; Regert 2011*).

The initial application of this approach, which combines the biomarker and the compound-specific $\delta^{13}C$ values of individual markers, was related to dietary plant lipids analysis. It was carried out by linking a gas chromatograph (GC) to the isotope ratio mass spectrometer (IRMS) used for stable isotope measurement (*Evershed* et al. *1991; 1994; 1999.22*). The molecular structures present in organic residues in the ceramic matrix were correlated with those known to be present in modern-day vegetables, and 'likely to have been exploited in antiquity'. The gas chromatographic profiles for the total lipid extracts of a medieval cooking pot show the biomarker distribution, which consists of FAs and their derivatives, and the wax esters hydrolysed into C_{29} and C_{31} alkanes, C_{29} ketones and C_{29} alcohol. The distribution of alkanes and ketones corresponds well with those in cabbage leaves (*Brassica oleracea*) boiled in an experimental replica vessel (*Charters* et al. *1997*). The $\delta^{13}C$ values for the C_{29} alkanes and ketone are consistent with those of higher plant leaf waxes, as shown by the similarity to the values obtained for the contemporary wild *Brassica* (–35.8‰ ±0.1) within the accepted limits of precision (±0.3%).

However, further studies of cooking of leafy vegetables of an Early Bronze Age cooking vessel show that the three major saturated long-chain ketones (the C_{31}, C_{33} and C_{35}) in the total lipids extract have $\delta^{13}C$ values of –26.8, –26.5 and –25.9‰ respectively (*Raven* et al. *1997*). These compounds are too enriched (*c.* 10‰) in ^{13}C to be derived from epicuticular leaf waxes of *Brassica oleracea* (–35.4‰). Two major FAs ($C_{16:0}$ and $C_{18:0}$) in the same extract have $\delta^{13}C$ values of –25.5‰ and –26.6‰ similar to those of ketones. This similarity suggests that since cooking vessels were continuously heated, ketones have formed by condensation of fatty acid moieties derived from fats absorbed into the ceramic matrix during vessel use. (Fig. 6).

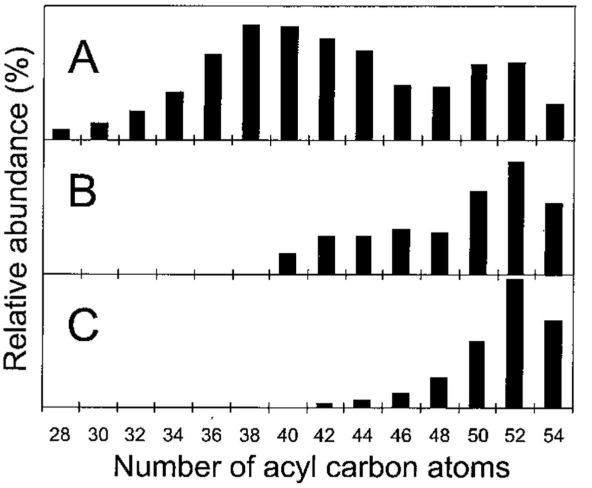

Fig. 10. TAGs distributions in (A) fresh milk, (B) milk absorbed in ceramic vessel and degraded in the laboratory under oxic conditions for 90 days, and (C) fresh ruminant (ovine) adipose fat. The distributions were determined by high-temperature GC of total lipid extracts (from* Dudd, Evershed 1998.Fig. 1*, reprinted with permission from AAAS).

Laboratory experiments involving heating (≤300°C) of either TAGs or FAs acids embedded in a ceramic matrix showed that during the heating of fats at high temperatures such mixtures of long-chain ketones can form readily. These findings indicate 'anthropogenic transformation markers' and the close similarity of the ketones produced by the pyrolysis of acyl lipids and those biosynthesised by higher plants (*Evershed* et al. *1999.23*).

The next approach combining the biomarker and the compound-specific $\delta^{13}C$ values of individual markers was related to the question of the origin of animal fats. Animal fats present greater challenges, because the major components, polyunsaturated fatty acids, TAGs that compose approx. 95% of fresh animal fats, rarely survive in pottery residuals, leaving mainly undiagnostic fatty acids.

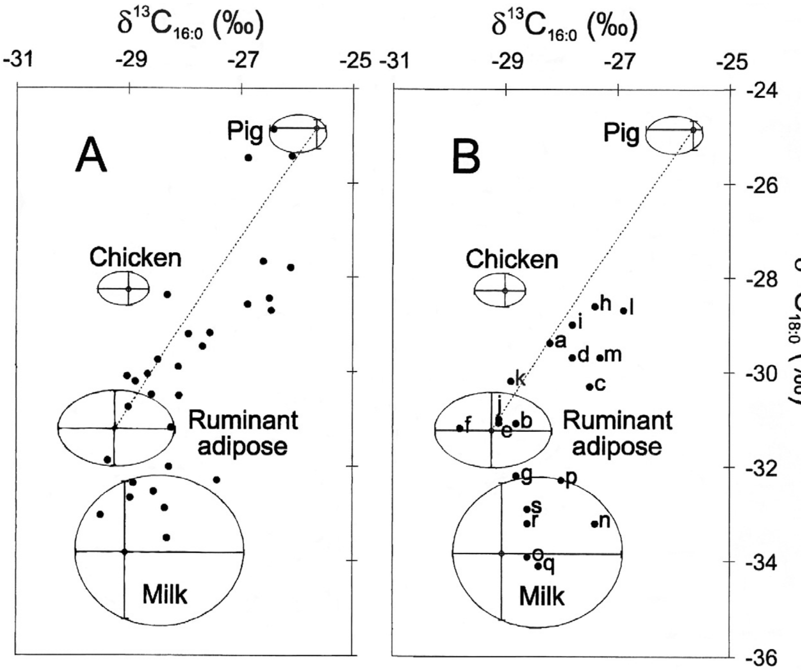

Fig. 11. Plot of the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ FAs of the lipid extracts* "from potsherds from (A) West Cotton (late Saxon to early medieval) and (B) Stanwick (Iron Age-Romano-British). The archaeological fats (solid circles) cluster near the reference adipose and milk fats (bovine and ovine). In the case of West Cotton, nonruminant (porcine) adipose fats have also been identified. The mixing curves (dashed lines) have been calculated to illustrate the $\delta^{13}C$ values that would result from the mixing of ovine/bovine and porcine fats in the vessels. The encircled fields encompass the ranges for reference animal fats, with the ranges crossing at the arithmetic mean. The numbers of different reference fats analyzed were as follows: pig adipose fat, 4; ruminant adipose fat, 9 (3 cow and 6 sheep); chicken adipose fat, 8; milk fat, 7 (6 cow and 1 sheep). All the animals were raised on C_3 diets. The more depleted $\delta^{13}C$ values for the C_{18} fatty acid in the milk fats arises through routing of a large proportion of fatty acids directly from the diet (after biohydrogenation) to milk production. The $\delta^{13}C$ values for the fatty acids in the reference fats have been corrected for the post- Industrial Revolution effects of fossil fuel burning, which has decreased the $\delta^{13}C$ value of atmospheric CO_2 by 1.2‰ since the middle of the 19th century. The letters adjacent to the points in (B) correlate with the triacylglycerol distributions ... and correspond to the following types of domestic archaeological vessels: a, b, e, f, h through m, p, r, and s are jar-form vessels of various sizes; c is a mortaria; d is a ceramic lid; g and n are flanged and wide bowls, respectively; and i, o, and q are small dishes. There was no obvious correlation between vessel form and the type of fat they contained. Analytical precision is ±0.3‰" *(from* Dudd, Evershed 1998.1479, Fig. 2, *reprinted with permission from AAAS).

It was shown, however, that it is possible to identify animal fats if the stable isotopic compositions of the FAs generated via the hydrolysis of TAGs are determined. For example, the $\delta^{13}C$ values of saturated $C_{16:0}$ and $C_{18:0}$ FAs that survive in degraded animal fats can be used to differentiate their sources. Ruminant and non-ruminant fats can be separated, and ruminant adipose fats distinguished from dairy fats, due to metabolic differences between the different animals and carbon sources utilised in the biosynthesis of different fat types (*Evershed 2008b. 899–900*).

The first attempt to distinguish animal fats focussed on medieval ceramic vessels of two different shapes, with various functions as lamps and 'dripping dishes'. The HT GC chromatographic profiles for the total lipid extracts (using derivatisation sampling protocol) showed biomarker distributions, which consist of a great quantity of saturated $C_{16:0}$ and $C_{18:0}$ and unsaturated $C_{18:1}$ FAs. MAGs and DAGs were present only in very low quantities, and it seemed that the hydrolysis was almost completed. The small amount of TAGs remained intact in ceramic matrices, as if they had been protected from degradation (Fig. 7). Although the extracts of all the vessels contained the same major saturated and unsaturated FAs ($C_{16:0}$, $C_{18:0}$ and $C_{18:1}$) there were clear differences in the relative proportions. In the lamps, the $C_{18:0}$ FA was more abundant than the $C_{16:0}$ component. In contrast, the dripping dishes had more $C_{16:0}$ (*Evershed* et al. *1997b; Mottram 1999*).

Clear differences were also apparent in the distributions of FAs identified by their FAME mass spectra for the two vessel types. The gas chromatograms show a series of branched iso- and anteiso FAs, with 15 and 17 carbon atoms (C_{15br} and C_{17br}), known to be formed in the gut by thermophilic bacteria synthesis. While they have a strong biological signature in lamps, they were not found in the 'dripping dishes' (*Evershed* et al. *1997b; 1999; Dudd, Evershed and Gibson 1999; Mottram 1999*) (Fig. 8).

A parallel electron ionisation mass spectrometry (EI) associated with dimethyl disulphide (DMDS) and io-

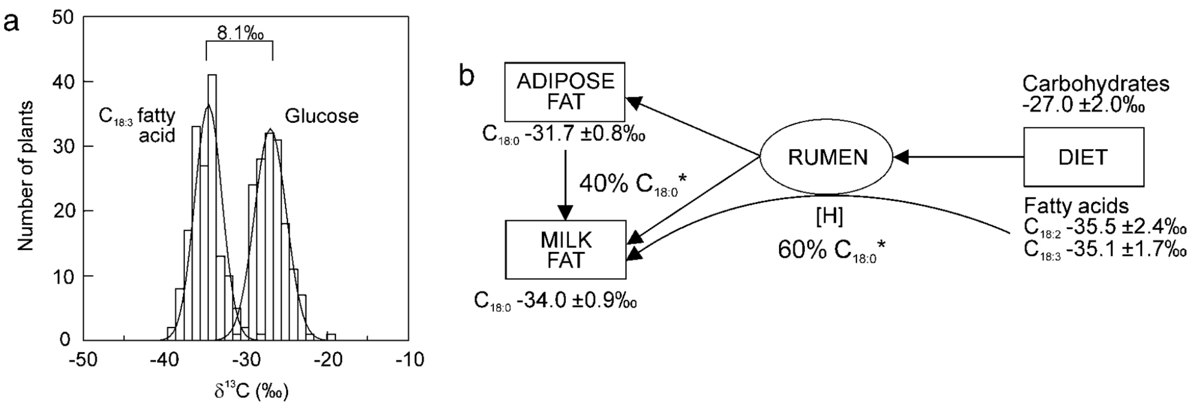

Fig. 12. (a) **"Histogram of the $\delta^{13}C$ values of $C_{18:3}$ fatty acids and glucose extracted from plants. The histogram of the $\delta^{13}C$ values of the major fatty acids and carbohydrates of 166 modern plants demonstrates that there is an 8.1‰ mean difference in the $\delta^{13}C$ values of $C_{18:3}$ fatty acid (mean = −36.3‰) and glucose (mean = −28.2‰) which is the basis of the difference in the $\delta^{13}C$ value of the $C_{18:0}$ fatty acid in dairy and milk fat. This difference in $\delta^{13}C$ value between lipids and carbohydrates is seen in both C_3 and C_4 plants."** ***(b)*** **"Diagram showing the routing of dietary fatty acids and carbohydrates in the rumen, adipose tissue and mammary gland of the ruminant animal. 60% of the $C_{18:0}$ in ruminant milk is directly incorporated from the diet following biohydrogenation of unsaturated fatty acids in the rumen (marked by asterisk), and reflects the inability of the mammary gland to biosynthesise $C_{18:0}$, and the remaining 40% is rerouted from adipose tissue and is comprised of carbon originating from dietary glucose and fatty acids. The 2.3‰ mean difference in the $\delta^{13}C$ values of $C_{18:0}$ in ruminant adipose tissues and dairy fats can be seen graphically in Fig. 12a"** ***(from*** **Copley *et al.* 2003.Fig. 1,** ***copyright 2003, The National Academy of Science).***

dine in diethyl ether treatment of FAMEs has revealed the existence of two kinds of monounsaturated fatty acid $C_{18:1}$ (oleic acid) distributions. While the single monounsaturated octadecenoic acid $C_{18:1\Delta 9}$ was identified in 'dripping dishes', a more complex composition characterised by a mixture of positional isomers of octadecenoic acid with a double bond located at different positions $C_{18:1\Delta 9,11,13,14,15,16}$ was identified in lamps (*Evershed* et al. *1997b; Mottram* et al. *1999*). It was suggested that this difference in fatty acid distribution reflects different origins of animal fats related to different diets and variations in animal metabolisms. While in ruminant animals (sheep and cattle), biohydrogenation of dietary fats occurs in the rumen, resulting in the formation of several positional $C_{18:1}$ isomers, in non-ruminant monogastric animals (pigs) a single isomer is present (*Evershed* et al. *1997b; 2002.664*).

The origins of animal fats were further studied by GC-C-IRMS analysis of $\delta^{13}C$ values of individual free FAs, palmitic ($C_{16:0}$) and stearic ($C_{18:0}$), and by corre-

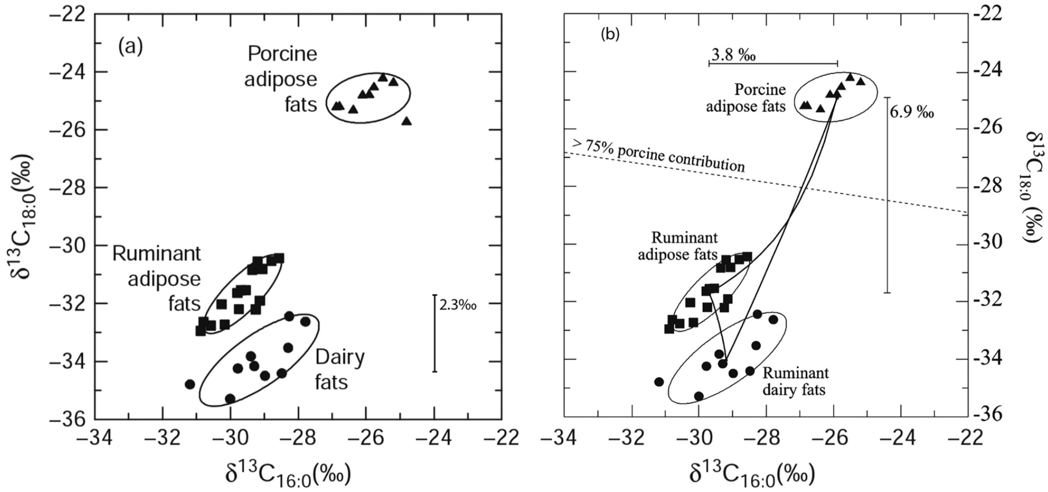

Fig. 13. Scatter plot showing the 2.3‰ mean difference in the $\delta^{13}C$ values of $C_{18:0}$ in ruminant adipose tissues and dairy fats, and the 6.9‰ mean difference in porcine body fat and ruminant adipose fat (reprinted and modified from **Evershed 2009.Fig. 14.18a** ***and*** **Mukherjee *et al.* 2007.Fig. 3,** ***with permission from Antiquity Publications Ltd).***

lation with modern reference fats considered to be the major domesticated species in the medieval period in the United Kingdom such as pigs, sheep and cattle. The analysis was supplemented with laboratory degradation experiments of those fats deposited in modern potsherds (*Evershed* et al. *1997b*).

The $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ FAs clearly indicated that these two types of vessel contained two kinds of animal fat (Fig. 9). The FAs in the lamps were depleted in ^{13}C, having higher $\delta^{13}C$ values compared to the 'dripping dishes'. Individually, in the lamps the $\delta^{13}C$ value of palmitic $C_{16:0}$ was higher compared to the $\delta^{13}C$ value in stearic $C_{18:0}$, whereas in the 'dripping dishes' the situation was reversed. The FAs in the latter cluster near the reference body porcine fats, while the former plot close to the values obtained for modern non-ruminant fats (*Evershed* et al. *1997b; 2002; Mottram* et al. *1999*). The $\delta^{13}C$ values were consistent with the biomarker compositions determined by GC-MS, as the set of FAs identified in lamps was consistent with ruminant fats, while those determined in 'dripping dishes' were characteristic of monogastric animals.

From biomolecular to stable isotope markers: from meat to milk

Subsequent studies focused on ruminant and non-ruminant fats and possible changes in patterns of animal exploitation and dietary practices in prehistory. Among the existing extraction protocols and instrumental analytical methods mentioned above, a number of precise chemical criteria were suggested for use in distinguishing between the residues of animal fats preserved in ceramic matrices. These criteria relate to both biomolecular and isotopic markers and were listed in order: "*(i) the positional isomers of monounsaturated fatty acids; (ii) the abundances of odd-carbon number ($C_{15:0}$ and $C_{17:0}$) iso- and anteiso- branched-chain fatty acids; (iii) fatty acid and triacylglycerol distributions; and (iv) the $\delta^{13}C$ values of the major saturated fatty acids $C_{16:0}$ and $C_{18:0}$, determined by GC-combustion-isotope ratio MS (GC-C-IRMS)*" (*Dudd, Evershed 1998a.1479*). Stephanie Dudd and Richard Evershed postulated that while bulk stable isotope studies allow the detection of remnant fats in either carbonised food residues or residues absorbed in pottery, the compound-specific $\delta^{13}C$ measurements allows the differentiation of nonruminant (omnivores) and ruminant (herbivores) animals' fats, and a distinction between adipose and dairy fats in ruminants. They hypothesised that one major category of fat that has to be detected in pottery is that derived from milk, and that just as with body fats, the processing of milk would result in the absorption of fat by the ceramic matrices. They presumed it would be easy to detect dairy fat, because of the presence of short-chain (C_4 to C_{14}) saturated FAs biomolecular markers, the main components of fresh milk. However, they failed to detect them in any lipid extracts from

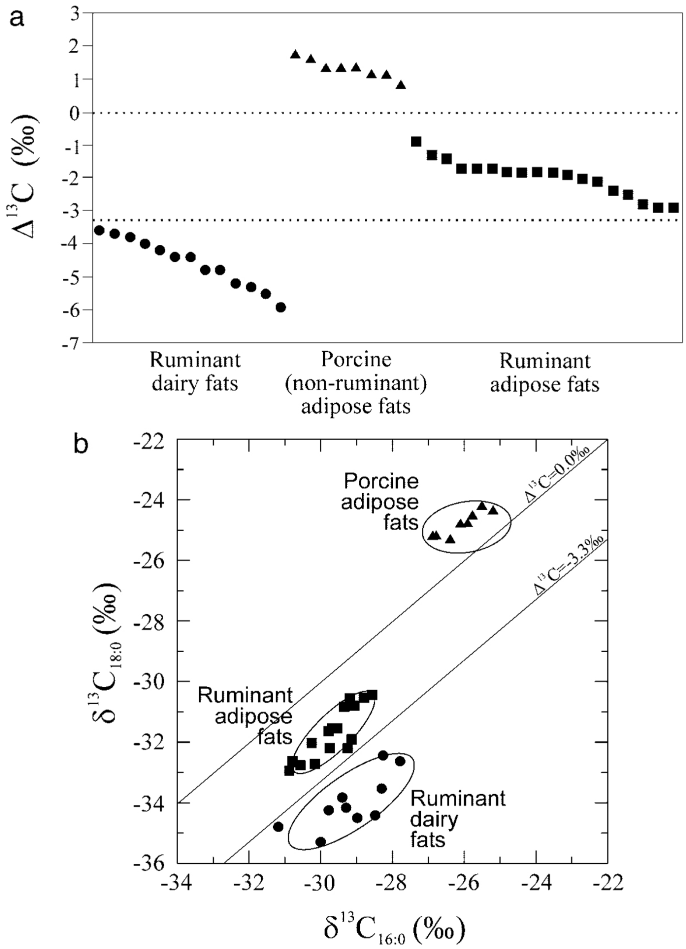

Fig. 14. **"Plot of the difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids (= $\Delta^{13}C$ value) obtained from the modern reference fats (a). Plot of the $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ fatty acids of modern reference fats (b). The three fields correspond to P = 0.684 confidence ellipses calculated for the $\delta^{13}C$ values of the domesticates known to comprise the major component of prehistoric economies in Britain. All of the animals were raised on C_3 diets. The $\delta^{13}C$ values obtained from the modern reference materials have been adjusted for post-Industrial Revolution effects of fossil fuel burning by the addition of 1.2‰. Analytical precision is ±0.3‰" *(reprinted from* Copley *et al.* 2003.1526, Fig. 2, *copyright 2003, The National Academy of Sciences).***

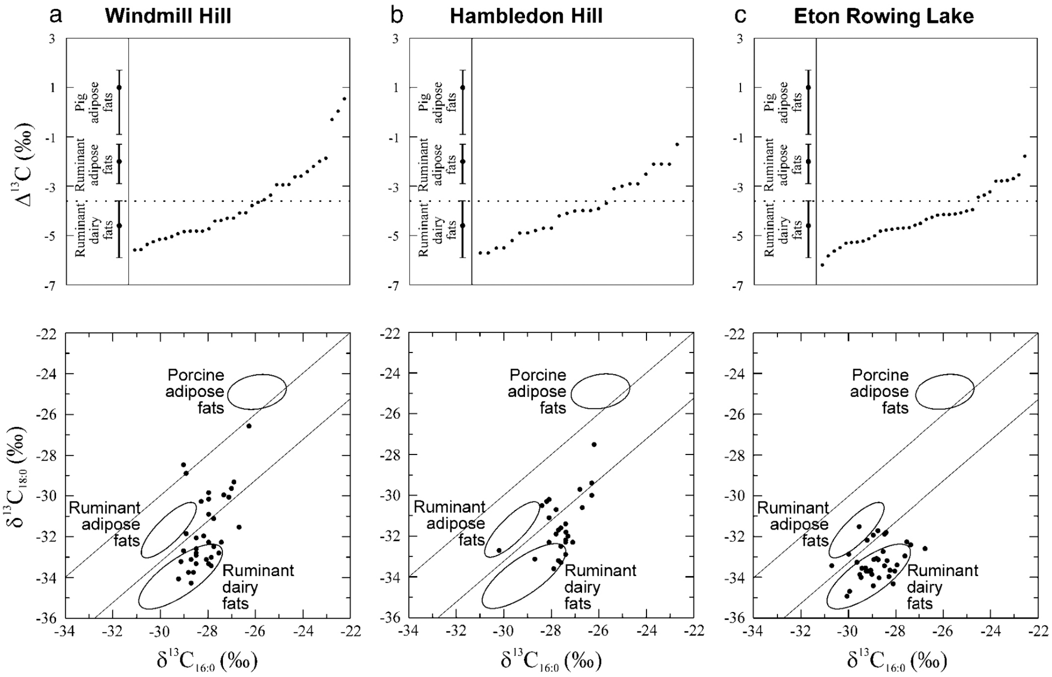

Fig. 15. Plots of the $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ FAs and $\delta^{13}C$ values of lipid extracts from Neolithic pottery from of Windmill Hill (a), Hambledon Hill (b), and Eton Rowing Lake (c) sites in the United Kingdom. The fields and ranges corresponding to the modern reference fats have served* “to classify the lipid extracts*”. Extracts that plot between the reference ellipses have been recognized to be* “indicative of the mixing of commodities in antiquity*” (reprinted from* Copley *et al.* 2003.Fig. 3*, copyright 2003, The National Academy of Sciences).

pottery. They ran a laboratory experiment to prove that their inability to detect dairy fats must have been related to milk processing and to compositional alteration through decay during burial. Meanwhile, they examined the existing biomolecular markers, *e.g.*, TAGs distributions of both, milk fat from fresh milk and of ruminant body fat after decay in the laboratory when absorbed into unglazed replica pottery (*Dudd* et al. *1998*). The results showed that when released from TAGs by hydrolysis, the short-chain FAs are more water soluble than their long-chain counterparts. Over a period of 90 days, the distribution of FAs in milk was transformed into a distribution similar to that of the adipose fat. They observed the same pattern in lipid extracts from ceramic matrices (Fig. 10). They realised that molecular analyses alone do not allow dairy fats to be distinguished from body fats, or ruminant from non-ruminant fats.

As most of the lipids extracted from pottery matrices are reduced to $C_{16:0}$ and $C_{18:0}$ FAs, the components of hydrolysed TAGs are often the only surviving lipids of degraded degradation and/or biological hydrolysis during deposition. Dudd and Evershed thus focused on the isotopic markers, the $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ FAs in lipids extracted from different pottery assemblages. The residuals from Late Saxon – Early Medieval and Iron Age – Romano-British pottery matrices were analysed first. The results showed that ruminant fats in pottery could be divided into two groups, one with low $\delta^{13}C$ values for $C_{18:0}$ (*Dudd, Evershed 1998*) (Fig. 11). They noticed that the isotope values of this group are similar to those they obtained on modern ruminant milk fats. They suggested, therefore, that the “*data show that milk and adipose fats from animals raised on similar diets are separable on the basis of the comparison of the $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ fatty acids and that this provides the basis for determining the presence of milk fat in archaeological pottery*” (*Dudd, Evershed 1998.1480*). As the biochemical evidences of processing of animal products in various archaeological vessels correspond well with the composition of the bone assemblage from the site, Richard Evershed *et al.* (*2002.665*) suggested further that the application of compound-specific stable isotope analyses “*to pottery from prehistoric periods is beginning to reveal important cultural biases in the exploitation of animal products*”.

Dudd and Evershed (*1998*) proposed that the isotopic higher values for FAs in ruminant body relate to a subtle difference in the way in which the $C_{16:0}$ and $C_{18:0}$ acids are synthesised in two types of fat. Body tissues are able to make both $C_{16:0}$ and $C_{18:0}$ FAs,

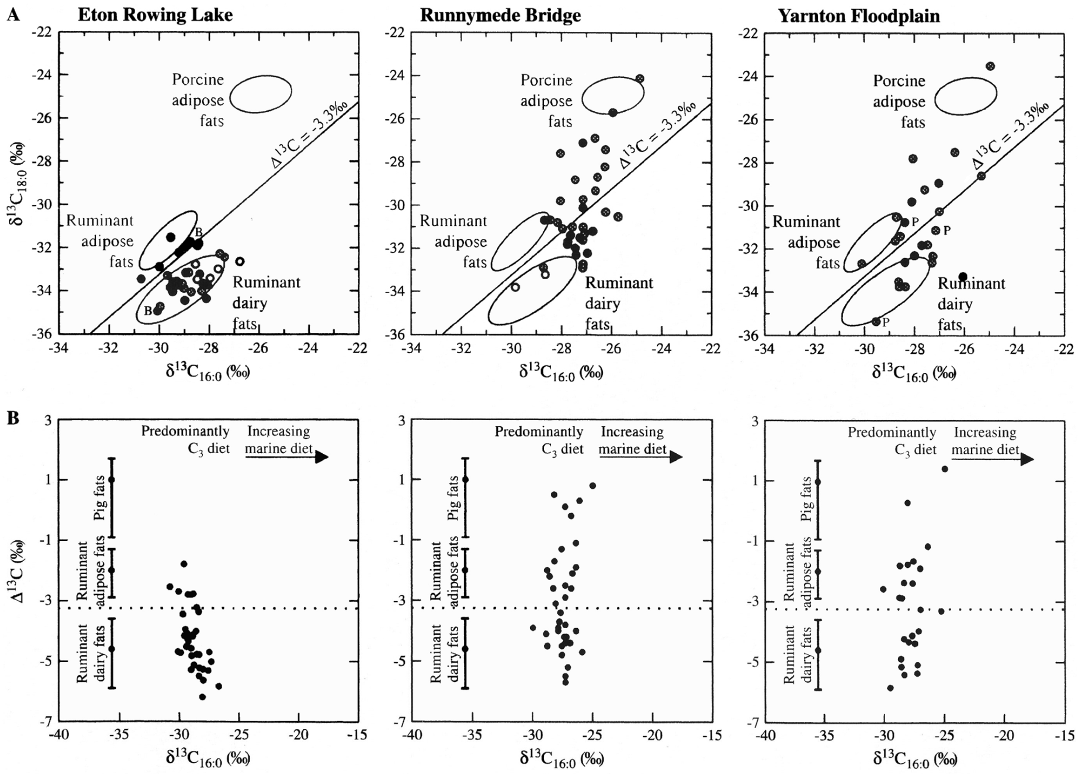

Fig. 16. **"(A) Plot of the $\delta^{13}C$ values of the FAMEs of $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$, prepared from lipid extracts from the six pottery assemblages. The ellipses indicate the $\delta^{13}C$ values of the reference animal fats, based on which the archaeological extracts are classified. Sherds plotting in between the ellipses represent the mixing of animal products in the vessel. $\Delta^{13}C$ (=$\delta^{13}C_{18:0}$ – $\delta^{13}C_{16:0}$) values of lower than –3.3‰ indicate dairy fats. The black filled circles represent extracts containing TAG distributions indicative of degraded adipose fats. The open circles represent those with typical degraded dairy fat TAG distributions, whilst the circles with crosses within them represent sherds that yielded no TAGs. A 'P' adjacent to the circle denotes that plant lipids were also detected, whilst a 'B' represents the presence of beeswax. (B) $\Delta^{13}C$ values of the extracts plotted against their $\delta^{13}C_{16:0}$ values. The further the sherds plot to the right, then the greater the marine component of the animals' diet. The reference materials are represented by their ranges and mean $\Delta^{13}C$ values"** ***(reprinted from*** **Copley** ***et al.*** **2005c.527, Fig. 3*****, copyright 2005, with permission from Elsevier).***

using acetate and other substrates derived from carbohydrates contained in the diet. This process involves an isotopic shift that results in the $\delta^{13}C$ value of the synthesised biomolecule being 1–2‰ higher than that of the dietary carbon. On the other hand, the mammary gland can synthesise $C_{16:0}$, but not $C_{18:0}$. It obtains them from FAs contained in the ingested plants, most of which are unsaturated, like $C_{18:1}$, $C_{18:2}$ and $C_{18:3}$. The biohydrogenation process in the rumen converts about 40% of them to saturated $C_{18:0}$ FAs. This conversion does not result in an isotopic shift. Therefore, the $\delta^{13}C$ value of the $C_{18:0}$ in milk, or in any dairy product, is slightly lower than that in body tissue.

A few years later Mark Copley *et al.* (*2003*) confirmed that a range of chemical criteria, like saturated fatty acid compositions, double-bond positions, TAGs distributions, and $\delta^{13}C$ values, can be used to assign the origins of fats to domesticated animals (sheep goats, cattle, and pigs) in prehistory. As the critical distinction between meat and milk fats is possible by determining $\delta^{13}C$ values in the $C_{18:0}$, the analytic focus turned to the study of the $\delta^{13}C$ values of individual FAs and to the differences in values for ruminant adipose and diary fats, and for non-ruminant fats in prehistoric and modern animals.

The $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ FAs from 16 ruminant adipose and 10 dairy fats, and 8 non-ruminant (porcine) body fats from modern animals that were raised on strict C_3 diets were calculated. The results show that stearic $C_{18:0}$ acid in milk fat has a $\delta^{13}C$ value ≈2.3‰ lower compared to the same FA in adipose fat due to the biohydrogenation process in the rumen. The differences in $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ between porcine body fat and ruminant adipose and milk fats are ≈4.6‰ and ≈6.9‰ respectively (*Copley* et al. *2003.1525–1526; Mukherjee 2007.745*) (Figs. 12 and 13).

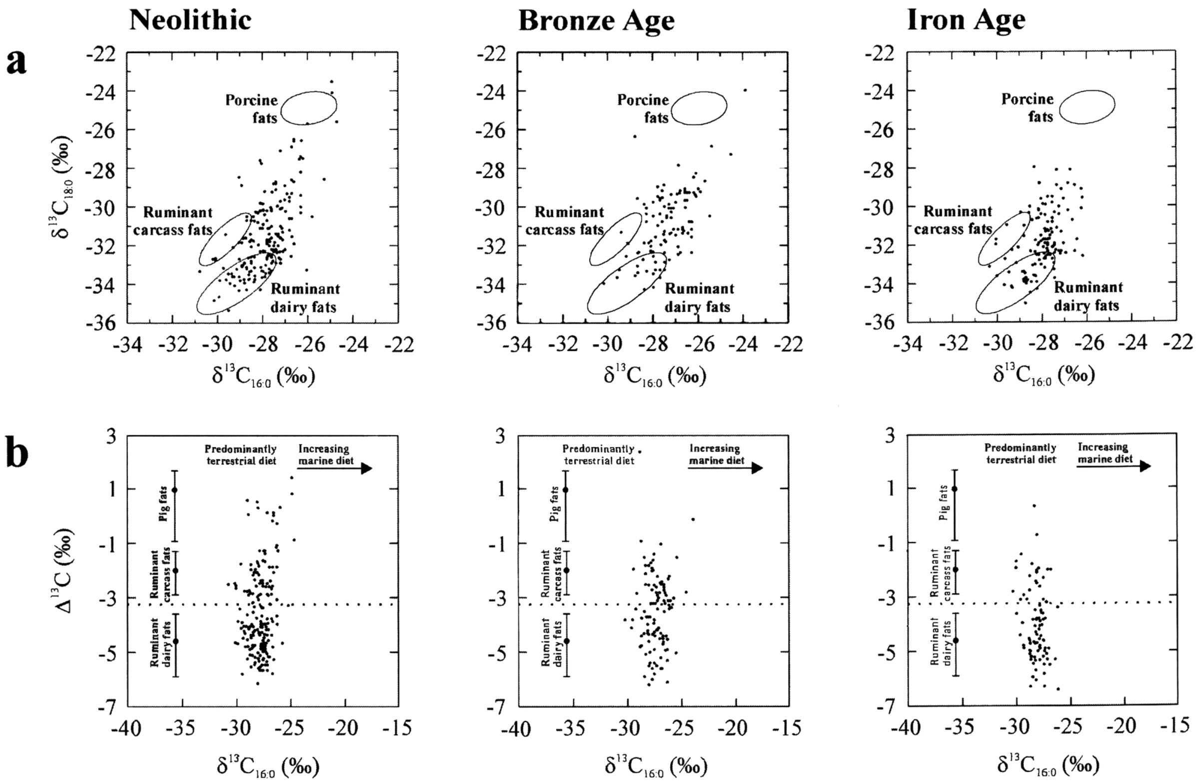

Fig. 17. **"(a) Plot of the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids extracted from Neolithic, Bronze and Iron Age pottery. Pottery plotting in between the ellipses represent the mixing of animal products in the vessel ... $\Delta^{13}C$ values of lower than –3.3‰ are a further method of identifying dairy fats. Further the sherds plot to the right, higher the percentage of marine derived food was utilised in the animal's diet"** ***(reprinted from*** **Copley** ***et al.*** **2005.Fig. 3*****, with permission from Antiquity Publications Ltd).***

In order to remove any exogenous influences, such as variability in diet, season and other environmental factors, and retain only the metabolic influences on the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ correction factor – $\Delta^{13}C$ proxy was introduced.[2] It was expressed as $\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$ (*Copley* et al. *2003*) (Fig. 14).

The $\Delta^{13}C$ proxy values were calculated for the three fat types of modern animal, and the species were grouped together by using 'confidence ellipses'. The distributions of ^{13}C values for the major FAs $C_{16:0}$ and $C_{18:0}$ of modern reference fats (bovine, ovine and porcine adipose and bovine milk) are marked with the ellipse positions within the graphs. The three positions correspond to confidence ellipses calculated for the ^{13}C values of the domesticates 'recognized to comprise the major component of prehistoric economies in Britain' (*e.g.*, pig, sheep/goat and cattle). All of the animals were raised on C_3 diets. The $\delta^{13}C$ va-

2 Within a grazing food web (chain) the energy and nutrients move from plants to the herbivores consuming them, and to the humans, who consume the flesh or milk of those animals. During the complex process of plant photosynthesis two biochemical reactions, the carbon fixation and fractionation determine the main plant photosynthetic pathways. The C_3 pathway or cycle is marked by the first organic carbon compound that contains a molecule with three carbon atoms. In C_4 pathway it has four carbon atoms. All the plants (vegetables, fruits, wheat and grasses) in temperate ecosystems use the C_3 cycle. Plants in tropics environments (millet, maize, sugar cane and savanna grasses), adapted to hot and arid environments, use the C_4 photosynthetic cycle. They differ in the levels of stable isotopic fractionation while assimilate atmospheric CO_2 into tissues. Plants selectively incorporate carbon into tissues taking up proportionally less ^{12}C and ^{13}C than is available in their carbon reservoir in the atmosphere. In the process of conversion of atmospheric CO_2 into organic compounds (carbohydrates, lipids and fatty acids, amino acids, and fats and oils) plants prefer to take in ^{12}C over ^{13}C and thus create different ratio of stable isotopes values ($\delta^{13}C$) than the atmosphere has. The C_3 plants show higher isotopic fractionation and $\delta^{13}C$ values range from –34 to –22‰. C_4 plants have lower isotopic fractionation and thus $\delta^{13}C$ values range within –16 and –9‰. Because carbon isotopic fractionation between the tissues of the consumer and its diet is very small, from 1‰ to 2‰, $\delta^{13}C$ values of animals are directly linked to those of plants consumed by the herbivores at the beginning of the trophic chain. The negative $\delta^{13}C$ values lower than –22‰ thus indicate that the food that the individual has consumed comes mainly from C_3 plants, as well as from the flesh (fats) or milk of animals that subsisted on C_3 plants only (*Vogel 1993; DeNiro M. J., Epstein S. 1978*).

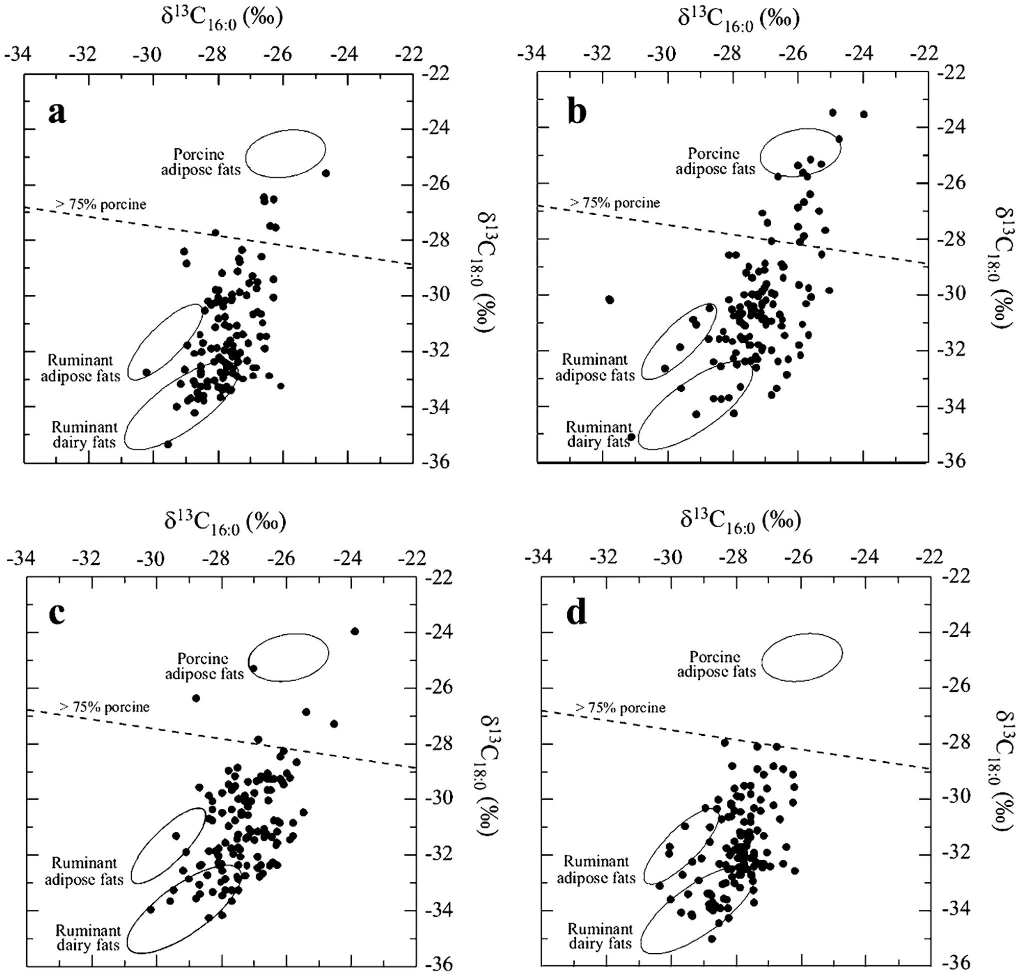

Fig. 18. Scatter plots of δ^{13}C values of $C_{16:0}$ and $C_{18:0}$ FAs from lipid extracts of* "all (a) Neolithic (not including Grooved Ware), (b) Grooved Ware, (c) Bronze Age and (d) Iron Age vessels*" in the United Kingdom (reprinted from* Mukherjee *et al.* 2007.Fig. 4*, with permission from Antiquity Publications Ltd).

lues for modern FAs have been corrected for post-Industrial Revolution effects of fossil fuel burning. By assuming that the isotopic fractionation in the pre-industrial biogeochemical carbon cycle was determined by today's known photosynthetic mechanisms and metabolic pathways, we could expect the δ^{13}C ratios of $C_{16:0}$ *vs.* $C_{18:0}$, and $C_{18:0}$ *vs.* $C_{18:1}$ co-variation for plants and consumers at that time to be shifted by 1.2‰ toward more positive δ^{13}C values (*Copley* et al. *2003.1526*). Spangenberg *et al.* (*2006.9*) have corrected the δ^{13}C ratios of $C_{16:0}$ and $C_{18:0}$ FAs of modern reference fats by 1.6‰ which they believe to be a more accurate comparison between their archaeological data from a Neolithic site in Switzerland and modern reference fats. The correction was based on a study of the isotopic composition of CO_2 recorded in Antarctic ice cores.

The Δ^{13}C proxy of the main FAs vary from –5.9 to +1.8‰. While values lower than –3.3‰ indicate ruminant dairy fats (cattle, sheep and goat milk and the production and consumption of milk products), values lower than –1.1‰ suggest ruminant body fat (cattle, sheep and goat meat processing and consumption). Values close to 0 and higher indicate non-ruminant body fats (porcine meat processing and consumption). Ruminant dairy fats are thus distributed between –3.3 and –6‰, and adipose between –1.1 and –3.2‰ (*Copley* at al. *2003.1526*).

The Δ^{13}C proxy approach was first applied to lipids extracted from 930 ceramic vessels from 14 prehistoric sites in the United Kingdom (UK). They represent the largest regionally based pottery assemblage to be studied. The classification of lipids was performed through a comparison of plots of the isotopic composition of FAs from ceramic matrices and the reference animal fat ellipses and their Δ^{13}C values. They are presented as scatter plots of the δ^{13}C values obtained from the $C_{16:0}$ and $C_{18:0}$ FAs extracted from pottery matrices along the plots of 'confidence ellipses' that indicate the δ^{13}C values of the

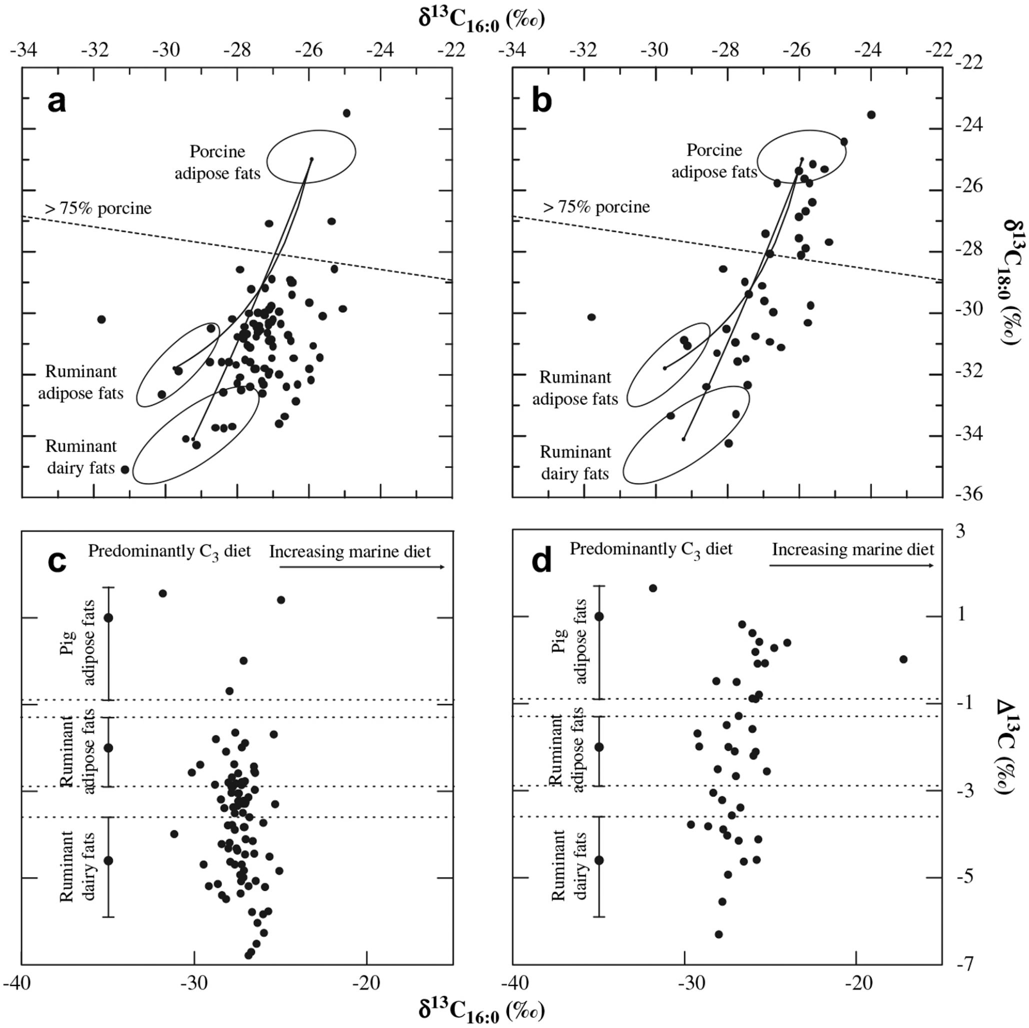

Fig. 19. Scatter plots of $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ FAs* "from (a) domestic Grooved Ware, (b) ceremonial/non-domestic Grooved Ware, and plots of $\Delta^{13}C$ values for all (c) domestic Grooved Ware and (d) ceremonial/non-domestic Grooved Ware*" in Neolithic in United Kingdom (reprinted from* Mukherjee *et al.* 2008.Fig. 9*, copyright 2008, with permission from Elsevier).

reference animal fats from which the extracts are classified. The $\Delta^{13}C$ proxy distributions are graphed separately (Fig. 15).

The dairying trajectory has been systematically charted from the Neolithic to the Iron Age across the British Isles (*Copley* et al. *2005a; 2005b; 2005c; Cramp 2014a*). The results show site-to-site variation, although at some sites the intensity of dairying was high, and no mixing of ruminant and non-ruminant fats was evident in any of the vessels (Fig. 16). However, the processing of ruminant animal products (both adipose and dairy fats) strongly prevailed through the prehistoric periods. Very few of the $\delta^{13}C$ values plot within, or in the vicinity of, the reference pig body fat ellipses, suggesting that vessels used only to process porcine products were rare. At a few sites, mixing of porcine and ruminant adipose fats in the vessels was evident (*Copley* et al. *2005*) (Fig. 17).

Copley *et al.* (*2005a.528*) suggested that about 50% of the extracts that contained significant quantities of lipids can be classified as predominantly dairy fats. On the other hand, they point out that very few of the extracts plot within the reference isotopic values of pig body fats. There was even no evidence of the processing of porcine products in vessels from sites where bones were preserved, suggesting that porcine products were processed by other methods (*e.g.*, spit roasting) that did not involve the pottery they analysed (*Copley 2005.898; 2005a.528*).

The identification of the origin of dairy fats residue has been related to the question of whether fats arise through the processing of milk or milk products, such as yoghurt, or represent residues of the use of butter. The laboratory experiments performed on replica vessels indicate that milk degrades much faster than butter, probably because of the presence of

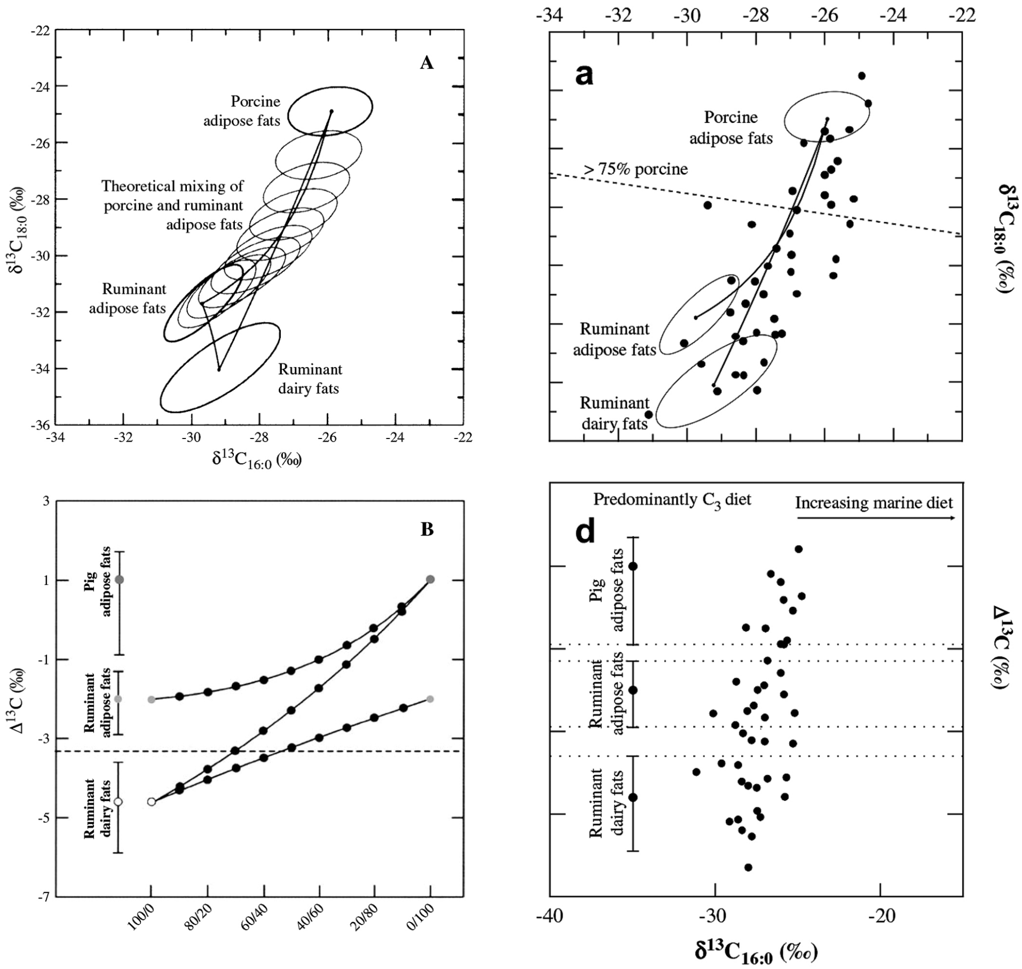

Fig. 20. (A) The theoretical mixing of animal fats.* "The labelled ellipses are generated from the reference animal fats, and the minor ellipses correspond to the theoretical fields that would result from the mixing of the respective fats (each ellipse represents a 10%increase/decrease in the specific commodities). The lines are the actual mixing curves joining the centroids of the respective fields. (B) The theoretical effect on the $\Delta^{13}C$ ($=\delta^{13}C_{18:0} - \delta^{13}C_{18:0}$) values of mixing the specific fats as in (A). The reference materials are represented by their ranges and mean $\Delta^{13}C$ values." *Curves from the porcine adipose ellipse to the ruminant dairy and adipose ellipses and between the ruminant dairy and adipose ellipses represent theoretical $\delta^{13}C$ values for mixtures of these fats. Extracts plotting above the dotted line contain a 75% or greater contribution of porcine fat (a,d) (reprinted from* Copley *et al.* 2005b.508, Fig. 2*, copyright 2004, with permission from Elsevier; and* Mukherjee *et al.* 2008.2068, Fig. 6*, copyright 2008, with permission from Elsevier).

proteins and carbohydrates that are excellent nutrients for soil micro-organisms. In contrast, butter is composed of pure lipids and is not a suitable substrate for microbial growth. It was concluded, therefore, that the accumulation of dairy fats in several prehistoric vessels may have derived from 'the processing of large amounts of butter fat, probably over extended periods of time' (*Copley* et al. *2005.905*).

While there were no differences in vessel form or actual use in the Neolithic, it was demonstrated that dairy products were generally processed in vessels with smaller rim diameters than those used for cooking meat products in the Bronze Age. There were differences in vessel use, type and form, and rim diameter in the Iron Age (*Copley* et al. *2005*).

The subsequent analyses based on lipids extracts from 385 vessels from 16 sites from the UK showed that 16% of late Neolithic Grooved Ware vessels contained 'significant proportions of porcine fat, and half of these were used to process solely porcine products'. The pottery from preceding Peterborough and Impressed Wares sites, while predominantly used to process dairy products, also showed evidence of the processing of porcine products, but only 7% of the extracts were composed of predominantly porcine fats (*Mukherjee* et al. *2007*). To put these results in a wider prehistoric context in Britain, they were incorporated into an accumulated dataset of $\delta^{13}C$ values for pottery lipid residues from prehistoric sites analysed by Copley *et al.* (*2005*) (Fig. 18).

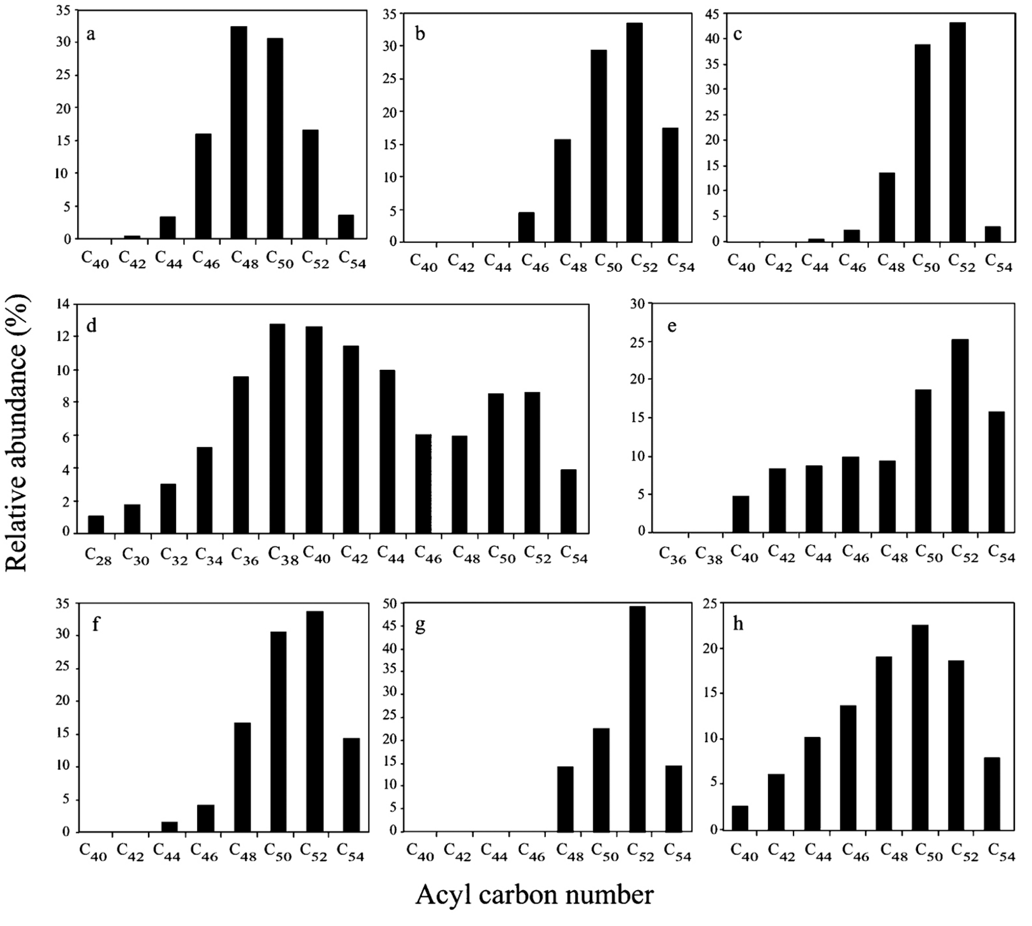

Fig. 21. Histograms "*of typical saturated acyl carbon number distributions in modern reference animal fats: (a) cow adipose fats, (b) sheep adipose fat, (c) pig adipose fats, (d) fresh milk, (e) milk degraded for 90 days; and animal fats extracted from prehistoric pottery: (f) ruminant adipose fat, (g) porcine adipose fat, (h) ruminant dairy fat*" (reprinted from* Mukherjee *et al.* 2007.Fig. 2*, with permission from Antiquity Publications Ltd).

Site-to-site analysis of Grooved Ware sites showed that the processing and consumption of pig or pig products was more important at non-domestic, ceremonial sites than at domestic settlement sites. This may be due to 'the suitability of the pig to be raised and slaughtered for large-scale feasting events' at ceremonial sites or it could relate to a special significance of pigs to the Grooved Ware people', allowing them to be consumed only at certain places or by specific people (*Mukherjee, Gibson and Evershed 2008*) (Fig. 19).

A broad discrepancy between the $\delta^{13}C$ distributions of lipid extracts and principal ellipses of reference animal fats representing domesticates known to have been raised in prehistory in the UK can be seen from the plots. Very few of the extracts plot within, or in the vicinity of, the reference ruminant and non-ruminant body fat fields. It was suggested that those embedded between the ellipses indicate the mixing of these fats in the vessels (*Copley 2005.897*) (Fig. 17).

Theoretical mixing curves have been calculated to illustrate the effect of vessel re-use and the processing of mixtures of foods. Each ellipse in Figure 20A "*represents the effect of mixing a specific percentage of each of the respective commodities*[3]*. The resultant mixing lines display curved trends due to differences in the relative abundances of the fatty acids in the animal fats, and hence their influence on the overall $\delta^{13}C$ values. … [W]henever a lipid extract is classified, it is necessary to refer to the extract as being of predominantly dairy/ruminant adipose/porcine adipose origin rather than simply being of ruminant adipose origin, for instance. Furthermore, it is likely that classifications based on both of these plots depend upon the ex-*

3 The term commodity is broadly accepted "*to designate all kind of raw or transformed natural substance that has been exploited by ancient communities*" (*Regert 2011.184*).

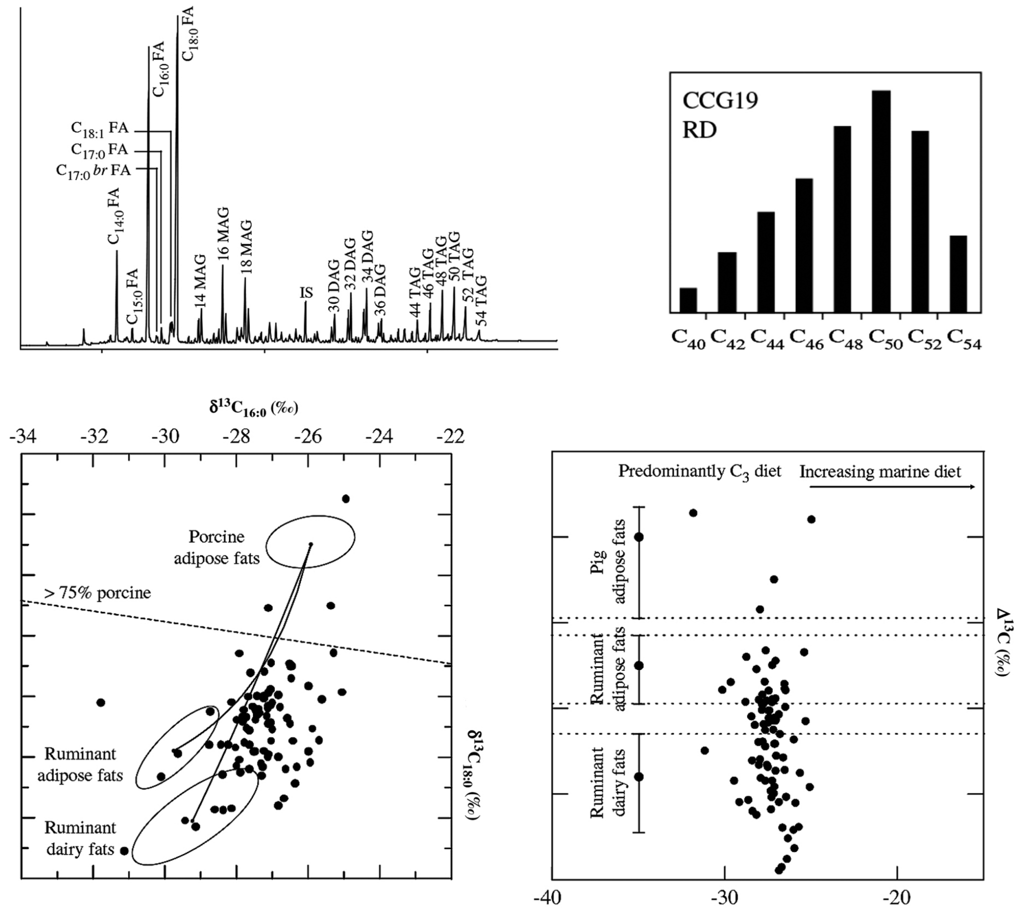

Fig. 22. Partial high temperature gas chromatograms of total lipid extract, and histogram of TAGs carbon number distributions indicative of ruminant dairy from the same extract. They both correlate to scatter plot showing the $\delta^{13}C$ of $C_{16:0}$ and $C_{18:0}$ FAs, and $\Delta^{13}C$ proxy measured for domestic Neolithic Grooved Ware pottery in UK (reprinted from* Mukherjee *et al.* 2008.Figs. 4, 5, 9, *copyright 2008, with permission from Elsevier).

tent of vessel re-use in antiquity... The three principal ellipses from the $\delta^{13}C$ values of the reference animal fats representing the domesticates known to have been raised in British prehistory ... The corresponding $\Delta^{13}C$ values ... are shown as ranges and means..., and further aid in the classification to predominant commodity group" (*Copley* et al. *2005.507*). It was suggested that the environmental variations in $\delta^{13}C$ values (calculated in $\Delta^{13}C$ proxy) would potentially have the effect of shifting the $\delta^{13}C$ values of the extracts along the axis of the ellipses. The mixing model postulates that within the percentage abundance of each fatty acid in reference porcine and ruminant fats and their $\delta^{13}C$ values, "*a contribution of porcine fat equal to or greater than 75 per cent of the total mixture were classed as 'predominantly porcine*" (*Mukherjee* et al. *2007.749*).

In looking for milk and pig 'signatures' in prehistory the analysis of TAGs distributions in extracted lipids have recently been reactualized. TAGs are major constituents of animal fats, and their carbon number distributions in pottery lipids have been recognised as a biomarker of lipid origin to species level. The biomarker studies of modern animal fats have shown that bovine adipose fats contain saturated TAGs of total acyl carbon numbers that range between C_{42} and C_{54}. Ovine adipose fats contain TAGs ranging from C_{44} to C_{54}. In milk fat, the TAGs distribution is very broad, ranging from C_{28} to C_{54} due to presence. In body fat of non-ruminant species (porcine) the TAGs range from C_{44} to C_{54}, with very low amounts of C_{44}, C_{46} and C_{48} (*Regert 2011.186*) (Fig. 21).

The analyses of prehistoric pottery showed that about 19% of extracted lipid residues display preserved TAGs. The carbon number distributions of half of them, either indicative of degraded dairy or adipose fat, correlate well with $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ FAs, and $\Delta^{13}C$ proxy values of the same samples (*Mukherje* et al. *2008; Copley* et al. *2005a; 20005b; 2005c*) (Fig. 22). Biomolecular and isoto-

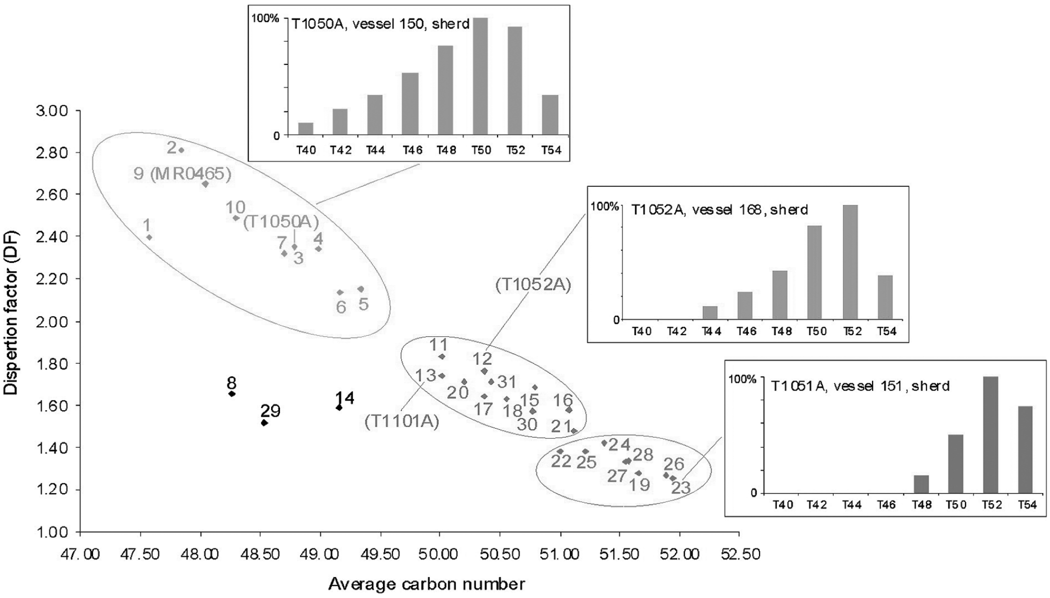

Fig. 23. Statistical 'reference confidence ellipses' model was calculated for TAGs distributions in modern reference and late Neolithic pottery extracts using average carbon number and dispersion factor (reprinted with permission from **Mirabaud, Rolando and Regert 2007.Fig. 2*****, copyright 2007, American Chemical Society).***

pic data have thus been equally used in detecting and interpreting the exploitation of domesticated animals for their 'secondary products', and their roles in non-domestic ceremonial contexts.

A parallel statistical 'reference confidence ellipses' model was calculated for TAGs distributions in modern reference and late Neolithic pottery extracts (*Mirabaud, Rolando and Regert 2007*). TAGs distributions of cow, sheep and goat milk were analysed after decay in the laboratory when absorbed into unglazed replica pottery. By calculating the 'average carbon numbers in the TAGs distribution' the three different 'classes' of TAGs distribution were determined; they are reminiscent of earlier calculated 'reference confidence ellipses' of three fat types. The 'first class' relates to a 'large distribution of TAGs, from T_{40} to T_{54}', which can be associated with degraded dairy products. The second relates to the 'medium distribution of TAGs, from T_{44} to T_{54}', and to body degraded fat. The third relates to a 'narrow distribution of TAGs, from T_{46} or T_{48} to T_{54}', which can be associated with body fats (*Ibid. 6186*) (Fig. 23).

However, it is "*necessary to consider TAGs distributions as preliminary information*" in detecting the origins of FAs (*Regert 2011.188*). Laboratory experiments showed that TAGs distributions are unstable when absorbed in a pottery matrix. They are degraded by hydrolysis and microbial activity during deposition. Degradation pathways are not fully understood yet, and might differ, depending on the burial micro environments. We already mentioned that when released from TAGs by hydrolysis, the short- and medium chain FAs are more water soluble than their long-chain counterparts. Over 90 days, the distribution of FAs in milk was transformed into a distribution similar that of the adipose fats. Research in food sciences has demonstrated that FAs decomposition is an extremely complex process that can produce a diverse range of organic compounds, depending on environment (*Eerkens 2007*).

The $\Delta^{13}C$ correction factor was recognised, on the other hand, as a 'very powerful' tool to decouple the proxy from the C_3/C_4 and other environmental influences, which makes reference fat data sets (collected in the UK) with relating confidence ellipses and their $\Delta^{13}C$ values 'globally applicable' (*Evershed 2009.417; Salque 2012*). The $\Delta^{13}C$ proxy approach has recently been used to provide the earliest evidence for prehistoric milk use in Southeast Europe, Anatolia and the Levant (*Evershed* et al. *2008a*). It was shown that milk was in use by the 7th millennium BC and that milking was particularly important in north-west Anatolia, pointing to regional differences linked with conditions more favourable to cattle compared with other regions, where sheep and goat were relatively common and milk use less important (Fig. 24). This work involved the greatest number of analysed pottery samples so far, 2225 in all, from 23 archaeological sites in the Levant, Anatolia, and Southeast Europe, dating from 6500–3500 BC. Surprisingly, only 255 pottery sam-

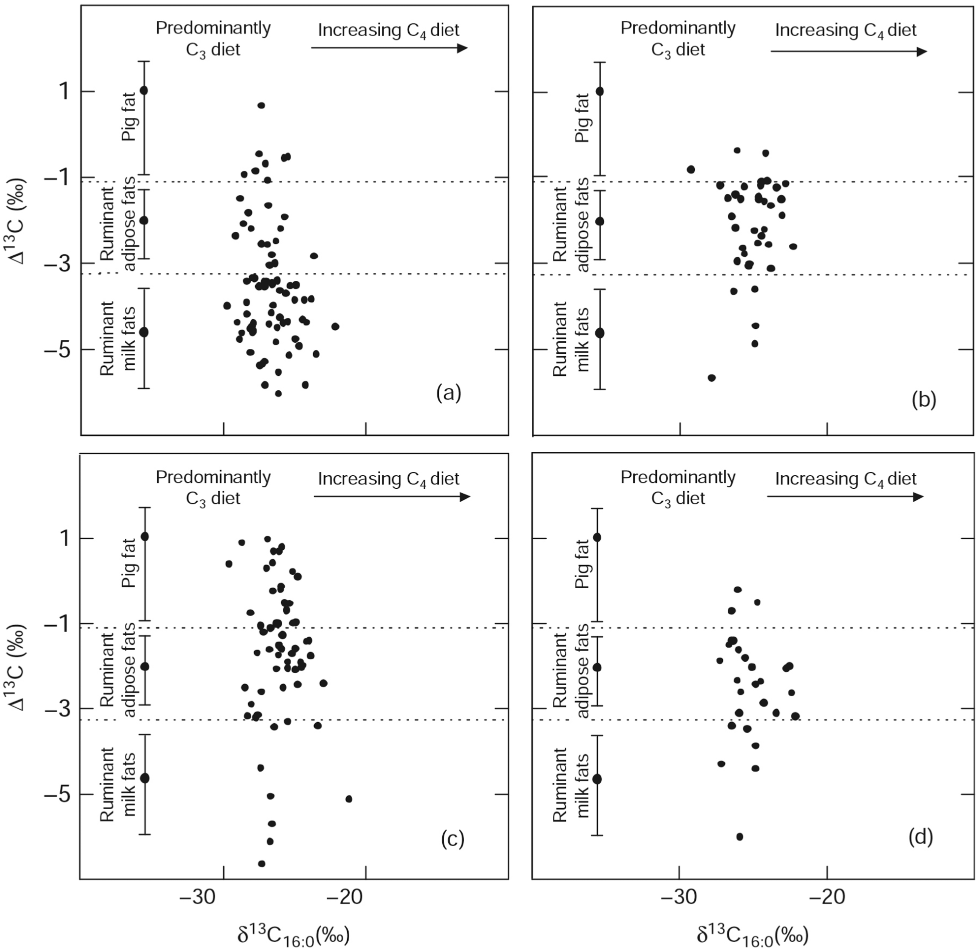

Fig. 24. Plots of the $\Delta^{13}C$ values for Early Neolithic animal fat residues in pottery show the milk use in Southeastern Europe and Anatolia dating back to the 7th millennium BC. Pottery was from: (a) northwestern Anatolia; (b) central Anatolia; (c) northern Greece; and (d) eastern Anatolia and the Levant (reprinted by permission from Macmillan Publishers Ltd: Nature, **Evershed *et al.* 2008a.Fig. 3*, copyright 2008).***

ples contained absorbed residues, a substantially smaller number than anticipated from past experience with pottery assemblages from UK. The relatively low success rate might have been due to increased diagenesis in warmer climates and variations in the calcareous soil conditions in Southeast Europe, Anatolia, and the Levant, or could possibly reflect differences in the absorptive powers of the types of clay used in different parts of the world. The results showed that milk was being used in all the regions from which potsherds were obtained, including the earliest sites, and that dairying was particularly widespread in northern Anatolia. In this area, 70% of the potsherds that contained residues yielded strong signs of the presence of milk. In contrast, at sites from eastern Turkey and the Levant, closer to the areas where farming began, the proportion of pottery showing signs of milk usage were much smaller. This distribution may relate to differences in the vegetation patterns of the various regions, with parts of northern Anatolia providing much better grazing conditions than eastern Turkey and the Levant, thus being more suitable for breeding cattle.

Recently, Michael Gregg and Greg Slater were able to extract $C_{16:0}$ and $C_{18:0}$ FAs from 34 of 65 archaeological pottery fragments (52%) from nine Neolithic settlements in the Middle East dated between 7300 and 4700 calBC by using a microwave-assisted liquid chromatography solvent extraction protocol in combination with purification and analytical protocols. The isotopic values are consistent with those obtained from the modern body fats of wild boar and goat pastured on lands adjacent to the Jordan Valley, and residues from a modern pottery vessel used in the manufacture of yoghurt in Central Turkey (*Gregg, Slater 2010.835*).

The long sequence of dairying and milk usage was recently embedded within the archaeogenetic scenario of demic diffusion of Near Eastern farmers and

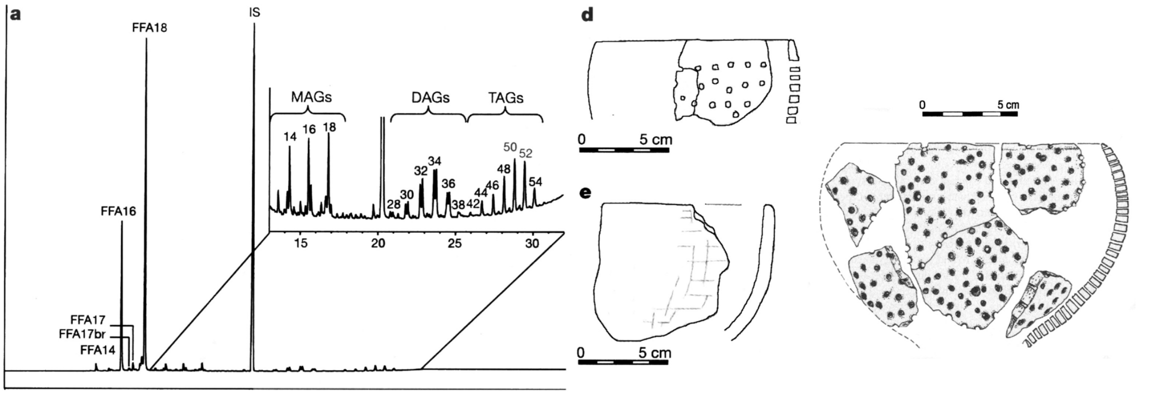

Fig. 25. Partial gas chromatograms of total lipid extracts from ceramic sieve associated with cheese production in Linear Pottery culture (reprinted by permission from Macmillan Publishers Ltd: Nature,* Salque *et al.* 2012.Figs. 1–2, *copyright 2012).

the evolution of lactase persistence in the Neolithic population in Eurasia. It was hypothesised on the one hand that strong selection for lactase persistence runs within the 'niche construction' at the forefront of the demic diffusion, where local environmental conditions and subsistence strategies led to a population increase and concentration on milk resources (*Gerbault* et al. *2011*). On the other hand, it was suggested that lactase persistence appears in a relatively short period among dairy farmers in the northern Balkans in the Starčevo and Körös cultures, and is subsequently dispersed by demic diffusion to Central and Western Europe in the area of Linear Pottery (*Itan* et al. *2009*). However, archaeogenetic analyses revealed an absence of the lactase gene in Neolithic populations in Europe, suggesting that lactase persistence was very low or even zero (*Leonardi* et al. *2012.93*; for a discussion, see *Budja* et al. *2013*).

The first farmers were probably lactose intolerant and could not have used unprocessed milk without

		Triacylglycerols	Fatty acids	Other constituents	$\delta^{13}C$ and $\Delta^{13}C$ signature
NON-RUMINANT ANIMALS	Porcine adipose fats	- Narrow distribution C_{44} to C_{54} with low abundance of C_{44}, C_{46} and C_{54} - Rich in tripalmitin - Palmitic acid preferentially located in the 2-position (P:S ratio in *sn*-2 position is of ≈ 95:5)	- $C_{16:0}$ more abundant than $C_{18:0}$ - Absence of minor odd carbon number fatty acids - Monounsaturated fatty acid: only a single isomer *Z*-9-octadecenoic acid	- Odd-numbered ketones ranging from C_{29} to C_{35}, maximising at C_{33} - Monounsaturated ketones with 33 and 35 carbon atoms Result from condensation of fatty acids during heating animal fats - Free or bound oxidised fatty acids (diacids, hydroxy-acids), Fig. 11	- Palmitic and stearic acids enriched in ^{13}C compared to ruminant fats (Fig. 18) - $\Delta^{13}C$ > -1 ‰ (Fig. 21, D)
ADIPOSE FATS FROM RUMINANT ANIMALS	Cattle adipose fats	- Distribution from C_{42} to C_{54} - P:S ratio in *sn*-2 position is of ≈ 60:40	- $C_{16:0}$ less abundant than $C_{18:0}$ - Low amount of straight carbon chain with odd carbon number, specifically $C_{15:0}$ and $C_{17:0}$ - Low amount of branched-chain alkanoic acid ($C_{15:0}$ and $C_{17:0}$) - Mixture of isomers of octadecenoic acid (double bond at 9, 11, 13, 14, 15 and 16-positions)	- Same ketones as for porcine adipose fats	- $\Delta^{13}C$ from -3 to -1 ‰ (Fig. 21, D)
	Goat adipose fats	- Distribution from C_{44} (trace) to C_{54} - P:S ratio in *sn*-2 position is of ≈ 60:40			
	Sheep adipose fats	- Distribution from C_{44} (trace) to C_{54} - P:S ratio in *sn*-2 position is of ≈ 60:40			
DAIRY PRODUCTS OF RUMINANT ANIMALS	Cow milk	- Large distribution from C_{40} to C_{54} - in all triacylglycerols, $C_{10:0}$ present at lower abundance than in goat milk	- Same fatty acids as for adipose fats of ruminant animals	- Same ketones as for porcine adipose fats	- $C_{18:0}$ depleted in ^{13}C in comparison with adipose animal fats - $\Delta^{13}C$ < 3.3 ‰
	Sheep milk	- Large distribution from C_{40} to C_{54}			
	Goat milk	- Large distribution from C_{40} to C_{54} - in all triacylglycerols, $C_{10:0}$ present at higher abundance than in cow milk			
AQUATIC RESOURCES	Marine fish	Not preserved	- Palmitic acid more abundant than stearic acid - Long chain fatty acids with more than 18 carbon atoms - Triunsaturated fatty acids (usually not preserved in archaeological contexts)	- Presence of isoprenoid acids (phytanic acid 3,7,11,15-tetramethylhexacosanoic acid and 4,8,12-trimethyltridecanoic acid = 4,8,12-TMDT) at low abundance - Series of isomers containing 16, 18 and 20 carbon atoms of ω-(o-alkylphenyl) alkanoic acids (cyclic compounds) with a wide range of positional isomers formed by degradation of triunsaturated fatty acids	- Palmitic and stearic acids are isotopically enriched in ^{13}C compared to those of terrestrial animals, eventhough they plot not far from adipose fats of domestic pigs (Fig. 18)
	Freshwater fish	Not preserved	- Same acids as for marine fish	- Same constituents as for marine fish	- freshwater fishes are depleted in ^{13}C for both $C_{16:0}$ and $C_{18:0}$ fatty as compared to marine resources

Fig. 26. Summary of molecular and isotopic criteria to distinguish animal fats in archeological ceramic vessels (reprinted from* Regert 2011.Tab. 2, *copyright 2010 by Wiley Periodicals, Inc.).

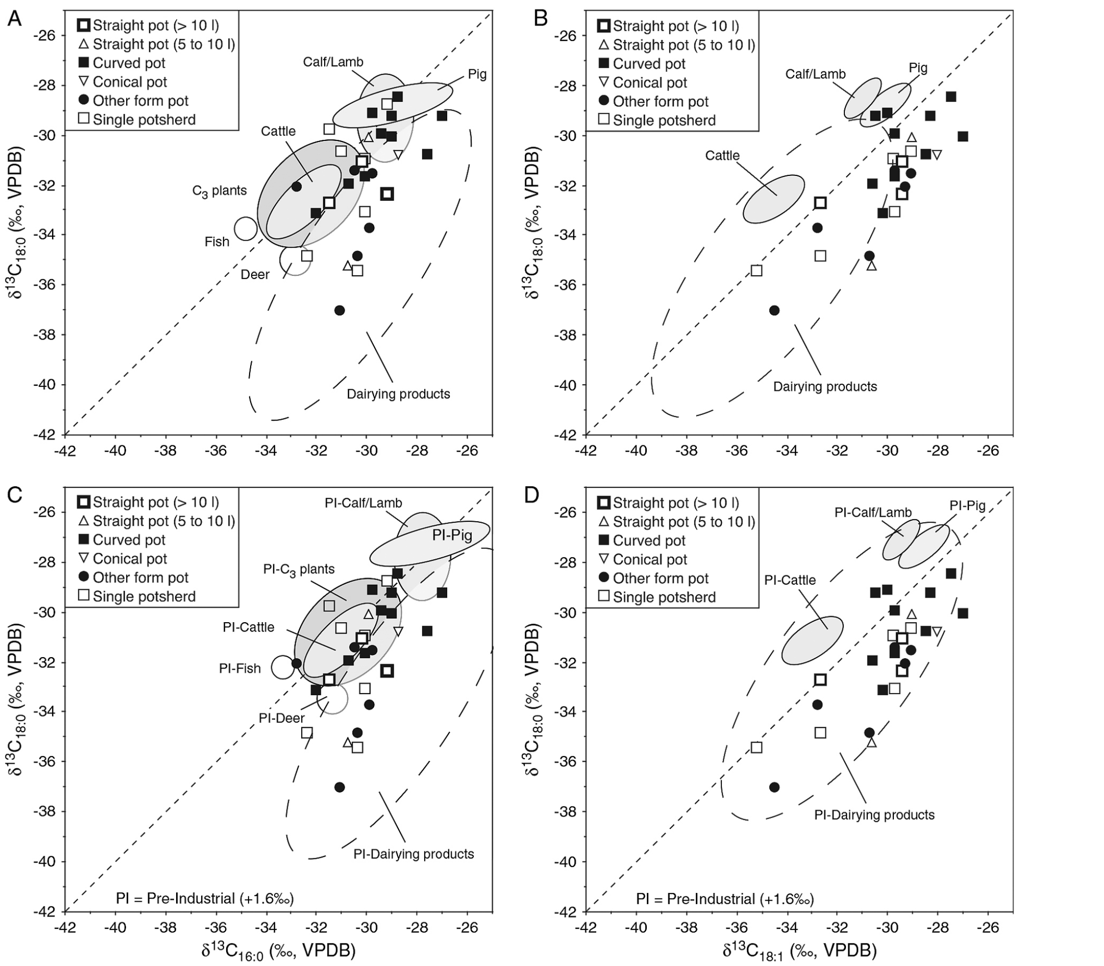

Fig. 27. Comparison of the carbon isotope composition of stearic acid ($\delta^{13}C_{18:0}$) versus palmitic ($\delta^{13}C_{16:0}$) and oleic ($\delta^{13}C_{18:1}$) acid of organic residues from Arbon Bleiche 3 Neolithic site with those of modern (A and B) and pre-industrial animal and plant fats (C and D) (reprinted from **Spangenberg *et al.* 2006.Fig. 5, *copyright 2005, with permission from Elsevier).***

having digestive problems. It should be noted that lactose is progressively reduced by milk processing. The lactose content of fresh milk ranges between 4.42–5.15g/g% in cattle, 4.66–4.82g/g% in goats and 4.57–5.40g/g% in sheep. It can be reduced to 50–60% by bacterial fermentation. Some processed milk products (such as cheese and butter) have very low lactose content, ranging from 0–3.7g/g% (*Nagy 2011. 267*). Lactose intolerant farmers were thus able to digest processed milk products better than fresh milk. It would therefore be possible that the earliest dairy farmers not only recognised the nutritive value of milk, but also understood how to convert milk into what would have been, for them, more palatable dairy products. Milk is extremely perishable and many methods have been developed to preserve it; fermentation was the earliest method. Inoculating fresh milk with the appropriate bacteria can ferment milk at temperatures that favour bacterial growth. As the bacteria grow, they convert milk sugar or lactose into lactic acid. The lowered pH caused by lactic acid preserves the milk by preventing the growth of pathogenic bacteria, which do not grow well in acidic conditions. The lactic acid bacteria (*e.g.*, *Lactobacillus acidophilus*, *Lactobacillus bulgaricus*, *Lactobacillus caucasius* and *Lactococcus lactis*) thus turn milk into yoghurt, kefir, buttermilk and cheese. They make milk available as a nutritional source throughout the entire life of individuals, and also have advantages for storing and transporting dairy products and making them available in periods of low milk production on the other.

The presence of abundant milk fat in specialised vessels comparable in form to modern cheese strainers was identified in Northern Europe in the Early Neolithic LBK complex at *c*. 5200 and 4900–4800 calBC. It provides compelling evidence that vessels were used to separate fat-rich milk curds from the lactose-containing whey, which is characteristic of the production of cheese (*Salque* et al. *2012*) (Fig. 25). In Scandinavia, further to the north, dairy fat residue

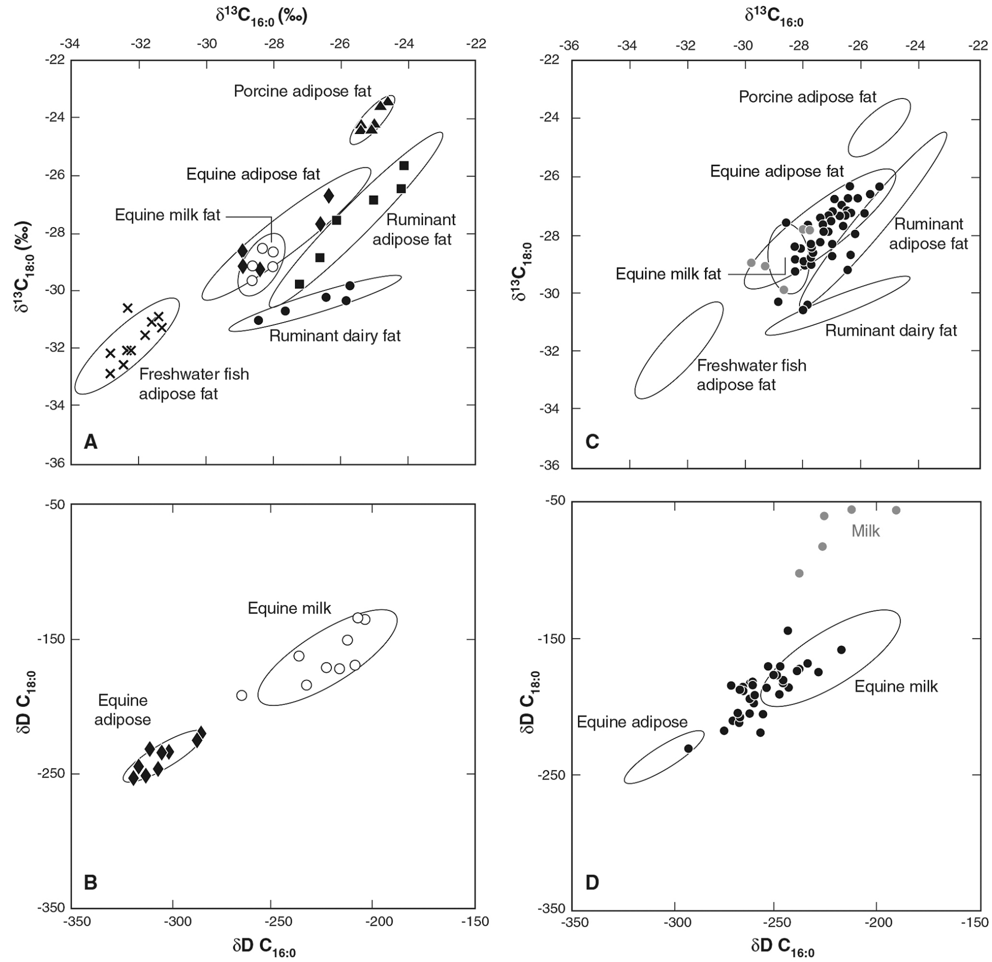

Fig. 28. Scatter plots of δ13C and δD values of the $C_{18:0}$ and $C_{16:0}$ fatty acid animal fats of modern reference fats (A and B) and of organic residues from archaeological pottery (C and D) from Kazakhstan. C shows the δ13C values of $C_{18:0}$ and $C_{16:0}$ FAs extracted from 89 pottery fragments of Eneolithic Botai culture; and (D) shows the δD values of the $C_{18:0}$ and $C_{16:0}$ FAs of the residues from pottery assigned as equine fats. All confidence ellipses correspond to the values exhibited by modern reference fats. The residues highlighted in red correspond to archaeological equine milk fats (from* Outram *et al.* 2009.Fig. 3*, reprinted with permission from AAAS).

was found in Corded Ware culture at *c.* 2500 calBC (*Cramp* et al. *2014b*). Oliver Craig *et al.* (*2005*) provided much earlier data for milk processing in the Early Neolithic in Southeast Europe. Degraded ruminant fatty acid in pottery in the Starčevo-Criş (5950–5500 calBC) and Köros cultures (5800–5700 calBC) suggest milk products and milk processing, *i.e.* the heating of milk. In the Northern Adriatic, initial milk processing is well embedded in Vlaška culture in the time span 5467–5227 calBC (*Budja* et al. *2013*).

Towards a new perception of reference isotopic values of modern animal fats and $\Delta^{13}C$ proxies

While all the molecular and isotopic criteria useful for discriminating different animal fats have been summarised (*Regert 2011.Tab. 2*) (Fig. 26), many recent studies of organic residues in archaeological pottery from Neolithic sites in Central Europe, Near East and Central Asia have raised questions about the use of stable carbon isotope values obtained from modern reference fats from animals pastured in the UK to characterise ancient organic residues from other regions of the world.

Gregg and Slater (*2010.847–849*; see also *Gregg* et al. *2009*) noted that the isotopic ratios of adipose fats of wild boar from Palestine, domesticated sheep from Israel and dairy food residues from Turkey do not correlate with ranges of $\delta^{13}C$ values for pig fats, and ruminant adipose and dairy fats from the UK. While $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ from sheep adipose fats from the Near East are significantly more positive, plotting near the observed range of domesticated pigs from the UK, those from wild boar adipose are both significantly more negative. None of the $\delta^{13}C$ values of pottery lipids extracts plot below the $\Delta^{13}C = -3.3$ line, and thus would not be catego-

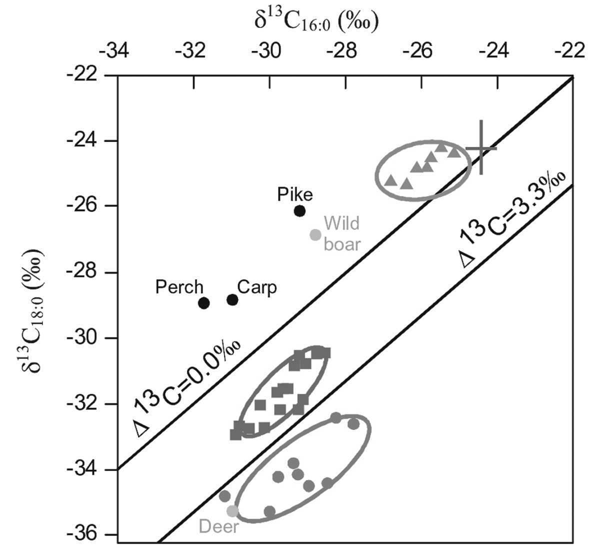

Fig. 29. Plot of the $\delta^{13}C$ values obtained on reference wild and domestic animals.* "Data in blue = porcine fats (*Copley* et al. *2003*); in red = ruminant adipose fats (*Copley* et al. *2003*); in green = ruminant milk fats (*Copley* et al. *2003*). Data in orange = wild species (*Craig* et al. *2007b*); brown crosses = marine fish (*Craig* et al. *2007b*)" *(reprinted from* Regert 2011.200, Fig. 18*, copyright 2010 by Wiley Periodicals, Inc.).

rised as dairy foods on the basis of the criteria postulated by Evershed *et al.*, Copley *et al.*, and Mukherjee *et al.* (see above). In Central Europe, $\delta^{13}C$ values for ruminant adipose fats plot above the $\Delta^{13}C$ = 0 line, and within the range previously observed for pig fats.

Jorge E. Spangenberg *et al.*'s (*2006*) study of lipids extracts from Neolithic pottery and modern reference adipose and dairy fats from Central Europe has demonstrated that there is greater diversity in the fractionation of carbon isotopes associated with the synthesis of $C_{16:0}$ and $C_{18:0}$ FAs in ruminant and non-ruminant animals than previously postulated. Stable carbon isotope values of modern pig fat, cow's milk, and goat cheese in this study all overlap the range of ruminant adipose values from the UK used to categorise potsherd extracts (Fig. 27). It was shown that the overlap in stable carbon isotope values of dairy foods and adipose fats of ruminant and non-ruminant species can result from a wide range of other factors that affect fractionation, not only in the synthesis of FAs in the animals themselves, but also during the subsequent preparation and storage of fermented milk byproducts. The boiling effect on modern milk samples showed different changes in the $\delta^{13}C$ values for the main FAs $C_{18:0}$ and $C_{18:1}$ in cow, goat and sheep milk during heating. The differences in $\delta^{13}C$ values were up to 8‰. On the other hand, these FAs in sheep and goat cheese samples are enriched in ^{13}C by ~4‰ compared to raw milk samples. This isotopic shift probably reflects the bacterial degradation of long-chain FAs during cheese making and storage (*Spangenberg* et al. *2006.9–11; 2008.197–198*). Interestingly, the $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ FAs from adipose fats from suckling calf and lamb cluster in the range of adult pig adipose. It was suggested that the use of glucose from mother's milk as carbon source for fatty acid biosynthesis by young animals probably explains why their adipose fat plots near porcine fats that derive from acetate and glucose carbon source, but not in the range of adult ruminant animals that mainly use acetate as a carbon source for fatty acid biosynthesis (*Spangenberg* et al. *2006.8–9*).

On the Kazakh steppe in Central Asia, isotopic values for modern ruminant dairy fats have also been reported as plotting above the $\Delta^{13}C$ = –3.3 line. The $\delta^{13}C$ values of horse milk and adipose fats fall within the range of previously published values for the adipose fats of ruminants in Northern Europe (*Outram* et al. *2009*) (Fig. 28). However, $\delta^{13}C$ values are not appropriate to discriminate mare's milk from horse carcass fats. Alan Outram *et al.* (*2009.1334–1335*) have introduced another proxy, the compound-specific deuterium isotope (δD) analysis, to discriminate milk and subcutaneous horse fats, and it was shown that the δD values obtained for these two types of horse products were distributed in two distinct clusters. The difference in values between milk and carcass fat is related to the variation kn δD values of summer and winter precipitation that differ importantly (>100%) on the Kazakh steppe. Adipose fats integrate water and dietary signal of all year, while mares produce milk only in summer to feed their foals, which explains the difference in δD signals between equine milk and adipose fats.

In the context of the hypothesised Mesolithic – Neolithic dietary shift in Northern Europe, $\delta^{13}C$ values for $C_{16:0}$ and $C_{18:0}$ FAs of a range of marine and freshwater (pike, perch, and carp) fish were determined. Marine fats have shown to be isotopically enriched in ^{13}C compared to those of terrestrial animals, even though they plot not far from adipose fats of domestic pigs (*Craig* et al. *2007*) (Fig. 29). The available data show that freshwater fishes are depleted in ^{13}C for both $C_{16:0}$ and $C_{18:0}$ FAs as compared to marine fishes. It was suggested that the formation of ω-(o-alkylphenyl) alkanoic acids 'could be undeniably considered as biodegradation markers of marine products' and evidence of fish consumption

(*Regert 2011.192*; see also *Evershed* et al. *2008b; Cramp* et al. *2014a; Cramp, Evershed 2014*). Lucija Šoberl *et al.* (*this volume*) show they can occur in high frequencies together with long-chain n-alcohols of C_{22} to C_{32} even-carbon number series and analogous odd-carbon number n-alkane series of C_{23} to C_{33} chain length, which are more characteristic of degraded plant waxes.

There is no doubt, however, that since the 1990s the determination of the nature and origin of lipids, which mostly derived from degraded animal fats based on the distribution of FAs, sterols, MAGs, DAGs, and TAGs, was a great challenge because they reflect a range of complex transformations and mixtures and have undergone a series of alteration processes.

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Ceramic petrography, mineralogy and typology of Eneolithic pottery from Krašnja, Slovenia

Andreja Žibrat Gašparič[1], Milena Horvat[1] and Breda Mirtič[2]
1 University of Ljubljana, Faculty of Arts, Department of Archaeology, SI
andreja.zibrat.gasparic@gmail.com
2 University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, SI

ABSTRACT – *In this article, we present newly excavated Eneolithic pottery from the site at Krašnja near Lukovica in central Slovenia. The material was AMS ^{14}C dated and is contemporaneous with archaeological sites from the Ljubljansko barje region in Slovenia. The vessels were reconstructed and then various types of pots, dishes, cups, and beakers were analysed using petrography and the X-ray diffraction method. Additionally, the clay remains of walls and the floor of an Eneolithic kiln excavated at the site were also analysed. The results show that Eneolithic potters used different fabrics to make vessels, and mostly one recipe with added calcite. The raw source material probably came from a nearby valley to the south of the site at Krašnja.*

IZVLEČEK – *V članku predstavljamo eneolitsko lončenino z novoodkritega najdišča Krašnja pri Lukovici v osrednji Sloveniji. Najdišče je bilo AMS ^{14}C datirano in je sočasno z najdišči iz območja Ljubljanskega barja. Lončenino smo lahko rekonstruirali v različne tipe posod, med drugim lonce, sklede, skodelice in čaše, ki smo jih nato preiskali še s petrografsko metodo in metodo rentgenske difrakcije. Dodatno smo preiskali tudi sledove glinenih oblog stene in tal ene od dveh eneolitskih peči, ki smo jih odkrili na najdišču. Rezultati kažejo, da so lončarji v obdobju eneolitika uporabljali različne glinene mase za pripravo posod, vendar predvsem en lončarski recept z dodanim zdrobljenim kalcitom. Naravno surovino, glino, so morda nabirali v sosednji dolini, ki se nahaja južno od najdišča Krašnja.*

KEY WORDS – *Eneolithic; pottery; typology; petrography; microfossils*

Introduction

The mineralogical properties of pottery and clay play an important part in pottery analysis and are helpful in understanding past technologies. Nevertheless, the mineralogical composition of ceramic objects can be significantly altered by production techniques, from the cleaning of clays, addition of temper, forming of objects, firing conditions and atmosphere. The life cycle of pottery and its use as well as post-depositional changes are also important and can contribute to altering the mineralogical composition. Through this whole operational sequence of pottery, we try to reconstruct past technologies and production techniques (*Sillar, Tite 2000; Whitbread 1995*).

In this article, we present recent analyses of pottery from the new site at Krašnja in central Slovenia, which was excavated in 2013 during the reconstruction of the gas pipeline M2/1 Trojane-Vodice. The excavated material dates from the Eneolithic and the Bronze Age period to the Medieval Ages and the Industrial period. We focus here on the Eneolithic material excavated, as well as on the remains of two kilns preserved *in situ*. The pottery assemblage is not large, but is nevertheless comprised of various types of pots, dishes, bowls, cups and beakers. The various types of vessels as well as the remains of a ceramic kiln were chosen for mineralogical analyses using petrography and X-ray diffraction techniques.

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Krašnja near Lukovica

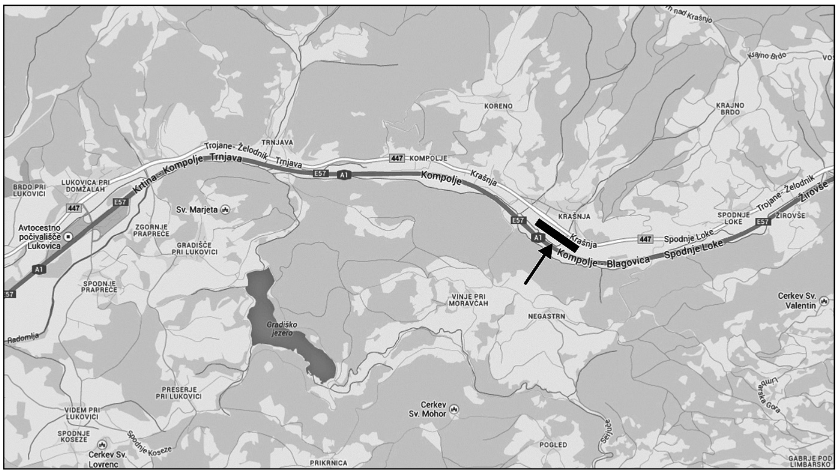

Fig. 1. The geographical position of Krašnja near Lukovica in the Črni graben valley in central Slovenia.

Krašnja is a village near Lukovica in central Slovenia located in the lower part of the Črni graben valley, north of the Radomlja River. To the south, it is bordered by the steep slopes of the Limbarska gora and Golčaj hills, and to the north by the mountain ridges of Jagodnik, Kotle and Cicelj. Many small streams flow from this direction, commonly flooding this area. The valley and surrounding hills are composed mostly of dark grey to black Palaeozoic siltstones and fine-grained sandstones. The archaeological site is located south of the local road and north of the A1 motorway between Kompolje and Blagovica (Fig. 1; *Horvat* et al. *2014a; 2014b*).

The Črni graben valley is the easiest passage between central and eastern Slovenia and was used as such for centuries. In the 1st century AD, Romans built a *via publica* through the valley, which became the main road between Italy and the Danube Regions until the 12th century, when the main road was moved north to the Tuhinjska dolina valley. The Črni graben road again became the most important road between the Adriatic and the Danube from the end of the 16th century and is still being used today (*Stražar 1985.626*).

The excavation site covers an area of 237 x 15m and is located directly on the alluvial beds of two torrents that flowed from the hills in the north to the Radomlja River in the south. The old torrent bed in the western part was filled with Eneolithic pottery, and two partly preserved kilns were dug into the youngest Eneolithic layer on the bank. Only the floor of the kiln remained intact. Charcoal and some pieces of pottery were documented on the floor of the kiln. The eastern torrent bed was also filled with Eneolithic pottery, some charcoal, parts of grind stones, and a stone mallet and an axe (*Horvat* et al. *2014a. 67; 2014b*).

The charcoal from the infill of the stream, from the Eneolithic layer, and from the kiln was AMS radiocarbon dated at the Poznan Radiocarbon Laboratory. According to the ^{14}C dates the calendar age of the Eneolithic material can be placed within the 37th–35th century calBC range, while the two kilns date to the late 37th and/or 36th century calBC; both the kiln samples show the same ^{14}C age of 4750±35 BP (Tab. 1; *Horvat* et al. *2014a.69; 2014b*). This makes Krašnja contemporaneous with sites in the Ljubljansko barje region, especially with Maharski prekop (*Bregant 1974a; 1974b; 1975; Mlekuž* et al. *2012*) and Hočevarica (*Velušček 2004*).

Pottery technology and typology

We described the pottery assemblage at the macroscopic level with the use of a hand lens to identify

Lab. No.	Material	Context	^{14}C Conventional age BP	Calibrated age calBC (68.2%)	Calibrated age calBC (95.4%)
Poz-58839	charcoal	layer SU 21	4655±35	3510–3365	3620–3360
Poz-58840	charcoal	layer SU 137	4820±35	3650–3535	3695–3520
Poz-58841	charcoal	kiln SU 136	4750±35	3635–3515	3640–3380
Poz-58842	charcoal	kiln SU 117	4750±35	3635–3515	3640–3380
Poz-58843	charcoal	layer SU 214	4910±35	3710–3650	3770–3640
Poz-58845	charcoal	layer SU 198	4930±40	3765–3650	3790–3645
Poz-58846	charcoal	layer SU 172	4870±40	3695–3635	3765–3530

Tab. 1. ^{14}C dates for the Eneolithic period at Krašnja.

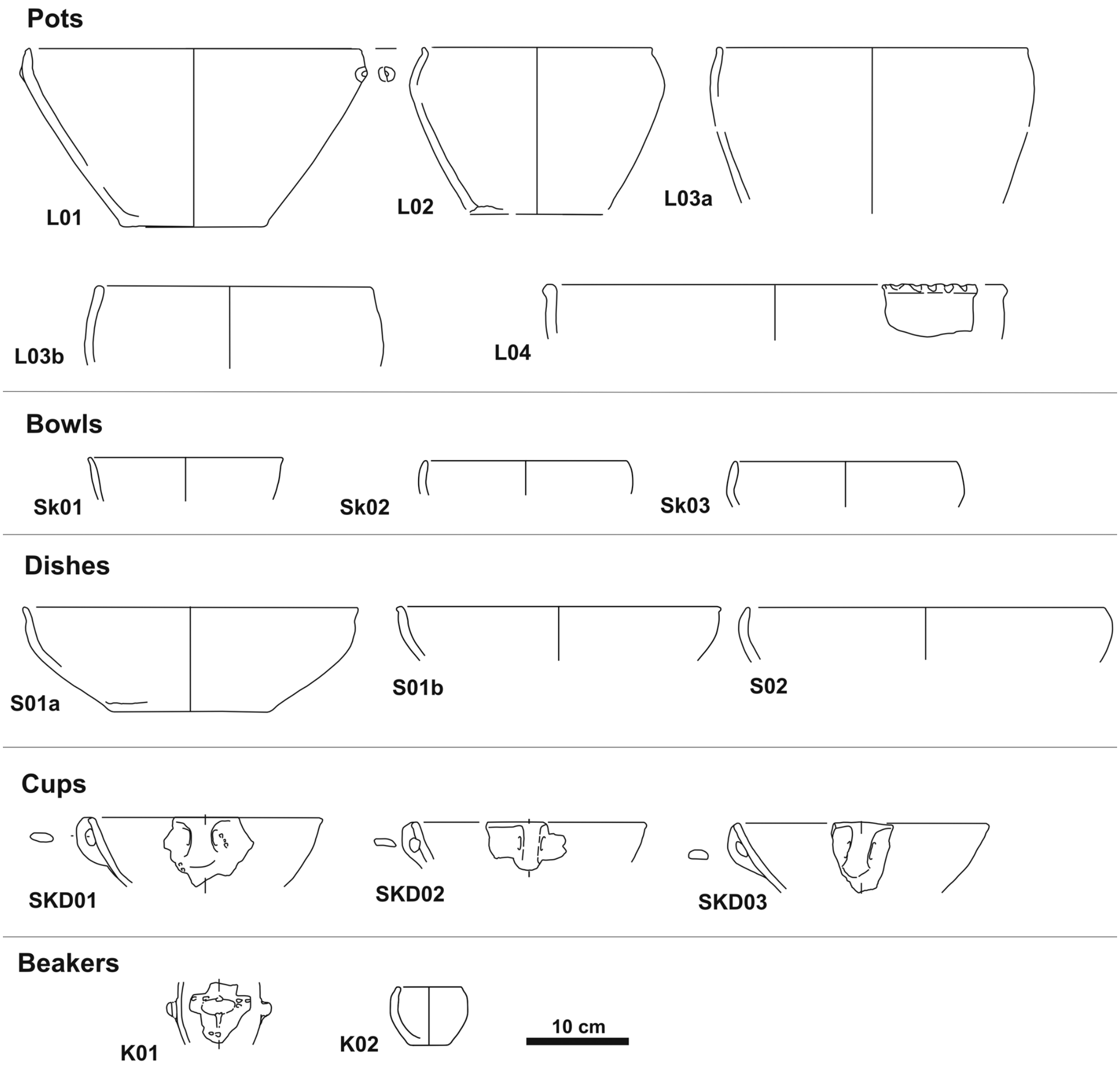

Fig. 2. Pottery typology of Eneolithic vessels from Krašnja.

inclusions, their size and frequency, the presence of voids, as well as hardness, colour after firing, and the firing atmosphere of the vessels (following descriptions after *Horvat 1999*). Because the vessels were fragmented to a great extent, the technological description was made only of typologically defined vessels and fragments of vessel rims, bases, and ornamented fragments. All the analysed pottery could be attributed to a single technological group, *i.e.* fine- grained fabric with quartz inclusions. The other inclusions are mica, ferrous oxides, organic matter and very rare crushed pottery or grog.

All the vessel surfaces are burnished and well formed, but also have many voids visible on the surface. The voids have angular and semi-angular shapes, and measure from 0.5 to 2mm. The majority of vessels (77%) were fired in an incomplete oxidising atmosphere, while the rest were fired in an oxidising atmosphere. The vessels have mostly grey and light brown surface colours, with rare fragments in red, grey and dark brown shades.

A total of 329 fragments of pottery were excavated at Krašnja in the Eneolithic assemblage, from which only 25 whole vessels could be reconstructed and assigned to five basic types: pots (11), dishes (5), bowls (3), cups (4) and beakers (2). Among the unclassified pottery fragments are mostly parts of vessel bases and parts of walls with hand-made appliqués. This classification was made using criteria such as shape and proportions (*Horvat 1999*). The Eneolithic pottery from Krašnja has many similarities with assemblages from contemporary sites in the Ljubljansko barje region, mostly with Maharski prekop (*Bregant 1974a; 1974b; 1975*), Hočevarica (*Velušček 2004*) and Stare gmajne (*Velušček 2009*).

Pots (Fig. 2) are classified into two groups according to their outline and the shape of the contact between the upper and lower parts of the vessels. The first group is comprised of pots without necks, with biconical (L01, L02) or ellipsoid shape (L03a, L03b, L04). The second group of pots is comprised of vessels with necks. At Krašnja, only the upper parts of these vessels were preserved, so a reconstruction of the shapes was not possible.

The biconical shapes present a special form of pot with a high bottom part and short shoulders. These pots were common in the Eneolithic period in central Slovenia. Pot variant L01 can be found at Hočevarica (*Velušček 2004.t. 4.1.5:7*) and pot variant L02 at Hočevarica (*Velušček 2004.186, Fig. 4.2.1:L2*) and Maharski prekop (*Bregant 1974a.t. 3.8*). For variant L03a and L03b, there are comparisons at Maharski prekop (*Bregant 1974a.t. 5.4; 1975.t. 30.11*) and Hočevarica (*Velušček 2004.186, Fig. 4.2.1:L3*).

We used functional criteria (*e.g.*, open/closed, deep/shallow) and the criteria of the vessels outlines to classify dishes and bowl (Fig. 2). Dishes are classified into open shallow dishes with a biconical outline with a semi-ellipsoid shape and a redesigned rim and a sharp contact with the wall of the vessel (S01a, S01b). Dishes S01a and S01b have parallels from Hočevarica (*Velušček 2004.t. 4.1:6, t. 4.1.8:5*) and from Maharski prekop (unpublished material). Only one type is a deep closed dish with a complex biconical outline with a semi-ellipsoid shape and a simple rim (S02). Variant S02 has parallels with a dish from Maharski prekop (*Bregant 1975.t. 22.10*).

Only three bowls could be classified in the assemblage (Fig. 2). The most significant is an open bowl with an oblique rim that has a fluid contact with the lower part of the body with a spherical shape (Sk01). Bowls similar to Sk01 can be found at Hočevarica (*Velušček 2004.Fig. 4.2.9:S8*), Maharski prekop (*Bregant 1975.t. 19.4*) and Stare gmajne (*Velušček 2009. t. 3.18:9*). Among the closed shapes of bowls, we could identify a bowl with a simple spherical shape (Sk02) and a biconical bowl with a conical spherical shape (Sk03), both with a simple rim and fluid contact with the body. Similarities to bowls of variant Sk02 are also found at Hočevarica (*Velušček 2004. t. 4.1.2:9*) and Maharski prekop (*Bregant 1975.t. 28.9*).

Cups and beakers are classified between shallow and deep vessel types (Fig. 2). The variants Skd01 and Skd02 are open bowls with a simple spherical outline, and variant Skd03 is an open bowl with a conical shape, an oblique rim and gradual contact with the lower part of the body. The cups Skd01 are similar to cups from Hočevarica (*Velušček 2004.t. 4.1.2:9*). The beakers have a simple ellipsoid shape (K01) or a biconical outline with a semi-ellipsoid shape (K02). Beakers K01 have similarities with vessels from Hočevarica (*Velušček 2004.196, Fig. 4.2.7: K4*) and K02 can also be found at Maharski prekop (unpublished material) and Stare gmajne (*Velušček 2009.t. 3.15: 11, Fig. 3.15: K1*).

The vessels are only modestly decorated, with only two basic types of decoration: impressions and appliqués. The most common techniques are awl impressing, pinching with two fingers, and simple hand-made appliqués; the latter two were also identified in combination.

Analytical methods

The Krašnja pottery was first analysed with the use of a hand lens and described at the macroscopic level, detailing the broader technological traits of the whole assemblage (*Horvat 1999*) such as the inclusions, their size and abundance, the presence of voids, the hardness, surface treatment, colour, and firing atmosphere. The pottery was then sampled according to its stratigraphic position, vessel type and ornamentation technique, and basic technological traits. We sampled 12 vessels from the Eneolithic period and three additional contemporary clay samples from the excavated kiln SU 117 at the site (Tab. 2).

For the mineralogical analyses, we used thin-section petrography and X-ray powder diffraction techniques. Ceramic petrography enhances the identification of non-plastic inclusions and allows for direct comparisons with regional geology (*Rice 1987.415; Whitbread 1995*). The pottery samples were prepared as standard thin sections of 30μm thickness (*Reedy 2008.1–3*) and then described under a polarising light microscope (*Whitbread 1995.App. 3; Terry, Chillingar 1955*). One of the clay samples from kiln SU 117 was fired in a controlled atmosphere to 800°C and prepared as a thin section.

We sorted the samples into fabric groups based on the composition of inclusions, the clay matrix and voids. On the basis of compositional, microstructural and textural criteria, we identified the presence of specific techniques, such as the addition of temper, raw material processing, vessel forming, and the at-

Sample No.	Catalogue No.	SU	Grid Square	Vessel Type	Description
OBD 16	13	21	F38	S01b	dish
OBD 180	2	21	G38	L02	pot
OBD 181	20	242	E36	K02	beaker
OBD 183	1	21	E39	L03b	pot
OBD 184	35	21	E38	/	vessel (base)
OBD 245	17	21	G38	SKD03	cup
OBD 247	18	21	E38	SKD01	cup
OBD 248	19	21	E39	K02	beaker
OBD 249	15	21	E39	SKD02	cup
OBD 251	14	21	E33	S02	dish
OBD 252	10	21	E38	S01a	dish
OBD 258	6	21	G38	L04	pot
Sample 17	/	117	E27	/	fired clay – part of kiln roof
Sample 18	/	117	E27	/	fired clay – kiln floor
Sample 28	/	117	E27	/	clay – part below the kiln

Tab. 2. List of pottery and kiln samples from Krašnja.

mosphere and firing temperatures (*Reedy 2008.146–148, 173–189; Whitbread 1986; 1995.393*).

The pottery and clay samples were also analysed using the X-ray powder diffraction method. For the analysis, approx. 3g of pottery were ground into fine powder and then recorded on a Philips PW3710 X-ray diffractometer (Cu X-ray tube; secondary graphite monochromator; 10kV; 10mA; 2 to 70° 2θ).

The results of ceramic petrography and X-ray diffraction

The petrographic analysis revealed many similarities with the pottery samples from Krašnja. The pottery was made from non-calcareous clay, with many inclusions, such as quartz, mica (muscovite, sericite, biotite), plagioclase feldspars and composed mineral grains such as chert, opaque aggregates, argillaceous rock fragments and, very rarely, organic matter. The main difference between the samples is in their microfossil content and the presence of opaque minerals. We could divide the samples into 5 fabrics according to their composition (Tab. 3).

The samples have very few (1–5%) angular voids, mostly in the medium to coarse sand size fraction, with many of them having a rhombohedral shape characteristic of calcite crystals. Based on their shape, we conclude that these voids were created as a result of dissolving calcite from pottery (*e.g.*, Fig. 4.D). Since voids are mostly sand grained with almost no voids in the silt size fraction common to non-plastic inclusions, this confirms that calcite was added to the clay paste as temper. The dissolution of calcium carbonate may occur in post-deposition of pottery due to the low pH environment of the soil (*Reedy 2008.208*). Afterwards, the voids were secondarily coated with amorphous hydrated iron oxide-hydroxides, *i.e.* limonite (Fig. 3). Such chemical alterations and deterioration in the composition of pottery are common post-depositional processes when vessels are buried in sediment (*Rice 1987.421; Reedy 2008. 208–210*).

Fabric 1 (Fig. 4.A) is a non-calcareous clay with frequent (30%) non-plastic inclusions that are well sorted and mostly in the silt size fraction. They include frequent monocrystalline quartz, common muscovite mica grains and opaque ferrous minerals, and rare biotite mica, plagioclase feldspars and chert. Microfossil sponge spicules are also common in the paste (10%). The fabric has rare (1%) angular and rhombohedral voids, showing that the crushed calcite was added to the fabric as temper. The fabric was recognised in only one beaker from the Eneolithic layer (OBD 248).

Fabric 2 (Fig. 4.B) is a non-calcareous clay with common (20%) non-plastic inclusions that are well sorted and mostly in the silt size fraction. They include common monocrystalline quartz, common muscovite

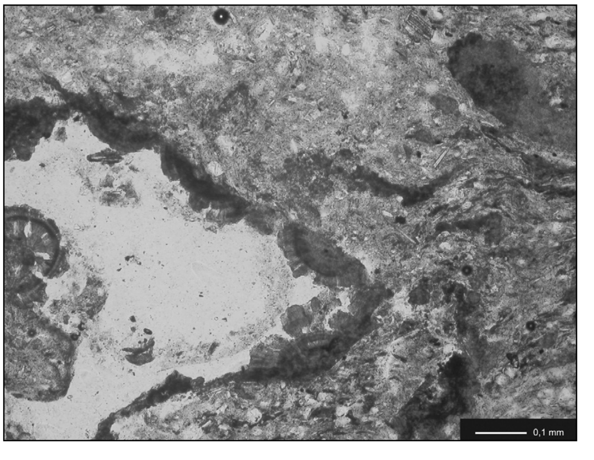

Fig. 3. Photomicrograph of a thin-section from cup OBD 245 from Krašnja. The voids in the sample are secondarily coated with amorphous limonite. Image taken in plane polarised light.

	Voids (in %)	Grog (in %)	Quartz (in %)	Mica (in %)	Spicules (in %)	Diatoms (in %)	Opaques (in %)	Sample No.
Fabric 1	1	/	40	20	10	0	10	OBD 248
Fabric 2	5	0–1	20–30	20	10–15	0–2	10	OBD 16, OBD 247, OBD 251
Fabric 3	1	/	20	5	10	2	30	OBD 184
Fabric 4	1–5	0–1	30–40	5–15	10–15	5–10	5–15	OBD 181, OBD 183, OBD 245, OBD 252, OBD 258
Fabric 5	1	/	20–30	10–20	10	15	10	OBD 180, OBD 249

Tab. 3. The basic compositions of pottery fabrics from Kršnja.

mica grains and opaque ferrous minerals, and rare biotite mica, chert and organic matter. Common (10–15%) sponge spicules and rare (0–2%) diatoms microfossils are also present in the paste. The fabric has few (5%) angular and rhombohedral voids, showing that the crushed calcite was added to the fabric as temper. The fabric was recognised in two dishes (OBD 16, OBD 251) and one cup (OBD 247). Dish OBD 251 also had rare (1%) angular grains in the coarse sand size (approx. 1mm) composed of non-calcareous clay with quartz and mica inclusions and sponge spicules. These grains could be attributed to crushed old pottery (*i.e.* grog) added to the fabric as temper.

Fabric 3 (Fig. 4.C) is a non-calcareous clay with common (20%) non-plastic inclusions that are well sorted and mostly in the silt size fraction. They include common monocrystalline quartz, a few muscovite mica grains, frequent opaque ferrous minerals, and rarely, biotite mica grains. Common (10%) sponge spicules and few diatoms (2%) are also present in the paste. The fabric has rare (1%) angular and rhombohedral voids, showing that the crushed calcite was added to the fabric as temper. The fabric was recognised only in one sample, *i.e.* a fragment of a base (OBD 184).

Fabric 4 (Fig. 4.D) is the most common fabric, since five samples could be attributed to it. The samples include two pots (OBD 183, OBD 258), a dish (OBD 252), a beaker (OBD 181) and a cup (OBD 245). They are made of non-calcareous clay, with common to frequent (20–30%) non-plastic inclusions that are well sorted and in the silt size fraction. They include frequent monocrystalline quartz, few to common muscovite mica grains and opaque ferrous minerals, and rare biotite mica, plagioclase feldspars and chert. Common sponge spicules (10–15%) and diatoms (5–10%) are also present in the paste. The fabric has rare to few (1–5%) angular and

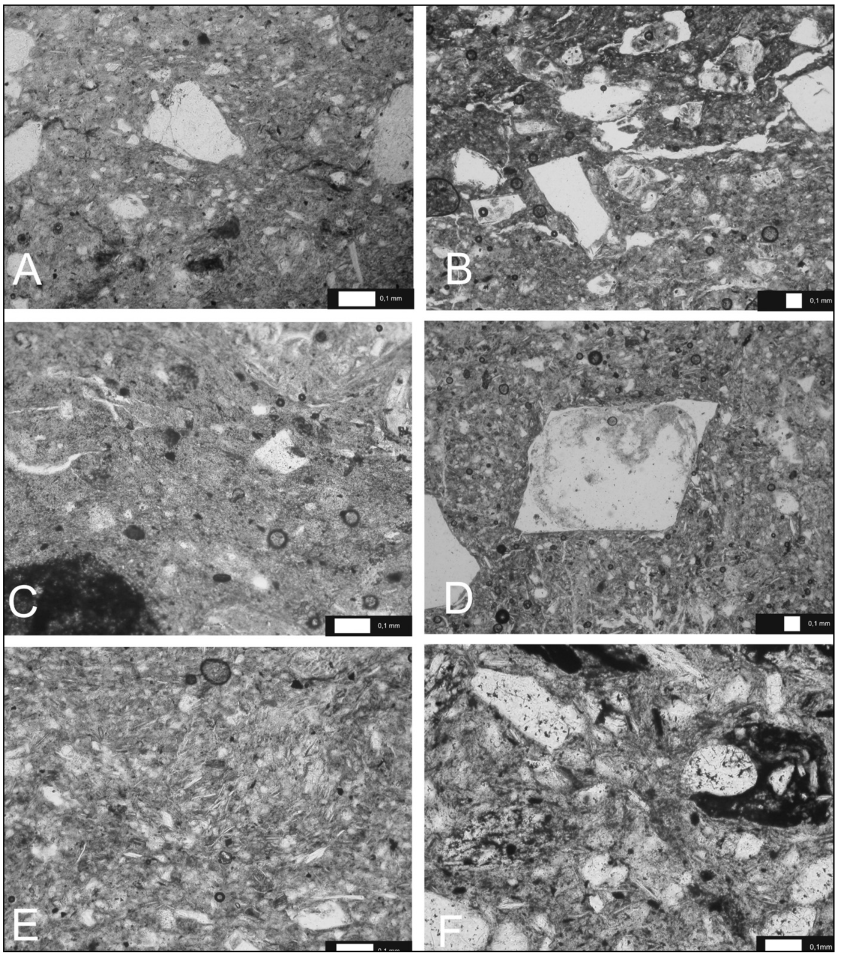

Fig. 4. Photomicrographs of pottery thin-sections from Kršnja: A – fabric 1 (beaker OBD 248); B – fabric 2 (dish OBD 251); C – fabric 3 (vessel OBD 184); D – fabric 4 (pot OBD 258); E – fabric 5 (pot OBD 180); F – fired sample 28 from kiln SU 117. Images taken in plane polarised light.

rhombohedral voids, showing that the crushed calcite was added to the fabric as temper. Beaker OBD 181 also had rare (1%) angular grains in the coarse grain size (approx. 1 mm) that are composed of non-calcareous clay with quartz and mica inclusions, as well as sponge spicules and diatoms. These could be attributed to crushed grains of ceramic vessels (*i.e.* grog) added to the fabric as temper.

Fabric 5 (Fig. 4.E) is a non-calcareous clay with frequent (30%) non-plastic inclusions that are well sorted and mostly in the silt size fraction. They include common monocrystalline quartz, mica (muscovite) grains and opaque ferrous minerals, as well as very rare biotite mica, plagioclase feldspars and chert. Diatoms comprise 15% of all inclusions and are slightly more common than sponge spicules (10%). The fabric has rare (1%) angular and rhombohedral voids, showing that the crushed calcite was added to the fabric as temper. The fabric could be recognised in two samples, *i.e.* pot OBD 180 and cup OBD 249.

The various fabrics were all made to a similar recipe, since they all contain added calcite temper that was later dissolved from the vessels. Pottery recipes with added calcite temper also comprise the most common type of pottery from the contemporary site at Maharski prekop near Ig in the Ljubljansko barje region (*Osterc 1975; Žibrat Gašparič 2013.153–155*). Only two samples had crushed old pottery or grog added as temper in addition to crushed calcite grains, *i.e.* beaker OBD 181 and dish OBD 251. A similar recipe with calcite and grog was also discovered at Maharski prekop, which has a rare type of fabric (*Osterc 1975; Žibrat Gašparič 2013.153–155*). The presence of added calcite is a common temper in cooking pots, since the shape and properties of these grains give a vessel greater thermal and shock resistance than quartz temper (*Tite* et al. *2001*).

The microfossils present in the samples are isotropic, have oval to spherical cross-sections and range from 20 to 100µm in size (Fig. 5). These are mostly fragmented remains of siliceous sponge spicules and diatoms (*Quinn 2008*). Their shapes suggest that the sponges and diatoms were saltwater organisms originating from sedimentary rocks, perhaps from local Middle Miocene marlstone (*Aleksander Horvat, pers. comm.*). Diatomaceous sediments are rare in Slovenia and could be confirmed only for some Middle Miocene sedimentary rocks from central Slovenia (*Horvat, Mišič 2004*). Nevertheless, Miocene sedimentary rocks can be found closest to Krašnja in the two valleys parallel to Črni graben and the valley of the Radomlja River: *i.e.* in the northern Tuhinjska dolina valley and in the south near Moravče and Izlake (*Premru 1983*).

The X-ray powder diffraction analysis shows even greater similarities between the pottery samples than the results of petrography (Tab. 4). All the samples have similar peaks of minerals such as quartz, muscovite mica and plagioclase feldspars (albite and/or anorthite).

As we have demonstrated, the most common recipe at Krašnja has crushed calcite grains added to the fabric. At temperatures around 850°C, calcite ($CaCO_3$) starts to decompose into lime (CaO), although the reaction can start as low as 700°C according to tests (*Cultrone* et al. *2001.628*). This reaction can damage vessels in the cooling process. Since the vessels at Krašnja were not damaged during firing and were being used, they were clearly fired below 700 to 800°C. The absence of clay minerals and clinochlore as well as the presence of cracked quartz grains, attributed to the quartz inversion reaction at 573°C (*Graimshaw 1971.221– 227*), show the lower firing temperatures of the Krašnja samples were around 600°C.

Analysis of kiln SU 117

The remains of two kilns were excavated at Krašnja (SU 136 and SU 117; *Horvat* et al. *2014*). Only the fired floors of the chamber and part of the firebox facing west were preserved, since the kilns were partly destroyed by water erosion. Nevertheless, the remains show that the kilns had spherical shape (Fig. 6) and could be the remains of a simple updraft kiln (*Rye 1981.100; Rice 1987.159–160*). The surface of

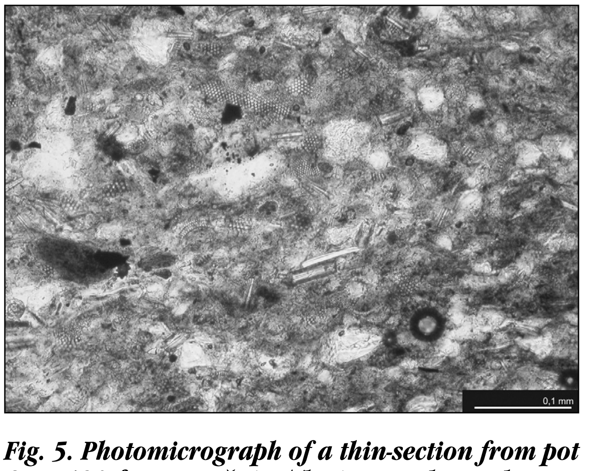

Fig. 5. Photomicrograph of a thin-section from pot OBD 180 from Krašnja. The image shows the presence of sponge spicules and diatoms inside the clay matrix. Image taken in plane polarised light.

the chamber was later filled with dark grey-brown silt with pieces of charcoal and Eneolithic pottery. The radiocarbon dates of charcoal from both kilns date the material to the second half of the 37th and/ or the 36th century calBC (Tab. 1).

We analysed three samples from kiln SU 117, including one fired clay sample from the floor of the kiln, one from the roof and one sample of partly fired clay from beneath the kiln (Tab. 2). Sample 28 is a light yellowish brown fired clay from below the floor of the kiln; sample 18 is a reddish brown fired clay from the central floor of the kiln, and sample 17 is a brown fired clay from the roof part of the kiln. The samples were dried and prepared for X-ray powder diffraction analysis.

The mineralogical composition of all three samples is very similar (Tab. 4), as according to the analysis they all contain minerals such as quartz, muscovite mica, plagioclase feldspars and clinochlore. The clay samples are similar to pottery; only the presence of clinochlore in the samples points to a lower firing temperature than the temperature achieved in pottery from Krašnja. Clinochlore starts to decompose at 500 to 600°C (*Grimshaw 1971.221– 227*). Therefore, we conclude that the temperatures inside the kiln wall did not exceed 500°C for most of the firing process. Since the Eneolithic pottery from Krašnja was fired above this temperature and showed no presence of clinochlore, we could presume that the kiln was not used to fire pottery. Nevertheless, we have to bear in mind that temperatures inside a kiln can be a few hundred degrees higher than temperatures during kiln construction (*Rye 1981.102–103; Harrison 2008; Urankar 2012; Kramar 2013*).

Sample 28 was additionally fired in a controlled oxidising atmosphere at 800°C and prepared as a standard thin section for petrographic analysis. The aim of this analysis was to establish a comparison between the Eneolithic pottery samples and this *in situ* clay sample from a contemporaneous kiln. The fired test sample had a reddish yellow colour and Mohs hardness 4. The sample is a non-calcareous clay, with frequent (40%) non-plastic inclusions, mostly in the silt size fraction (Fig. 4.F). These include frequent monocrystalline quartz, common muscovite mica and frequent opaque ferrous minerals. There are also a few (5%) polycrystalline quartz grains present, such as sandstone grains and chert, and rarely, other minerals such as biotite mica, plagioclase feldspars, microcline alkali feldspars, argillaceous rock fragments and organic matter. Clay sample 28 had no traces of microfossils such as sponge spicules or diatoms.

Samples 17, 18 and 28 from kiln SU 117 have a similar mineralogical composition to the Eneolithic pottery; however, as demonstrated by the test-fired sample 28, the clay samples were more coarse grained, contained more polycrystalline quartz and muscovite mica than the pottery, and had no traces of sponge spicules or diatoms characteristic of the Krašnja pottery. We conclude that the potters at Krašnja obtained clay for their vessels from a different source, and did not use the clay that was available at the site. As already mentioned, the microfossils found in the pottery had to come from material outside the Črni graben valley, since such rocks are not part of the local geology.

For additional provenance analysis, we sampled two more clays, one obtained near Krašnja (sample KR) and one near Moravče (sample MO). The first clay sample came from sediments excavated during the construction of the renewed pipeline, some 100m east of the archaeological excavation site. The second sample was obtained from a Miocene quartz-sand quarry near Moravče, some 5km south of Krašnja in the neighbouring valley, where layers of plastic clay can be found between the sand (*Rokavec 2014.79*). The samples were fired in a controlled oxidising atmosphere at 700°C, 800°C and 900°C, and then prepared as standard thin sections for petrographic analysis.

Fig. 6. Partly preserved Eneolithic kiln SU 117 from Krašnja.

Sample No.	Quartz	Muscovite	Clinochlore	Plagioclase
OBD 16	x	x		x
OBD 180	x	x		x
OBD 181	x	x		x
OBD 183	x	x		x
OBD 184	x	x		x
OBD 245	x	x		x
OBD 247	x	x		x
OBD 248	x	x		x
OBD 249	x	x		x
OBD 251	x	x		x
OBD 252	x	x		x
OBD 258	x	x		x
Sample 17	x	x	x	x
Sample 18	x	x	x	x
Sample 28	x	x	x	x

Tab. 4. The mineralogical composition of pottery and clay samples from Krašnja after X-ray diffraction analysis.

The preliminary petrographic results show that clay KR near Krašnja contained more frequent mica grains and no microfossils in the matrix and differs considerably from the Eneolithic pottery found at the site, thus confirming that Krašnja potters obtained their raw material outside the Črni graben valley. Sample MO has more similarities with the Eneolithic pottery, which the petrographic results predicted, but contained only very rare remains of sponge spicules. The question of whether clay from the Moravče valley or some other material was used to produce the pottery at Krašnja will have to be answered in the future with additional samples.

Discussion

The technological choices of potters are always linked to natural resources, the cultural traditions of their community and its natural backdrop. Therefore, the choices of natural materials, ceramic fabrics and recipes, firing conditions and ways of forming vessels are linked to the local environment as much as to the abilities and experience of the potters (*Sillar, Tite 2000.7–9*). But they are also linked to culturally defined pottery traditions that reveal symbolic gestures or individuality of the potters, which can be postulated, for example, in the use of old vessels as an integral part of a new pot (*Quinn, Burton 2009.288*). Similarly, the use of crushed calcite can be seen as a purely technological choice, since low-fired vessels with a high calcite temper perform better as cooking vessels due to the higher resistibility to changes in temperature needed in cooking vessels (*Tite* et al. *2001*), but could be also linked to a special role of this mineral in a community, *e.g.*, calcite was used for making ornaments in the Eneolithic period (*Žibrat Gašparič 2013*).

Both these techniques were documented at Krašnja. Most of the pottery was made of fine-grained material with added crushed calcite as temper, with only few pots with both added crushed calcite and old pottery as temper. A similar technology was documented at the Maharski prekop site in the Ljubljansko barje region, where the addition of crushed calcite is the most common pottery recipe in the Eneolithic period, while pottery with added calcite and grog is also present (*Osterc 1975; Žibrat Gašparič 2013*). The main difference between Krašnja and Maharski prekop pottery is the mineral composition of the clay matrix, the presence of microfossils at Krašnja, and the different firing atmospheres documented for each site, *i.e.* oxidizing conditions at Krašnja and reducing atmosphere at Maharski prekop (*Žibrat Gašparič 2013*).

The non-calcareous clays used for making vessels at Krašnja had a similar composition of quartz, mica, feldspars, chert, opaque ferrous minerals and several remains of microfossils, *i.e.* sponge spicules and diatoms. According to changes in the composition, we could define 5 different fabrics, although the main mineralogical composition in the fabrics is quite similar, as shown by the petrography and X-ray diffraction. The observed variations between the fabrics could be the result of fluctuations in composition between the different locations of clay pits, but also within a single clay pit (Fig. 4; Tabs. 3–4).

The shape of diatoms and sponge spicules inside the clay suggest that they belonged to saltwater species of these organisms (Fig. 5). These organisms therefore did not live in a freshwater environment of the Eneolithic period, as is the case of sponge spicules documented at the Neolithic site at Resnikov prekop in the Ljubljansko barje, but represent the remains of weathered sedimentary rocks, most probably from marlstones of the Miocene age (*Aleksander Horvat, pers. comm.*). The surrounding geology of Krašnja has no Miocene rock formations, but they are present in two valleys less than 10km from Krašnja: in the Moravče valley to the south and the Tuhinjska dolina valley to the north (*Premru 1983*). This distance is still within the area of the site-catchment proposed for traditional potters (*Arnold 1985*). The clay material used in the construction of the Eneolithic kiln SU 117 found *in situ* at Krašnja (Fig.

6) had a different composition than the Krašnja pottery, especially lacking any remains of microfossils (Fig. 4.F), which is additional proof that natural materials available around Krašnja were not used for pottery production. This is also supported by two additional clay samples, one obtained near Krašnja and one from a Miocene quarry near Moravče in the south.

The clay was then shaped into various types of vessels. At Krašnja we could document types such as pots, dishes, bowls, cups and beakers that were only rarely decorated (Fig. 2). For the shaping of different vessels, the Krašnja potters used various fabrics, but mostly only one recipe, *i.e.* with added calcite as mentioned above. Pots were made with fabrics 3, 4 and 5, dishes with fabrics 2 and 4; cups were made with fabrics 2, 4 and 5, and beakers with fabrics 1 and 4. This proves that the same fabrics and recipes were used for a variety of vessels, *e.g.*, fabric 4 was the main component of pots, dishes, cups and beakers alike (Tabs. 2–3). The vessels were then dried and fired usually in an incomplete oxidising atmosphere, probably inside kilns such as were excavated at the site. These vessels share many similarities in pottery typology and technology with material from contemporaneous sites such as Hočevarica, Maharski prekop and Stare gmajne in the Ljubljansko barje region (*Bregant 1974a; 1974b; 1975; Velušček 2004; 2009; Mlekuž* et al. *2012; Žibrat Gašparič 2013*).

The story of pottery from Krašnja did not end with the discarding of pots and deposition. The depositional conditions of the sediments where the vessels lay for thousands of years have changed its composition significantly. Chemical alterations are common in vessels in a buried environment (*Rice 1987. 421*). The crushed calcite grains that were added as temper were not preserved inside the pots, but dissolved; all that is left behind is the typical rhombohedral shape and size of the voids (Fig. 4.D). A similar event was documented with a petrographic analysis of Eneolithic pottery from Moverna vas in the Bela Krajina region in southern Slovenia, where the dissolution of calcite could be connected to very acid soils (*Žibrat Gašparič 2008.127–174*). In addition, the remaining voids inside the vessels from Krašnja were then secondarily coated with amorphous hydrated iron oxide-hydroxides, *i.e.* limonite (Fig. 3).

Conclusions

The mineralogical and petrographic analyses of Eneolithic Krašnja pottery showed that the vessels were made with at least 5 different fabrics that nevertheless have a similar mineralogical composition and vary mostly in their microfossils and opaque ferrous mineral content. The composition of the clay points to an origin from weathered marlstone, probably Miocene, that is present in an area less than 10km north and south from Krašnja, but is not present in the Črni graben valley. The local clays have a different mineralogical composition, without microfossil remains, as we proved with the analysis of the remains of a contemporaneous kiln excavated *in situ*.

Krašnja also had two of the very rare pottery kilns dating to this period in Slovenia. They are oval in shape and probably used for firing pottery. The maximum temperature inside the kiln was only around 800°C, as proved by the analysis of pottery from Krašnja; the kiln walls were fired at even lower temperatures (see above).

All the fabrics contained added crushed calcite grains that could also have been gathered in the valley north and south of Krašnja. The potters rarely added crushed old pottery or grog along with calcite to the fabrics. The vessels were then shaped, dried, and fired in an open fire in a mostly incomplete oxidising atmosphere.

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The Neolithic-Eneolithic sequence and pottery assemblages in the fifth millennium BC in north-eastern Slovenia

Bine Kramberger
Ljubljana, SI
bine.kramberger@siol.net

ABSTRACT – *This paper discusses the settlements at Andrenci, Stoperce, Ptuj-Šolski center, Zgornje Radvanje and Hoče-Orglarska delavnica, all located in north-eastern Slovenia. The settlements are dated on the basis of the results of radiocarbon analyses. The characteristics of the material and cultural-chronological site structures were studied through analyses of pottery (pottery production, form, decoration) and comparative analyses.*

IZVLEČEK – *V prispevku obravnavamo naselbine Andrenci, Stoperce, Ptuj-Šolski center, Zgornje Radvanje in Hoče-Orglarska delavnica, ki se nahajajo v severovzhodni Sloveniji. Na podlagi rezultatov radiokarbonskih analiz ugotavljamo starost naselbin. Z analizami keramičnih najdb (način izdelave keramike, oblike, okras) in s primerjalnimi analizami pa smo raziskali značilnosti materialne kulture in kulturno-kronološko strukturiranost najdišč.*

KEY WORDS – *Neolithic; Eneolithic; settlement; NE Slovenia; 5th millennium BC; pottery analysis; ^{14}C analysis; chronology*

Introduction

The study of the Neolithic and Eneolithic periods in north-eastern Slovenia (for an overview of the earlier part of the history of research, see *Budja 1983*) does not have a long tradition, in comparison with neighbouring countries, and this area consequently lacks knowledge and archaeological research of this era. Mainly due to archaeological research on the motorway network, only archaeological periods after the second half of the 5th millennium onwards in north-eastern Slovenia are relatively well-studied (*i.e.* the Lasinja Culture), while only individual pits, structures and finds from the end of the first half of the 5th millennium are known, and older settlement have not even been identified to date.[1]

The present research has therefore been focused on analyses of pottery and an assessment of selected north-eastern Slovenian settlements dating to the first and the second half of the 5th millennium BC. The settlements are located relatively close to one another, in an area which is also important in the interpretation of archaeological records elsewhere (primarily in Austria, Hungary and Croatia) due to its transitional location between the Alps and the Pannonian Plain. The settlement of Andrenci is located on a hill 335m high, called Andrenški vrh, in western Slovenske gorice. Stoperce is located in Haloze, along the Majšperk-Rogatec road, while Ptuj-Šolski center, Zgornje Radvanje and Hoče-Orglarska delavnica are

1 Bukovnica (*Šavel 1992.59–60; 1994.47–48; 2006.90*), Andrenci (for both see also *Budja 1983.81; Guštin 2005.9–16; Tomaž 2010.164; Kavur 2010.71; Velušček 2006.32–35; 2011.211–216*), Ptuj-Šolski center, and partly, to a small extent, Ptujski grad (for both see *Guštin 2005.Fig. 1; Tomaž 2010.164; Kavur 2010.Fig. 1*), are sites that have been most often mentioned in literature as the only late Neolithic sites in north-eastern Slovenia. Most of the pottery from Ptuj-Šolski center has, until recently, not even been drawn or mended and, with the exception of Ptuj-Šolski center, no ^{14}C dates were available for these sites.

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situated on the edge of the Drava plain (Fig. 1).

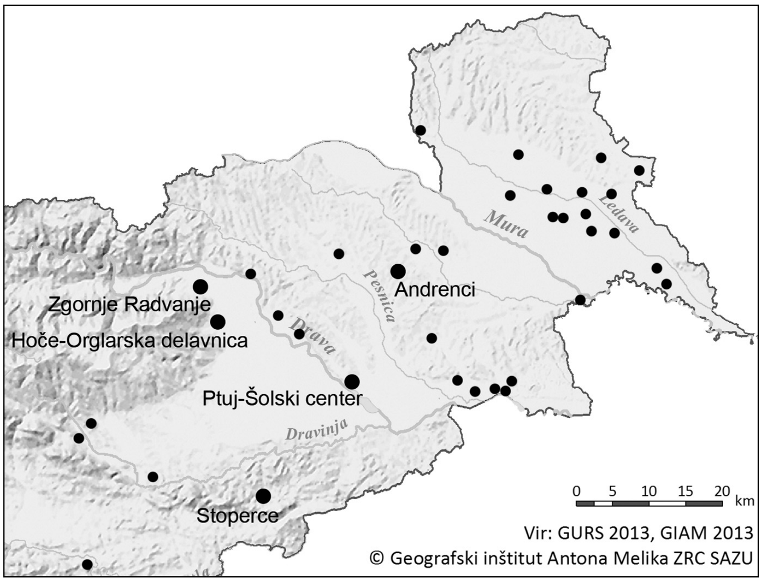


Fig. 1. Map of north-eastern Slovenian sites with settlement remains dating to the 5th millennium BC. Larger dots and inscriptions mark settlements, which are analysed in this paper.

Settlement contexts

Andrenci

Small-scale trenches dug in the 1950s at the settlement on Andrenški vrh partially explored two structures (*Pahič, Lorber 1954; Pahič 1973; 1976*).

Structure A was represented by a large pit containing two cultural layers, the bottom (A1) and top (A2). They both contained residue of charcoal, burnt clay, fragments of pottery vessels (A1: Pl. 1.1–9; see also *Pahič 1976.Pl. 2*; A2: Pl. 1.13–20; see also *Pahič 1976.Pl. 3 – Pl. 4.24*) and stone tools (A1: *Pahič 1976.Pl. 1.2, 8, 16–18*; A2: *Pahič 1976.Pl. 1.3, 11–12*),[2] but they were delimited by a thinner layer, A2a, which in addition to individual pottery fragments (*Pahič 1976.Pl. 4.25–27*) and stone tools (*Pahič 1976.Pl. 1.9*) also contained charcoal, ash, rare bones and two spindle whorls (*Pahič 1976.Pl. 24.28–29*) (Fig. 2).[3]

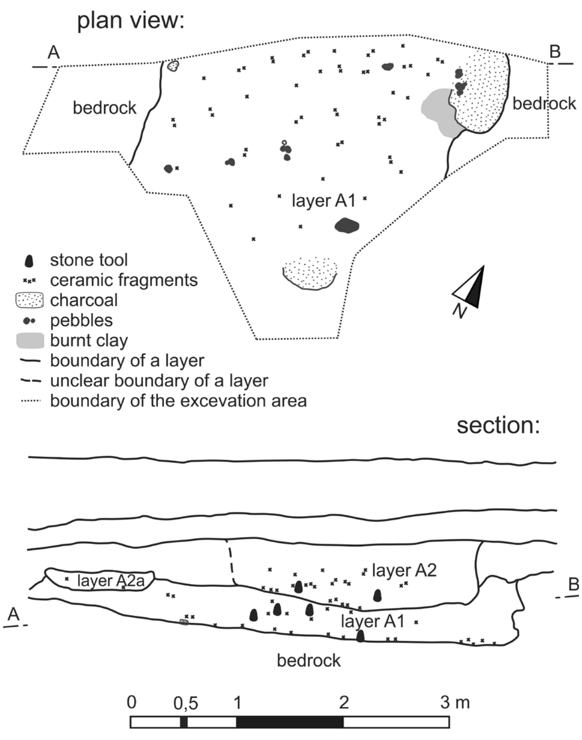


Fig. 2. Andrenci. Strucure A. Plan and section.

Structure B also comprised a large pit with two cultural layers, bottom (B1) and top (B2). Both layers contained fragments of ceramic vessels (B1: Pl. 2.25–34, B2: Pl. 2.35–51; see also *Pahič 1976.Pl. 5.1–Pl. 22.6*) and stone tools (*Pahič 1976.Pl. 1.6–7, 13–15*), and were delimited by charcoal. In the bottom layer, and partly under it (*Pahič 1976.41*), two straight lines of pebbles with their intersection forming a right angle were discovered, which may be interpreted as part of a wall or building foundation (Fig. 3).

The ^{14}C analysis of charred food residues obtained from the inner surface of a vessel base from the top layer (B2) in structure B showed a conventional age of 5730±40 BP, which means that it dates between 4689 and 4466 calBC (95.4% probability) or (between) 4652 and 4505 calBC (68.2% probability). Pottery assemblages from Andrenci are typologically homogeneous (Pls. 1–2), so it is possible to assume that both structures presented above were contemporaneous.[4]

Stoperce

Based on the results of ^{14}C analyses, analyses of stratigraphic sequences and analyses of pottery, it is

2 Layer A1 also yielded two large concentrations of charcoal and burnt clay (Fig. 2), which might represent the remains of a structure or a hearth (see also *Pahič 1976.35*).

3 Parts of individual vessels were found in both layers (Pl. 1.13–20), while Structure A also yielded individual finds (*Pahič, Lorber 1954.335–338*) with unknown location details (Pl. 1.21–24).

4 The conventional value of all the dates presented in this paper was calibrated using the program OxCal version v4.2.3 (*Bronk Ramsey, Lee 2013*), with a current calibration curve (*Reimer* et al. *2013*).

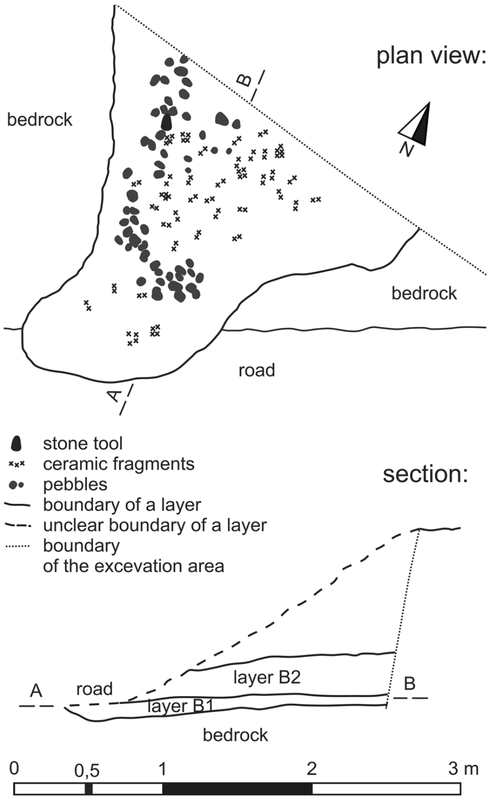


Fig. 3. Andrenci. Structure B. Plan and Section.

possible to conclude that the area researched in 2009 was settled twice (Fig. 6). The first (earlier) phase is represented by Structure I, and the second by Structure III – area 2. At least three (II, IV and V) other structures were discovered. They did not contain pits with pottery, and absolute dates were not obtained. However, it seems that they belong to the second settlement phase, because smaller pits (Pl. 4.75–77), ditches and post-holes were discovered in the vicinity which contained pottery comparable to pottery found in the pit from Structure III (compare with Pl. 4.70–74); fragments of such vessels were also found in a thin cultural layer, stratigraphic unit (SE) 003, which was examined in isolated areas on top of the structure remains.

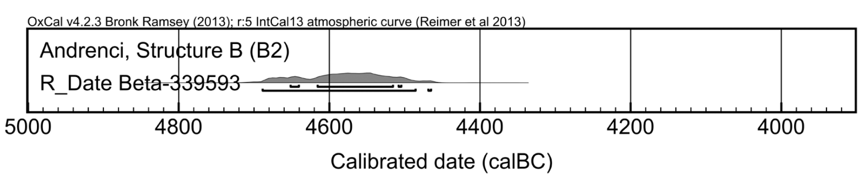
Structure I was single-spaced, partially deepened (pit SE 128) and, based on the distribution of post-holes, probably had a trapezoidal floor plan. The hollow/pit was filled with a single layer which contained charcoal, burnt clay, fragments of Late Neolithic pottery vessels (Pl. 3) and individual stone tools (Fig. 7). The ^{14}C measurements of charcoal sample Beta-339594, gained from this layer showed a conventional age of 5690±30 BP, which means that it dates to the end of the first half or the turn of the first to the second half of the 5th millennium BC, and that Structure I was contemporary with Structure B from Andrenci (Figs. 9–10).

Structure III, which represents the second settlement phase, was perhaps two-spaced.[5] Area 1 was not deepened, and rare pottery fragments were discovered only in a thin cultural layer above the post-holes. The central part of Area 2 was some 30cm deepened, with two cultural layers and a hearth detected in the pit itself (SE 150). The upper layer (layer 2) contained charcoal, burnt clay, a number of Early Eneolithic vessel fragments (Pl. 4.70–74) and stone tools. The bottom layer (layer 1) did not yield any finds.[6] The hearth was discovered in the specially formed north-eastern part of the pit SE 150 which appeared as a layer of charcoal 2cm thick containing some burnt clay fragments (Fig. 8).

Two ^{14}C dates are available from pit SE 150 (Structure III – Area 2), which significantly differ: the first date was calibrated to the end of the 5th and the beginning of the 4th millennium BC (Beta-362539) and the second to the end of the first half of the 4th millennium BC (Beta-339595). It is important to emphasise that the pottery from the pit is homogeneous, that comparable pottery occurs at sites within the region and beyond at the end of the 5th and the beginning of the 4th millennium BC, and that pottery, or any other proof of dating to the end of the first half of the 4th millennium BC, was absent

Site	Context	Lab Code	Material	Age (BP)	SD (±a)	CalBC (68.2%)	Cal BC (95.4%)	Reference
Andrenci	Structure B (B2)	Beta-339593	food crust	5730	40	4652–4505	4689–4466	first published here

Figs. 4 and 5. Andrenci. Structure B, layer B2. ^{14}C AMS date.



5 There is a possibility that areas 1 and 2 were actually two separate structures, where one was older than the other, or perhaps they co-existed, but no stratigraphic data exist.

6 Cultural layers were separated based on the differences in the colour and fragments of pottery, stone objects and charcoal which concentrated on the boundary between them.

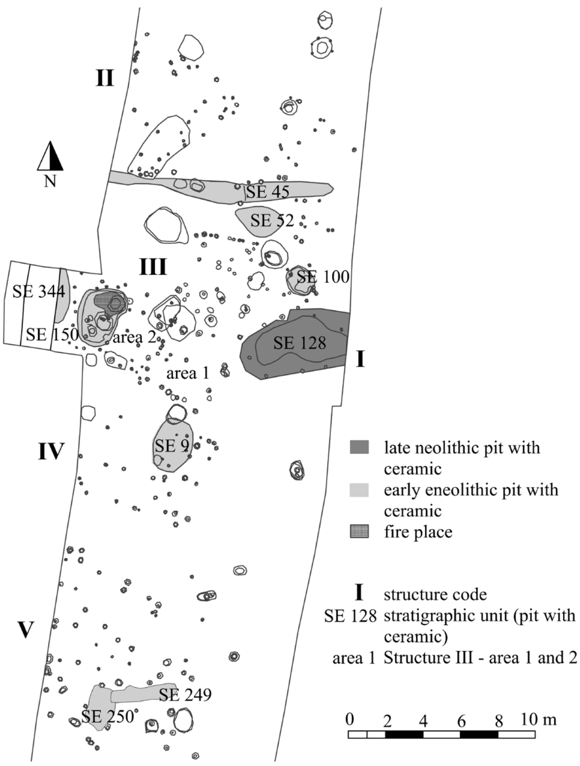


Fig. 6. Stoperce. General plan of the site.

from Stoperce.[7] Therefore, it is possible to assume that the date of Beta-339595 is too late for the presented context (Figs. 9–10).

Ptuj-Šolski center

During 1980/1981 (Structure I), 2000 (Structures II and III) and finally 2010 (Structure IV), this multiperiod site yielded four structures from the 5th millennium BC (*Strmčnik Gulič 1983; Lubšina Tušek 2004.74*). Structures II and IV have been radiocarbon dated and are presented in detail below.

Structure IV was deepened in the central part, where two cultural layers and a number of small pits were found (Fig. 11). Most of the pottery was found in layer SE 410, which was the top layer of a pit (Pl. 5.78–85), layer SE 430, which was located beneath (Pl. 5.89–91) and in a smaller pit SE 435, which was found at the deepest point of the structure. Parts of individual vessels were detected in all of the mentioned stratigraphic units (Pl. 5.86–88), so we can assume that all layers were deposited within a short time span. This can be partially confirmed by ^{14}C analyses of charcoal samples, which place Structure IV between the second half of the 45th and 43rd centuries BC (Figs. 13–14).

Structure II was probably rectangular. It was deepened along its entire length. The shallow deepening contained two cultural layers, a hearth and a greater concentration of burnt clay, probably the remains of a wall destroyed by fire. Two construction phases were documented, but they were more or less contemporary, as the northern and western sides of the building were only slightly modified during the second construction phase (Fig. 12).[8] The bottom layer, which yielded a few stone artefacts and a large number of pottery fragments (Pl. 6), was deposited between the two construction phases. The upper, yellowish brown layer was deposited after the second construction phase and contained less pottery.

Two ^{14}C dates are available to determine the age of Structure II; however, one of these is unreliable and

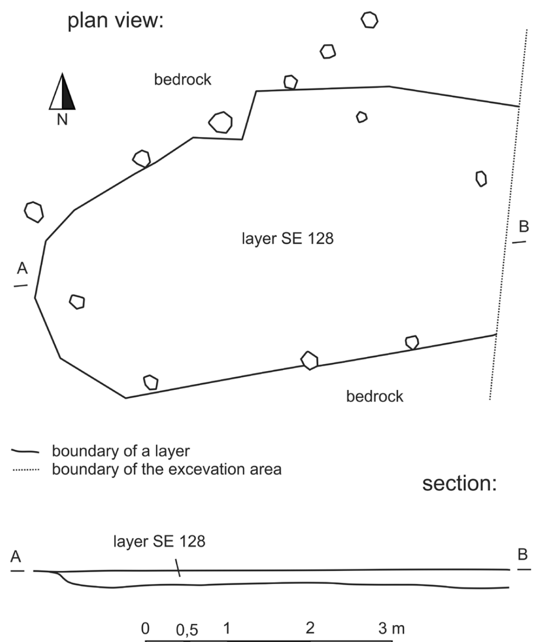


Fig. 7. Stoperce. Structure I. Plan and section.

7 In north-eastern Slovenia, pottery from the end of the first half of the 4th millennium was discovered at ^{14}C dated settlements at Kalinovnjek near Turnišče (*Kerman 2013a.242–245*), Turnišče (*Tomaž 2012.277–280*), Gornje njive near Dolga vas (*Kerman 2013b.407*) and a ^{14}C dated graveyard Pod Kotom – jug near Krog (*Šavel 2009.64, 94*). The absolute date from pit SE 11 at Ivankovci in Lendava is more or less simultaneous to dates, mentiones above. The pit yielded very fragmented (!) vessels from the Early Eneolithic period (*Kavur 2011.125–127*) together with fragments that are believed to be later, from the end of the first half of the 4th millennium BC (*Kavur 2011.find nos. 31 and 101*).

8 Construction phases were determined based on the heights of the post-holes. Individual post-holes were discovered at the base of the pit, while others were above the bottom layer.

therefore was not included in further analyses.[9] The second available date places, with 68.2% probability, Structure II to the period between 4527–4366 calBC, which means that it may be slightly earlier than Structure IV. However, it has to be stressed that Structure II yielded one reliable ^{14}C date, while Structure IV offers three (Figs. 13–14).

Zgornje Radvanje

The area of the site was intermittently inhabited from the Eneolithic to the Early Modern Period (*Kramberger 2010b.311; 2010a.7; Murko 2012.141–142; Arh 2012*). This paper presents 23 Eneolithic settlement structures, which were investigated in 2007 and 2008.[10] The settlement was probably circular in form. Structure 22 was located in the central part in the first visible circumference, together with structures 31–36, which had not been deepened and yielded no finds.[11] The second circumference contained structures 5–21 and 26, with associated smaller pits; the third circumference was represented by structures 2–4, with associated smaller pits, while the partly researched fourth circumference might be represented by Structure 1 in the far north-eastern part of the excavation area and smaller pits SE 212, SE 245, SE 247 in the far western part (Fig. 15).

In addition to the structure studied already in complex 10 (*Kramberger 2010b*), labelled as Structure 5, ^{14}C dates were also obtained from structures 22, 1, 4, 6, 7 and 10. The size and form of Structure 22 is comparable to Structure 5. Furthermore, it contained two phases; both were ^{14}C dated (Fig. 16). Phase 1 was identified by several small pits containing

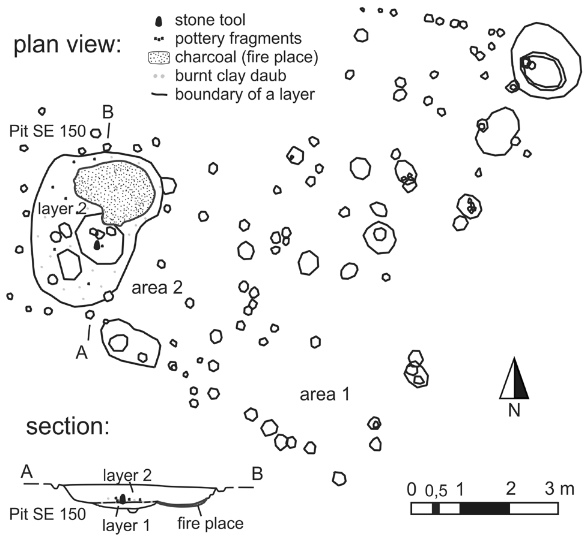
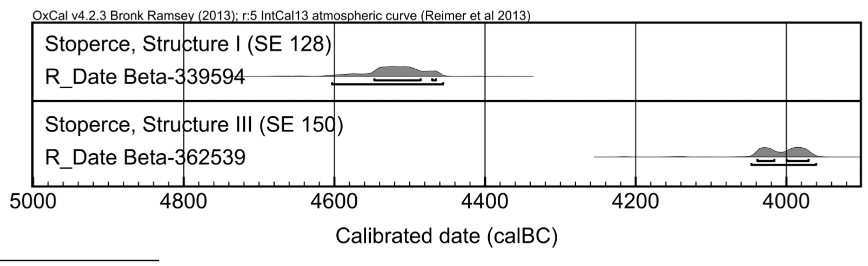


Fig. 8. Stoperce. Structure III with areas 1 and 2. Plan and section.

stone finds, pottery fragments (Pl. 7.109–118), fragments of burnt clay and wood, while Phase 2 was interpreted as the remains of a trapezoid house,[12] which was located above the Phase 1 pits. The daily activities of Phase 2 were documented by the remains of a hearth, with pottery (Pl. 7.119–122) and stone finds.

Based on the position of the post-holes, structure 6 was rectangular (Fig. 17). In contrast to structures 5 and 22, a uniform cultural layer (SE 250 = 252 = 226) has been detected in a shallow deepening, which was ^{14}C dated. It contained fragments of charcoal and burnt clay, individual stone tools and pottery fragments (Pl. 8.123–133).

Site	Context	Lab Code	Material	Age (BP)	SD (±a)	CalBC (68.2%)	Cal BC (95.4%)	Reference
Stoperce	Structure I (SE 128)	Beta-339594	charcoal	5690	30	4548–4466	4604–4456	first published here
Stoperce	Structure III (SE 150)	Beta-362539	charcoal	5200	30	4039–3971	4047–3961	first published here
Stoperce	*Structure III (SE 150)*	*Beta-339595*	*charcoal*	*4820*	*30*	*3650–3536*	*3656–3526*	*first published here*



Figs. 9 and 10. Stoperce. First and second settlement phase. ^{14}C AMS date. The 'problematic' date, excluded from further analyses, is shown with inclined letters.

9 This is the date of sample Z-3015, which was created by combining five different samples of charcoal, which, as is generally known, strongly influences the results of ^{14}C analysis.

10 The rest of the settlement was studied by Monika Arh (*2012*).

11 Structures 31–36 have not yet been ^{14}C dated, but based on their position in the first circumference, they seem to be from the Early Eneolithic period.

12 A greater quantity of burnt plaster and charcoal has been documented just above small pits, but direct evidence of the existence of a wooden structure similar to Structure 5 (burnt wooden post) has not been found here (*Kramberger 2010b.Fig. 4*).

Early Eneolithic Structure 4 was discovered under alluvial layer SE 983, which contained finds from the same period. Two layers were discovered in pit SE 1129. The pit base was filled with layer SE 1128. The ^{14}C dated layer SE 1102 was placed on top. Fragments of charcoal, burnt clay, stone tools and pottery (Pl. 9.142–146) were detected in both layers and were especially concentrated between the two layers (Fig. 18).

The construction of Structure 7 was documented only with a few post-holes that were discovered in the central part of the deepening. The deepening of the structure yielded one cultural layer (SE 16 = 18 = 25), which was ^{14}C dated, with some smaller pits (SE 37, SE 26 and SE 21) beneath. The cultural layer contained fragments of burnt clay, charcoal, Early Eneolithic stone tools and pottery (Pl. 8.134–141), as well as two concentrations of burnt clay (Fig. 19).

The deepening of ^{14}C dated Structure 1 (SE 600) showed two major concentrations of charcoal with fragments of burnt clay (SE 623, SE 625), probably part of the structures' burnt construction, and a cultural layer SE 599. Stone tools and pottery fragments were found in SE 599 (Pl. 9.149–152) and in the concentrations of charcoal (Pl. 9.147–148, 153), where two ^{14}C samples were collected (Fig. 20).

The last ^{14}C dated structure, Structure 10, was identified as a pit (SE 1028) filled with layer SE 1027, which contained a large quantity of burnt clay, charcoal and fragments of pottery (Pl. 10.160–164). A hearth (SE 1029) was discovered next to the pit (both Phase 1). On top of layer SE 1027 and the hearth, another layer, SE 1004, was discovered which contained fragments of charcoal, burnt clay and various fragments of Early Eneolithic pottery (Pl. 10.154–157) (Phase 2). Post-hole SE 1040, also containing fragments of Early Eneolithic pottery (Pl. 10.158–159), was discovered under layer SE 1027. It was therefore assumed that it represented part of Structure 10 (Fig. 21).

Ten out of eleven dates from one part of the settlement at Zgornje Radvanje, which was investigated in 2007 and 2008, more or less overlap and date the settlement to the last third of the 5th millennium BC. Sample Beta-305862 from post-hole SE 1040 was dated somewhat later, to the end of the 5th and beginning of the 4th millennium BC (Figs. 22–23). The post-hole was, as already mentioned, discovered beneath layer SE 1027, so it was assumed that it was related to Structure 10 (Phase 1). However, charcoal sample Beta-305861 from SE 1027 yielded an earlier date, which is consistent with the rest of the settlement. So post-hole SE 1040 was perhaps dug into Structure 10 from the later layer SE 1004 (Phase 2), which is located above the layer SE 1027 and its cut into later layers was not detected (Fig. 21). This seems credible, but no ^{14}C dates are yet available from SE 1004, so we can not completely exclude the possibility that the ^{14}C dating of sample Beta-305862 from pit SE 1040 is incorrect in its context (*Bronk Ramsey 2009b.1023–1024*).[13]

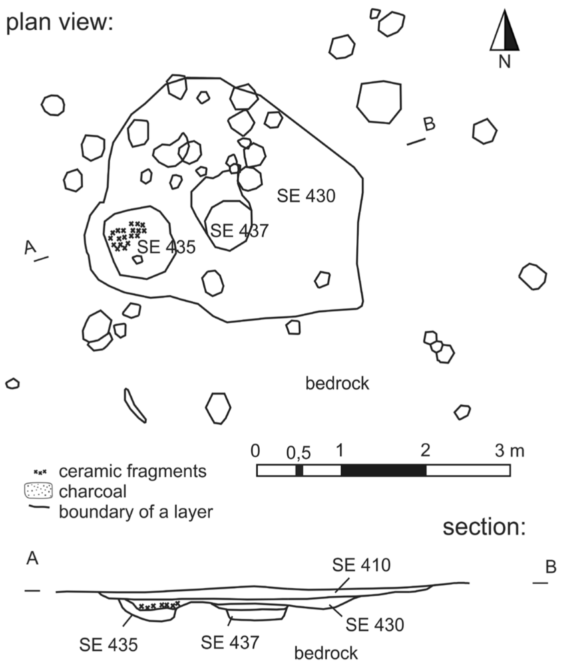


Fig. 11. Ptuj-Šolski center. Structure IV. Plan and section.

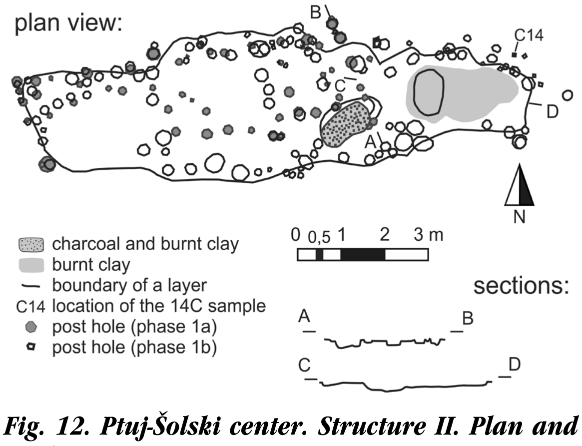
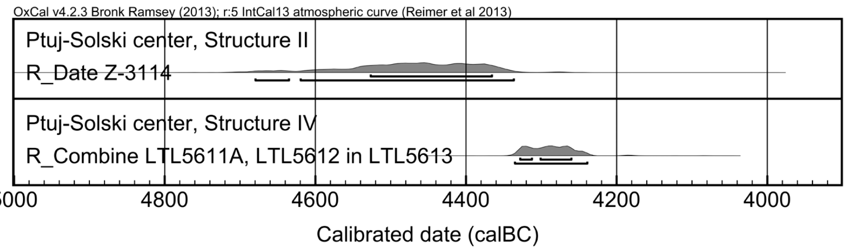


Fig. 12. Ptuj-Šolski center. Structure II. Plan and section.

13 Dates from the other part of the settlement at Zgornje Radvanje were presented by Monika Arh (*2012. Figs. 10, 40, 61, 65*).

Site	Context	Lab Code	Material	Age (BP)	SD (±a)	CalBC (68.2%)	Cal BC (95.4%)	Reference
Ptuj-Š.c.	*Structure II (?)*	*Z–3015*	*charcoal*	*5873*	*132*	*4901–4556*	*5202–4449*	*Obelić* et al. *2002.626*
Ptuj-Š.c.	Structure II (SE 10)	Z–3114	charcoal	5626	80	4527–4366	4680–4337	*Lubšina-Tušek 2004.75* (only mentioned)
Ptuj-Š.c.	Structure IV (SE 410)	LTL5611A	charcoal	5504	50	4445–4272	4455–4260	first published here
Ptuj-Š.c.	Structure IV (SE 430)	LTL5612A	charcoal	5387	45	4330–4176	4339–4059	first published here
Ptuj-Š.c.	Structure IV (SE 435)	LTL5613A	charcoal	5384	40	4328–4177	4336–4065	first published here



Figs. 13 and 14. Ptuj-Šolski center. ^{14}C AMS dates. Date, not included in further analyses, is shown with inclined letters.

Hoče-Orglarska delavnica

The latest site studied in this paper and the only one without ^{14}C dates is Hoče-Orglarska delavnica.[14] In 1988 and 1989 Roman and Bronze Age settlements were discovered and partially studied, together with five hollows from the period studied in this paper (*Strmčnik Gulič 1989.224–226; 1990.173–175*).

Most of the pottery was found in three pits which were investigated in 1989 and interpreted as pit-houses (*Strmčnik Gulič 1990.174–175*).[15] Pit-houses I and II contained a single cultural layer, which yielded burnt clay, charcoal, fragments of stone tools and pottery (Pl. 11 and Pl. 12.180–188), while pit-house III contained two cultural layers with pottery (Pl. 12.189–192) and a higher concentration of burnt clay mixed with charcoal. Layer 9 filled the deepening of the pit (Phase 1); a concentration of burnt clay and charcoal – probably the remains of a hearth – was situated on top of it, while layer 5 (Phase 2) represents the top layer (Fig. 24).

Neolithic-Eneolithic settlement in NE Slovenia

The settlements at Andrenci, Stoperce, Ptuj-Šolski center and Zgornje Radvanje yielded a total of 20 dated samples, while part of the site at Radvanje-Habakuk 2 (*Arh 2012*) offers another five dated samples. These provide a relatively good basis for explaining past events (Figs. 9–10, 13–14, 22–23 and their comments). Andrenci, two settlement phases at Stoperce and Ptuj-Šolski center offer only individual ^{14}C-dated structures,[16] while the studied part of Zgornje Radvanje yielded a number of dates, so it is possible to analyse the life span of the settlement. The dates of the samples derived from the same structure were combined before calibration (function R. Combine), so that they were evenly represented during the activity period.[17] In contrast, dates that refer to a variety of contexts were studied separately. The 'Span' function, which determines only the duration of directly dated events, was used, together with the 'Interval' function, which determines the whole range of activities between the beginning and the end of one phase (Fig. 25).[18]

Based on the presented ^{14}C dates, it is possible to conclude that the studied part of the settlement at Zgornje Radvanje, as well as the settlements at Andrenci, Stoperce and Ptuj-Šolski center document a time span of settlement activities in the period between the second half of the 47th and the first half of the 40th century BC, while the studied part of the Radvanje-Habakuk 2 settlement, partly dates back to

14 Early Eneolithic pits from Hoče-Orglarska delavnica were not radiocarbon dated because there were no suitable samples. The settlement is dated only indirectly by typological comparisons.

15 Post-holes were detected only at pit-house III, while the remaining pits were interpreted as pit-houses solely on the basis of the fragments of burnt clay and charcoal discovered in them.

16 As mentioned above, two structures were dated at Ptuj-Šolski center, but one reliable ^{14}C date comes from Structure II, with a large standard deviation.

17 The R_Combine function can, by definition, merge only ^{14}C dates relating to the same event, yielding a more precise date for this event, but it is also used to merge samples from the same pit (*Stadler, Ruttkay 2007*). The difference in the result is minimal in this case, as the merged dates relate to events which were more or less simultaneous.

18 Analyses were done with the OxCal program version v4.2.3 (*Bronk Ramsey, Lee 2013*) and the current calibration curve (*Reimer* et al. *2013*).

the first and the second half of the 4^{th} millennium BC (*Arh 2012.Fig. 10; 2012. Fig. 40*). According to the current chronology of the 'central and southern Slovenian Neolithic and Earlier Eneolithic' and ^{14}C dates that are known so far, the settlements at Andrenci, Stoperce, Ptuj-Šolski center and Zgornje Radvanje can be placed in the period between the Younger or Late Neolithic and Early Eneolithic, while the settlement in the studied part of Radvanje-Habakuk 2 dates partly to the Middle Eneolithic period (*Velušček 2011. 225–233*).

The earliest settlement, dating to the end of the first half and the middle of the 5^{th} millennium BC, was documented at Andrenci and Stoperce (Structure I – SE 128). Ptuj-Šolski center – Structure II, is younger and dates to the 4527–4366 calBC (68.2% probability), followed by a whole range of contexts with dates which more or less overlap: Structure IV at Ptuj-Šolski center, and Structures 7, 4, 5, 1, 22, 6 and 10 (Phase 1) at Zgornje Radvanje.[19] With the Span function, the life span of the part of settlement at Zgornje Radvanje, determined by structures 7, 4, 5, 1, 22, 6 and 10 (Phase 1) has been estimated to not more than 95 years (95.4% probability), or not more than 43 years (68.2% probability), between 4355–4186 calBC and 4337–4226 calBC respectively; moreover, the 'Interval' function yielded a maximum life span of 146 years in the period between 4355 and 4186 BC (95.4% probability) or a maximum of 60 years in the period between 4337 and 4226 calBC (68.2% probability).[20]

Structures 7, 4, 5, 1, 22, 6 and 10 (Phase 1) at Zgornje Radvanje are earlier than Structure III (SE 150) at Stoperce, from post-hole SE 1040 at Zgornje Radvanje and individual contexts from part of the settlement at Radvanje-Habakuk 2, researched in 2010 (*Arh 2012.Fig. 61*). These latest contexts are dated to the end of the 5^{th} and the beginning of the 4^{th} millennium BC.

Pottery assemblages

The Neo-Eneolithic settlements at Andrenci, Stoperce, Ptuj-Šolski center, Hoče-Orglarska delavnica and the studied part of the settlement at Zgornje Radvanje yielded 38 398 pottery fragments (over 409.479kg). The pottery assemblages differ in quantity: the largest was discovered at Zgornje Radvanje (26 408 sherds (291.7kg)), followed by Ptuj-Šolski center (5908 sherds (65kg)), Hoče-Orglarska delavnica (1584 sherds (33.9kg)) and the second settlement phase at Stoperce (2522 sherds (14.6kg)). The pottery assemblages from Andrenci and the first settlement phase at Stoperce are the smallest and comparable in quantity (Andrenci, according to *S. Pahič 1976.45* – 1050 fragments; Stoperce – 1186 fragments (4.3kg)) (Fig. 26).

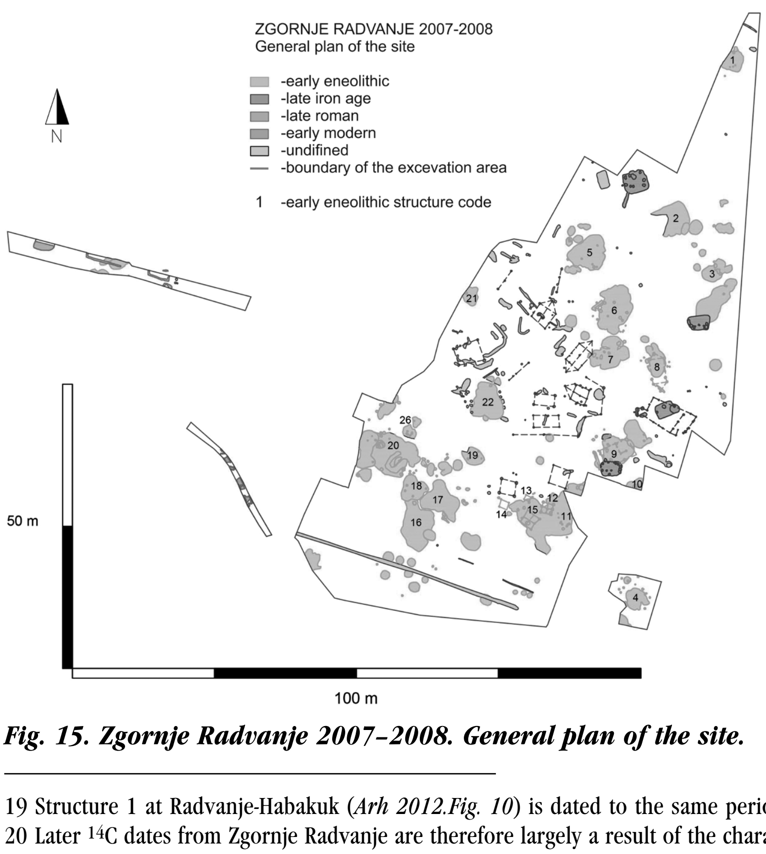


Fig. 15. Zgornje Radvanje 2007–2008. General plan of the site.

Pottery production

2723 ceramic objects, which were mended from 16848 pottery fragments, were analysed according to the established method of macroscopic standards (*Horvat 1999*); 62 different fabrics were identified. Quartz (A), mica (C) and iron oxide (E) are present in all fabrics, only the size of grains and their frequency differ. In addition, some fabrics were characterised by whitish, somewhat softer grains, undefined in more detail. LM20, LM23 and LM59 were charac-

19 Structure 1 at Radvanje-Habakuk (*Arh 2012.Fig. 10*) is dated to the same period.

20 Later ^{14}C dates from Zgornje Radvanje are therefore largely a result of the characteristics of the calibration curve in the second half of the 5^{th} millennium BC. This is quite curved and therefore more intersections of the value of the conventional dates with calibration curve occur, while dates have subsequently extended ranges (*Wiener 2012.428–429*).

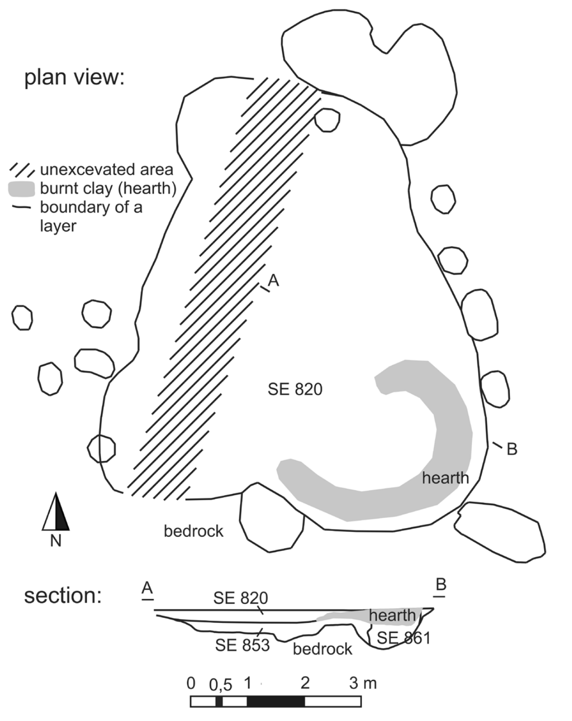


Fig. 16. Zgornje Radvanje. Structure 22. Plan and section.

terised by partially burnt organic material.[21] The fabrics are macroscopically comparable, apart from the Andrenci pottery, which differs slightly in having a smaller amount of mica, which is probably due to different clays being used, as mica is naturally present in clay and its decomposition takes a place around 900–950°C (*Guirao* et al. *2014.757–758*; App. 1).

Most of the pottery was made of fabrics without quartz temper, and fabrics with a small amount of quartz temper. Andrenci (83%), Zgornje Radvanje (61%), Hoče-Orglarska delavnica (74%) and pits from the second phase of the settlement at Stoperce (66%) are dominated by pottery fragments made of very fine-grained fabrics. Fine-grained pottery was less frequent (most of it was found in pits from the second settlement phase at Stoperce – 21%); coarse-grained fabric was even less common. Only Structure I at Stoperce and Ptuj-Šolski center yielded slightly more pottery made of fine-grained fabrics (58% and 52%) (Fig. 27).

The pottery was hand-thrown and finished with treatment of the exterior and interior to remove irregularities from the surface of the objects. At Andrenci, most of the pottery surface is uneven or rough, which means that their surface was smoothened before firing (98%). Structure I at Stoperce (91%), Ptuj-Šolski center (74%), Zgornje Radvanje (92%), Hoče-Orglarska delavnica (83%) and pits from the second phase of the settlement at Stoperce (88%) were dominated by pottery with smooth surfaces which were sponged before firing (Fig. 28).[22]

In some cases, the surface was coated with a coloured clay slip, most frequently red. This type of pottery was discovered at Andrenci (3%), Structure I at Stoperce (32%), Ptuj-Šolski center (9%), Zgornje Radvanje (3%) and at Hoče-Oglarska delavnica (7%); it was coated with either a thicker layer of resistant slip (probably applied before firing, it now crumbles off the pottery surface), or thinner slips that can be removed from the pottery surface if touched with a wet finger (Fig. 29).

The decoration was made with fingers or various tools prior to firing. Three techniques of decoration can be seen – impressions, incisions and applied decoration – wherein the motif was made with a single technique or a combination of two or three techniques. Impressions of the tips of various tools, and

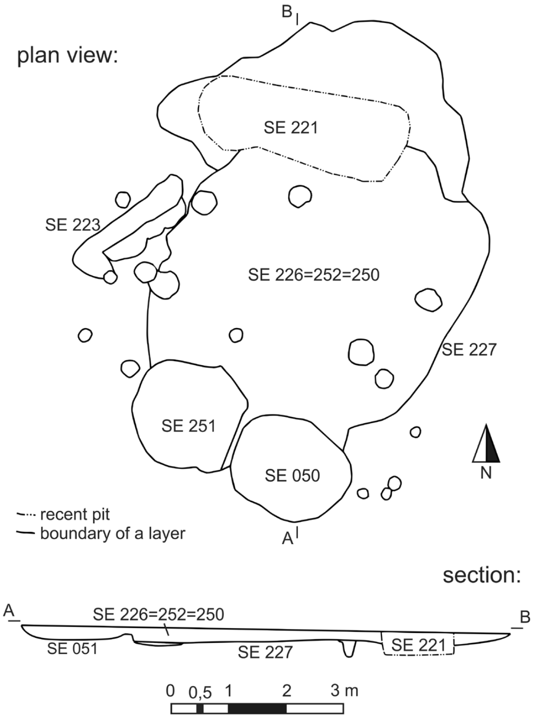


Fig. 17. Zgornje Radvanje. Structure 6. Plan and section.

21 Fabric LM18 is the only fabric containing grains of calcium carbonate. It was documented on the fracture of the base of a vessel from pit SE 52 at Stoperce. Its form resembles late prehistoric vessels, so it is assumed that it was not primary deposited in the pit.

22 Polished pottery is rare. It was found at Zgornje Radvanje (4%), Hoče-Orglarska delavnica (5%) and the Early Eneolithic pits at Stoperce (2%) (Fig. 27).

fingernail and fingertip impressions can be seen on the pottery surface. Incised decoration is a technique that includes dragging a tool tip/s across the surface, while applied decoration involves making an appliqué which is later applied to the surface.[23] The largest ratio of decorated pottery to undecorated vessels was discovered in Structure I at Stoperce (47%), Ptuj-Šolski center (39%) and in Hoče-Orglarska delavnica (37%). Less decorated pottery was found at Andrenci (28%), Zgornje Radvanje (25%) and in the pits of the second settlement phase at Stoperce (15%) (Fig. 30).[24]

Individual sites are dominated by different decorating techniques. At Andrenci, most of the pottery was decorated with simple protrusions made with applied decoration (80%) and rarely with impressions (15%) or incisions (5%). Structure I at Stoperce is dominated by applied decoration and impressions (both 30%), with incisions (13%), combinations of incisions and impressions (13%), a combination of applied decoration and impressions (9%) and a combination of incisions and applied decoration (5%). The pottery at Ptuj-Šolski center more often has impressions (46%), while the quantities of applied decoration (28%), incisions (14%) and combinations of incisions and impressions (9%) are comparable to pit SE 128 at Stoperce. Most of the pottery from Zgornje Radvanje (49%) and Hoče-Orglarska delavnica (52%) was decorated with incisions, while a smaller proportion has applied decoration (Radvanje 25%, Hoče 14%), impressions (Radvanje 14%, Hoče 15%) or combinations of incisions and impressions (Radvanje 10%, Hoče 15%). Most of the ware from the second settlement phase at Stoperce is decorated with impressions (40%) or a combination of incisions and impressions (30%) (Fig. 31).

The firing atmosphere differs from vessel to vessel, wherein two firing conditions are most common. Vessels from all the sites were most often fired under oxidising conditions, wherein the firing temperature was too low and the oxygen was insufficient for the complete combustion of organic material.

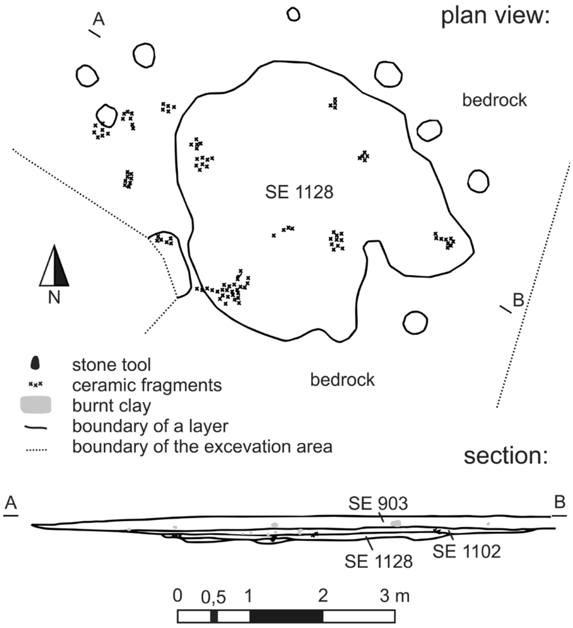


Fig. 18. Zgornje Radvanje. Structure 4. Plan and section.

Typically, the surfaces and fractures of pottery fired under these conditions have several bright hues (5 or more), with several grey areas that indicate partially burnt organic material.[25] Another common firing technique was with incomplete oxidation with a reducing phase at the end of the process. As the name suggests, vessels were constantly fired in oxidising conditions and the oxygen supply intentionally reduced during cooling. The pottery fractures are in bright colours, with darker grey tones on the surface. Such pottery was found in pit SE 128 at Stoperce. It is rare in comparison with pottery fired under incomplete oxidising conditions (13%), but occurs more often at Ptuj-Šolski center (29%), Zgornje Radvanje (30%), Hoče-Orglarska delavnica (24%) and the Early Eneolithic pits at Stoperce (40%). Some pottery fragments from Zgornje Radvanje (0.20%), Ptuj-Šolski center (1%) and from pits from the second phase of the settlement at Stoperce (3%) had fractures and surfaces with a uniform dark grey colour. These vessels were fired under reducing conditions, with constant temperature and reduced oxygen supply while firing as well as cooling (Fig. 32).[26]

23 Appliqués are discussed as parts of decoration, as some are very decorative (*Kramberger 2014a.Fig. 149*), although they probably also served as an aid in holding the object (like handles and lugs).

24 The results need to be observed with caution. Namely, analyses included all rim fragments of vessels of closed forms, all fragments of vessel girths, all handle fragments, all fragments of the feet of footed vessels. Some of these were, within the studied pottery assemblage, never decorated or decorated rarely.

25 All pottery from Andrenci was fired under these conditions, while SE 128 in Stoperce had 87%, Šolski center 70%, Zgornje Radvanje 63%, Orglarska delavnica 76% and the second phase of the settlement at Stoperce a total of 57% of pottery fired under these conditions.

26 According to the pottery fractures, complete oxidation, oxidation with reduced atmosphere in the final stage and reduced firing with the oxidising atmosphere in the final stage were determined. Fragments were mostly very small, so it is possible that the evaluation would be different if sherds were larger.

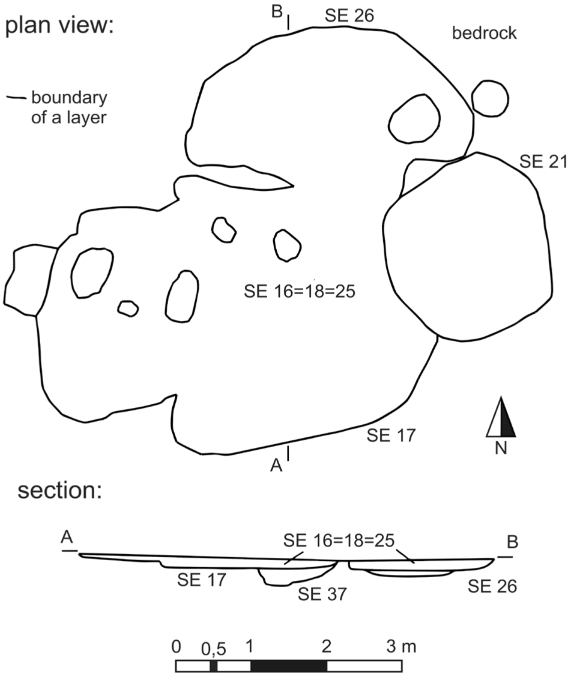


Fig. 19. Zgornje Radvanje. Structure 7. Plan and section.

The hardness of the pottery was determined by macroscopic analysis. A statistical comparison of the results of a Mohs test showed that the pottery from Structure I at Stoperce, Ptuj-Šolski center, Zgornje Radvanje, Hoče-Orglarska delavnica and the Early Eneolithic pits at Stoperce was on average harder (dominated by a value of 3–6 on the Mohs' scale of hardness) than the pottery from Andrenci (values 1–4 on the Mohs' scale of hardness) (Fig. 33). The hardness of pottery depends on many factors, the most important of which are the composition and microstructural properties of clay, the surface treatment of vessels prior to firing, firing temperature and atmosphere (*Rice 1987. 354*).[27]

Forms of pottery, decoration and typological comparisons

The pottery found at the settlements from the 5th millennium BC differs in form and decoration, with some notable differences from site to site which can be seen between contexts, which according to the results of ^{14}C analyses, date to different periods, as well as between contexts that were contemporaneous. Good comparisons are available in different geographic areas and the studied sites can be connected to different cultural groups.

As mentioned above, according to the current chronology of the 'central and southern Slovenian Neolithic and Earlier Eneolithic and ^{14}C dates known so far, the settlements at Andrenci, Stoperce, Ptuj-Šolski center and the studied part of the settlement at Zgornje Radvanje date to the Younger or Late Neolithic and Early Eneolithic (*Velušček 2011.225–233*). According to the above chronology, the earliest settlement in central and south-eastern Slovenia is culturally defined as pertaining to the Sava group of the Lengyel Culture, followed by the Lasinja Culture, dated to the Early Eneolithic period, and later by the horizon of pottery with furrowed incisions, which is dated to the Middle Eneolithic (*Velušček 2011.209*).

The chronological scheme of the 'central and south Slovenian Neolithic and Earlier Eneolithic' is comparable to the Austrian chronological scheme, with the only difference being the terminology used.[28] However, a very different chronological scheme exists in neighbouring Croatia (*Marković 1994.27– 29*) and Hungary. The transition from the Neolithic to the Copper Age is better defined in Hungary, where the Sé horizon, early and middle phases of the Lengyel Culture (West Hungary) and the Tisza Culture (East Hungary) define the Late Neolithic period. Phase Lengyel III (West Hungary), which according to Anton Velušček is correlated with the Sava group of the Lengyel Culture (*Velušček 2011.210–222*), and the Proto-Tiszapolgár and Tiszapolgár horizons (East Hungary) date to the Early Eneolithic period, while the Balaton-Lasinja Culture and the horizon of pottery with furrowed incisions ('Furhenstich') date to the Middle Eneolithic period (*Raczky 1974; Makkay 1976; Zalai-Gaál 1982; Kalicz 1973;* also *Bánffy 1995c.192; 1997.61*). The transition from the Neolithic to Eneolithic has been explained by changes in society and lifestyle, supposedly related to the spread of new technologies from the area of the central Balkans to Central Europe (*Bánffy 1995c.183–187*). Contacts with the central Balkans are also supposed to be seen in a number of new forms of pottery that first appear during the Late Lengyel Culture and which are a specific feature of the subsequent Balaton-Lasinja Culture (*Bánffy 2002*).

27 The results of the analysis need to be treated with caution, since the analysis was carried out with a magnifying glass, not a microscope. Moreover, the Mohs hardness test is not entirely relevant for gritty pottery (*Rice 1987.357*).

28 In Austria, the Lengyel Culture and related cultural groups (*e.g.*, Moravia – East-Austrian group of painted ceramics, Stichbandkeramik, the Münschöfen Culture) define the Middle Neolithic, while the Kanzianiberg-Lasinja and related cultures define the earlier phase of the late Neolithic period, which equates to the Copper Age in Austria (*Krenn-Leeb 2006.Fig. 2*).

The second half of the 47th to the beginning of the 45th century BC

Differences in pottery forms and pottery decoration can be seen at Andrenci (Pls. 1–2) and Structure I at Stoperce (Pl. 3), although they were absolutely dated to approximately the same era, *i.e.* between the 47th and mid 45th century BC (95.4% probability) or between the second half of the 47th and the beginning of the 45th century BC (68.2% probability). Differences can be noticed mainly in the forms of pots and decorative motifs, while, for example, footed dishes, dishes and jugs are almost identical.

To begin with, we focus on finds with no significant differences, because such finds have been found over a wide geographical area. The pottery assemblages from Structure I at Stoperce (Pl. 3.52, 54, 56) as well as from both structures at Andrenci (Pl. 1.1.2, 16, 23; Pl. 2. 26, 38) often include dishes with a convex body and an everted rim (*cf. Kramberger 2014. 285–287*), which stood either on a base or low cylindrical foot (*cf. Kramberger 2014.288–289*).[29] Furthermore, all contexts contain dishes with a convex body and a straight rim (Pl. 1.3, 18; Pl. 2.37, 40; Pl. 5.3, 58; see also *Kramberger 2014.290*)[30] and jugs with a low-convex body, shoulders and a long or medium sloping neck (Pl. 1.10; Pl. 2.44; Pl. 3.59; see also App. 2.V11–V13).[31] The so-called beak-spouted rims (Pl. 1.21–22),[32] the 'buta' type of vessel with horizontal handles of a triangular form (Pl. 24.1; Pl. 2.49; see also *Kramberger 2014.159–161, 299*), ladles with a punctured handle attachment and a semi-spherical receptacle (Pl. 2.47–48) and a ladle with a punctured handle attachment and a semi-ellipsoidal receptacle (Pl. 19.1; *cf. Kramberger 2014.298*) only appear at Andrenci; these are generally known types of pottery from the 5th millennium BC in Central and South-eastern Europe.

Differences in pot forms are more significant. Apart from differences, defined as versions, it was discovered that structures A and B at Andrenci yielded only pots with rounded body (Pl. 1.11–12, 20) and an everted neck (Pl. 1.6, 11–12; Pl. 2.28, 31, 33–34),[33] while better preserved pots from Structure I at Stoperce have concave bodies (Pl. 3.66–69) and strongly everted (Pl. 3.63, 69), slightly everted (Pl. 3.60) as well as ellipsoidal necks (Pl. 3.62, 64) (see also App. 3. L24.1–L15.1–2). The upper parts of pots have vertical strap handles, a characteristic of pots from the end of the first half of the 5th millennium BC onwards in Austria (MOG IIa and IIb; *Stadler, Ruttkay 2007.142–143*) and Hungary (end of the Phase II and Phase III of the Lengyel Culture; *Bánffy 1995b.87; Zalai-Gaál 2003.294–295*).

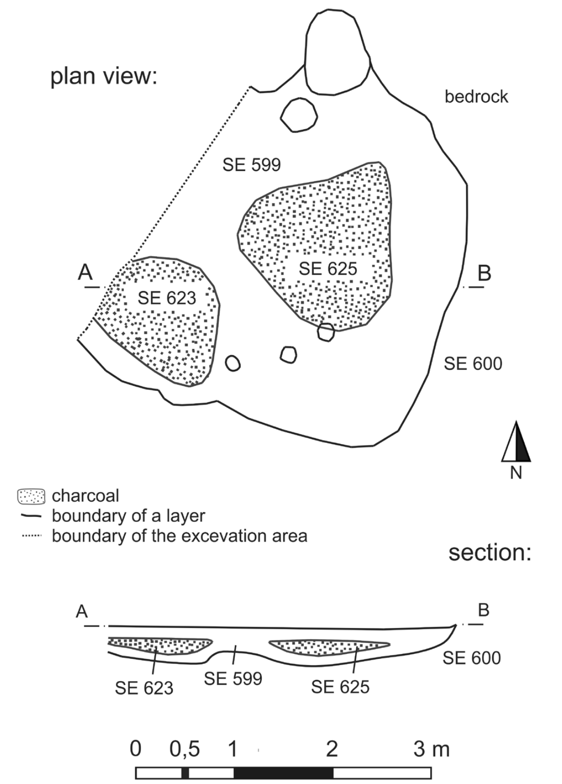


Fig. 20. Zgornje Radvanje. Structure 1. Plan and section.

A common feature of pottery decoration at Andrenci and SE 128 from Stoperce are plastic motifs on girths (Pl. 1.1–2, 7, 9, 10, 12, 17, 20; Pl. 2.29–30, 32, 37, 42–44, 46; Pl. 3.58–60, 63, 65, 68), while there is a great difference in the frequency of occurrence of such motifs in comparison with other types of decoration. Applied motifs are the most common tech-

29 Simple dishes with feet tapering at the end appear individually at Andrenci (Pl. 13.1).

30 SE 128 at Stoperce yielded a similarly formed dish with a concave body (Pl. 3.57).

31 Good comparisons are available at, for example, the Late Lengyel sites of Nagykanizsa-Inkey-Kápolna, Zalaszentbalázs-Szőlőhegyi mező and Čatež-Sredno polje (*cf. Horváth, Kalicz 2006.58; Velušček 2011c.214–242; Kramberger 2014.Fig. 186*).

32 Comparisons can be found at, for example, the sites of Lengyel Culture, the Sopot Culture and at Čatež-Sredno polje (*Kramberger 2014.291*).

33 Although only three such pots are typologically identified, based on fragments of the lower parts of the vessels, it is possible to assume that the majority were of this form. All fragments of closed vessels from structures A and B have rounded bodies, while the necks of all closed vessels from structures A and B were everted. We can assume that most of these fragments are fragments of pots, while some could be from jugs or the 'buta' type of vessels.

nique of decoration at Andrenci,[34] while the decoration of pottery from Structure I at Stoperce is diverse. Apart from applied decoration, one can notice impressions (Pl. 3.64, 66–67), a combination of impressions and applied decoration (Pl. 3.63, 68), a combination of impressions and incisions (Pl. 3.62, 69), incisions and a combination of incisions and applied decoration (Pl. 3.65). A feature of the ware from Andrenci has to be stressed, *i.e.* decoration with a large bulge on the rim of a vessel (Pl. 2.45) and horizontally perforated appliqué (Pl. 1.5), while only pottery from SE 128 at Stoperce has two small plastic bulges (Pl. 3.58) and horizontal elongated appliqués (Pl. 3.52, 54).

Pottery which disparates Andrenci from Structure I at Stoperce can be found in different geographic areas. The Andrenci pottery mainly resembles pottery assemblages dating to the end of Phase II and from Phase III of the Lengyel Culture in West Hungary, in Styria (for a review, see *Obereder 1989; Tiefengraber 2006*) and Bukovnica (*Šavel 1992.59–60*), and is thus the extreme southwest site where such pottery occurs. The West Hungarian sites are the most researched among the sites mentioned. Firstly, the site at Zalaszentbalázs-Szőlőhegyi mező has to be mentioned (for an analysis of decoration, see *Bánffy 1995b. 78–80*), followed by, for example, sites at Nagykanizsa-Inkey-Kápolna (*Kalicz 2003; Horváth, Kalicz 2006*), Tekenye (*Katalin 1987*), Veszprém (*Regenye 2007*), Szentgál-Füzi-Kút (*Regenye 1994*) and Kaposvár-Gyertyános (*Regenye 2006*). These sites yielded pots with rounded bodies, everted necks and vertical strap handles (*cf.* Pl. 12.1 with *Bánffy 1995b.Pl. 71.179*, with *Regenye 2007.Fig. 2.1*), which are almost identical to the pots described above. Moreover, the pottery is decorated with similarly formed appliqués (*cf.* Pl. 1.5: *Bánffy 1995b.Pl. 53.16; Pl. 63.109; Pl. 71.199; Pl. 92.126–127*, *Kalicz 2003.Pl. 4.12–14, Pl. 5.4*, *Regenye 1994.Fig. 8.19, Fig. 11.7*, *Regenye 2006*, with *Šavel 1992.Pl. 5.16; cf.* Pl. 2.45: *Bánffy 1995b. Pl. 71.179*, *Katalin 1987.Fig. 26.12*). Similar forms and decoration also appear at sites dated to the late phase of the Moravia – East Austrian group of painted pottery (MOG) in Austria (*Stadler, Ruttkay 2007. 140, 142–143*; *cf.* Pl. 1.11 with *Ruttkay 1976.Pl. 3.3*), while similar forms, but decorated with painted ornament, occur at sites dated to the middle phase of the MOG (*e.g., Stadler, Ruttkay 2007.138–139, 142; cf.* Pl. 1.12 with *Neugebauer, Neugebauer-Maresch 2006.Fig. 3.8*; Pl. 2.45 with *Carneiro 2006. Fig. 5. 1–2*). Good comparisons can, moreover, be found in late phases of the Brodzany-Nitra Group in Slovakia (*cf.* Pl. 2.45 with *Rakovský 1986.Fig. 1.1, Fig. 2.1, 4*, with *Kuča* et al. *2011.Fig. 5.10* and *Košturik 1979.Pl. 1.8, Pl. 4.4, Pl. 7.5, 7*).

The form and decoration of pottery from Structure I (SE 128) at Stoperce, on the other hand, mainly resembles sites in central and south-eastern Slovenia. Good comparisons can be found at settlement phase 2 at Moverna vas (*Budja 1995.Fig. 4; Tomaž 1999*), at Resnikov prekop (*Harej 1975*; *Korošec 1964*) and at Gradišče pri Stiški vasi (*Velušček 2005*). Individual comparisons also occur at, for example, Čatež-Sredno polje (*Tomaž 2010; Tomaž, Kavur 2006*) and Dragomelj (*Turk, Svetličič 2005*), where it seems

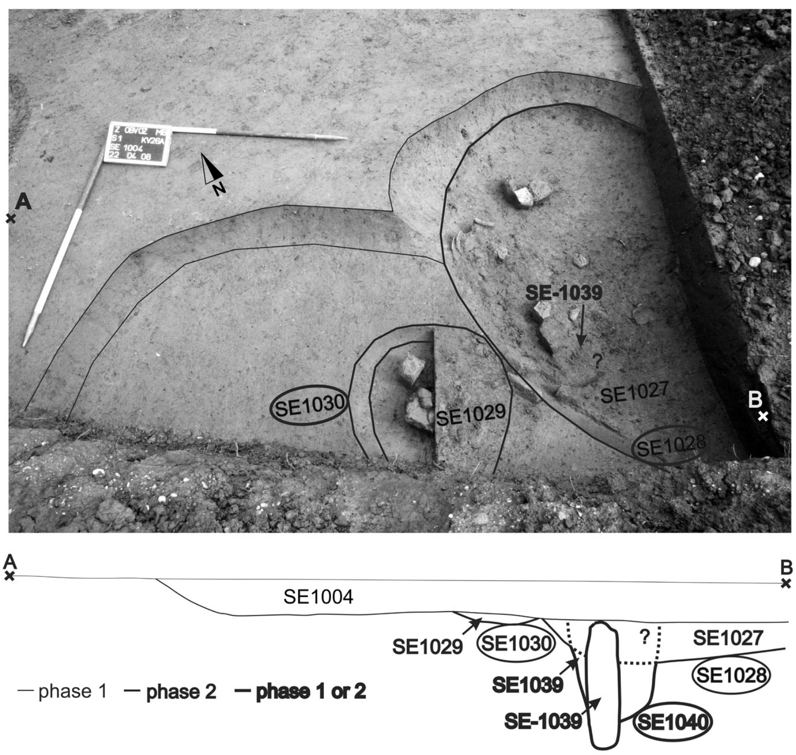
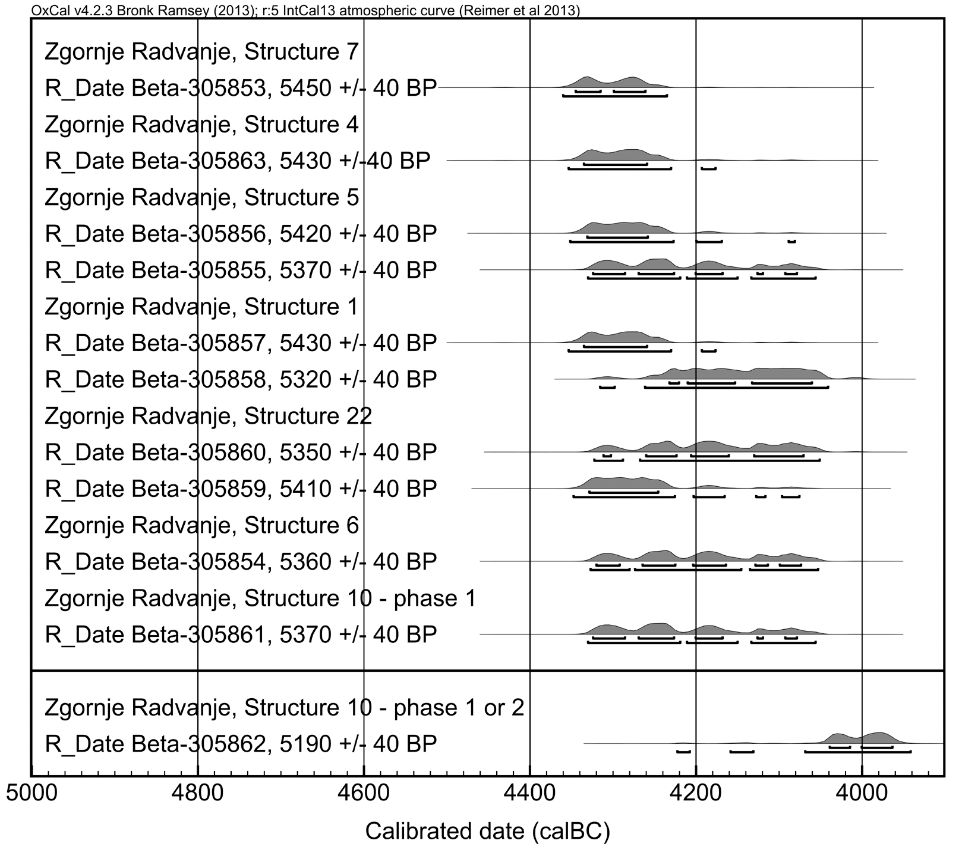


Fig. 21. Zgornje Radvanje. Structure 10. Photo and segment of partially researched structure.

34 Structure A yielded 19 vessels decorated with plastic motifs, while Structure B yielded 9 vessels with this type of decoration. According to the statistics, as already stated, this means that 80% of pottery was decorated with plastic motifs, 15% of motifs were impressed (Pl. 28.2, 34, 50) and only 5% were incised (Pl. 1.8).

Site	Context	Lab Code	Material	Age (BP)	SD (±a)	CalBC (68.2%)	Cal BC (95.4%)	Reference
Zg. Radvanje	Structure 7 (SE 20)	Beta-305853	charcoal	5450	40	4346–4262	4361–4236	first published here
Zg. Radvanje	Structure 4 (SE 1102)	Beta-305863	charcoal	5430	40	4336–4260	4354–4177	first published here
Zg. Radvanje	Structure 5 (SE 324)	Beta-305855	charcoal	5370	40	4325–4079	4331–4057	first published here
Zg. Radvanje	Structure 5 (SE 330)	Beta-305856	charcoal	5420	40	4332–4259	4352–4082	first published here
Zg. Radvanje	Structure 1 (SE 623)	Beta-305857	charcoal	5430	40	4336–4260	4354–4177	first published here
Zg. Radvanje	Structure 1 (SE 625)	Beta-305858	charcoal	5320	40	4233–4061	4316–4042	first published here
Zg. Radvanje	Structure 22 (SE 853)	Beta-305860	charcoal	5350	40	4312–4071	4323–4052	first published here
Zg. Radvanje	Structure 22 (SE 820)	Beta-305859	charcoal	5410	40	4329–4246	4348–4076	first published here
Zg. Radvanje	Structure 6 (SE 250)	Beta-305854	charcoal	5360	40	4321–4074	4328–4054	first published here
Zg. Radvanje	Structure 10 (SE 1027)	Beta-305861	charcoal	5370	40	4325–4079	4331–4057	first published here
Zg. Radvanje	Structure 10 (SE 1040)	Beta-305862	charcoal	5190	40	4040–3964	4223–3824	first published here



Figs. 22 and 23. Zgornje Radvanje. ¹⁴C AMS dates from part of the settlement, which was investigated during 2007 and 2008.

that more pottery is decorated with impressions.[35] These sites yielded identical or similar decorated pots, with concave bodies, strongly everted (*cf.* Pl. 3.63 with *Tomaž 1999. Pl. 14.1*, with *Harej 1975.Pl. 1.6*; *cf.* Pl. 3.69 with *Tomaž 1999.Pl. 12.1–2*),[36] slightly everted (*cf.* Pl. 3.60 with *Tomaž 2010.find no. 668*) and ellipsoidal necks (*cf.* Pl. 3.62 with *Velušček 2005.find no. 8*; see also the pot from settlement phase 2 in *Budja 1995.Fig. 4*). Dragomelj, Resnikov prekop, Čatež-Sredno polje and Gradišče pri Stiški vasi, all of these with artefacts that are comparable to the studied pottery, have been dated to the so-called Sava Group of the Lengyel Culture. According to Mitja Guštin, Moverna vas in Bela Krajina is not attributed to this group (*Guštin 2005.Fig. 1*). However, Velušček considers that the distribution of this cultural group is wider and includes sites in Bela Krajina, around Karlovac, Kočevsko and Slovenian Styria (*Velušček 2011.206*), which is confirmed by the pottery from the deepening of Structure I at Stoperce.

35 According to the analysis, which was presented by Alenka Tomaž, this is reliable, especially for Čatež-Sredno polje (*Tomaž 2010*), while a study of the whole Dragomelj site has to be published first in order to confirm or disprove this.

36 The second settlement phase of Moverna vas offers the best comparisons with footed dishes decorated with a horizontally elongated appliqué (*cf.* Pl. 3.52, 54 with *Tomaž 1999.Pl. 5.2*).

End of the 46th to 43rd century BC

Based on individual ^{14}C date from Structure II and dates from Structure III, the site at Ptuj-Šolski center can be dated to between the end of the 46th and 43rd century BC (Fig. 25). The date partly overlaps with dates from both, *i.e.* Structure I at Andrenci and Zgornje Radvanje. This indicates that Ptuj-Šolski center may have been contemporary with Structure I at Stoperce and with Andrenci, as well as with the structures at Zgornje Radvanje. However, the pottery assemblages found in the structures differ from site to site.

Based on pottery assemblages, Ptuj-Šolski center is culturally dated to the Late Lengyel Culture (*Kavur 2010.71*) or the 'wider Lengyel Culture' (*Guštin 2005.9, Fig. 1; Tomaž 2010.164*). The comparisons presented in this paper are only partly consistent with this definition. In addition to finds that are comparable to material from Andrenci and Structure I at Stoperce, Structures I–IV also yielded finds comparable to the Lasinja Culture in the region. The most important feature of the Late Lengyel Culture (*Carneiro 2004.267–271*) and the 'wider area of the Lengyel Culture' (*Guštin 2005.12–13*) are vessels with a coloured clay slip.[37] It can be seen on dishes of identical or similar forms as those from Andrenci and SE 128 at Stoperce: on dishes with a convex body and an everted rim (Pl. 5.82; Pl. 6.100), simple hemispherical dishes (Pl. 5.78 ; Pl. 6.92), dishes with a convex body, of simple form with a tapered upper part, where the base is not preserved (Pl. 5.90; Pl. 6.94, 102), on high hollow cylindrical feet (Pl. 6.96) and on numerous foot fragments.[38]

In addition to the presented dishes with clay slip, which were probably footed, Ptuj-Šolski center yielded many footed dishes with a convex body and straight rim decorated with four tongued appliqués (Pl. 5.79, 81, 89; Pl. 6.93, 95) which have been identified as a typical find of the Slovenian Lasinja Culture (*Guštin* et al. *2005.47; Velušček 2011.222*). These were usually fired under incomplete oxidising conditions, with reducing conditions used at the end of the firing process. The same firing process was used for high hollowed sloping feet (Pl. 6.99), high hollowed sloping feet, convex in the middle (Pl. 5.83), high hollowed sloping feet, convex on top, and differently formed low feet (Pl. 6.97–98). Some footless dishes and bowls were similar in form (Pl. 6.101, 103) occur together with dishes with a simple semi-circular form (Pl. 5.91). Handles or spouts, semi-circular spouts with a partition (Pl. 5.91), or thrown spouts (Pl. 5.84) could be attached to all types of dishes and bowls as well as footed dishes.

Even more differences can be seen between jugs and pots from Ptuj-Šolski center and those from Andrenci and Structure I at Stoperce. In contrast with the jugs from SE 128 at Stoperce and Andrenci, the typologically determined jugs from Ptuj-Šolski center have a low concave body (Pl. 6.104–106), shoulders and either short and slightly sloping (Pl. 6.106) or long cylindrical necks (see also App. 2). Pots usually have a high concave body, shoulders and a medium (Pl. 5.86; Pl. 6.107) or short cylindrical neck or a long sloping neck (Pl. 6.108). Pots of different forms are rare (Pl. 6.88; see also App. 3).

The ceramic finds are most often decorated with impressed, applied, incised and impressed-incised motifs; some are comparable to those from Structure I at Stoperce (*cf.* Pl. 3.52, 54 with Pl. 6.92; *cf.* Pl. 3. 63, 68 with Pl. 6.106). Different motifs also occur (Pl. 6.103); they are more comparable to those at Zgor-

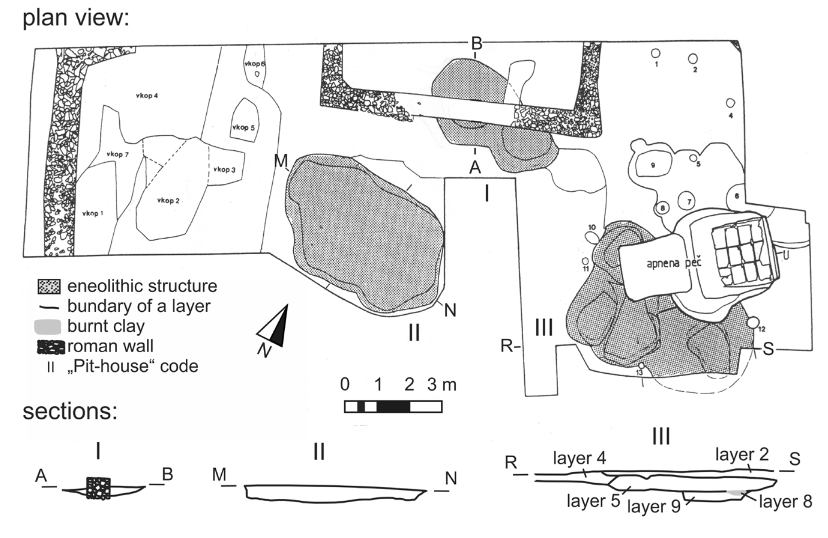


Fig. 24. Hoče-Orglarska delavnica. Plan of the part of the settlement that was excavated in 1989 and sections of Early Eneolithic 'pit-houses' (drawn according to* Strmčnik-Gulič 1990.App. 2*).

37 Ptuj-Šolski center, as already stated, yielded more slip-coated pottery than Andrenci, but less than SE 128 at Stoperce (Fig. 28).
38 No base fragments covered with slip were found at the site, so we can assume that most of the presented variations were footed.

nje Radvanje and Hoče-Orglarska delavnica (*cf.* with Pl. 8.128 and Pl. 12.182, 186, 188).

Typological comparisons reveal great similarities in the pottery from the nearby site of Rabenstein near Lawamünd, which, according to the chronology of E. Ruttkay, dates to the Early Lasinja Culture (*Tiefengraber 2004; Carneiro 2004*; see also *Krenn-Leeb 2006.195, Fig. 2*). The pottery from this site is relatively fragmented; however, several forms can be identified: dishes with a convex body and everted rim (*cf.* Pl. 5.82 with *Tiefengraber 2004.Pl. 5.45*) and dishes with a simple semi-circular form with a conical top (*cf.* Pl. 6.102 with *Tiefengraber 2004.Pl. 2.15–16, Pl. 4.33, Pl. 14.152–153*) coated with red slip and probably footed; simple spherical dishes with spouts, with partition of semi-circular form (*cf.* Pl. 5.91 with *Tiefengraber 2004.Pl. 5.49, Pl. 9.95*); jugs with a low concave body (*cf.* Pl. 6.105 with *Tiefengraber 2004.Pl. 2.20–21, Pl. 8.79, Pl. 11.114–115*) and almost identical decoration (*cf.* Pl. 5.87 with *Tiefengraber 2004.Pl. 10.101*; Pl. 6.103 with *Tiefengraber 2004.Pl. 3.29*; Pl. 6.101 with *Tiefengraber 2004.Pl. 14.150*). Comparisons of some forms of pottery which from Ptuj-Šolski center which differs from that found at Andrenci and Structure I at Stoperce are known from some sites in central and south-eastern Slovenia, the most important being: the ^{14}C dated settlement phases Moverna vas 4, 5 and partly 6 (*cf.* dish with a thrown spout – Pl. 5.84

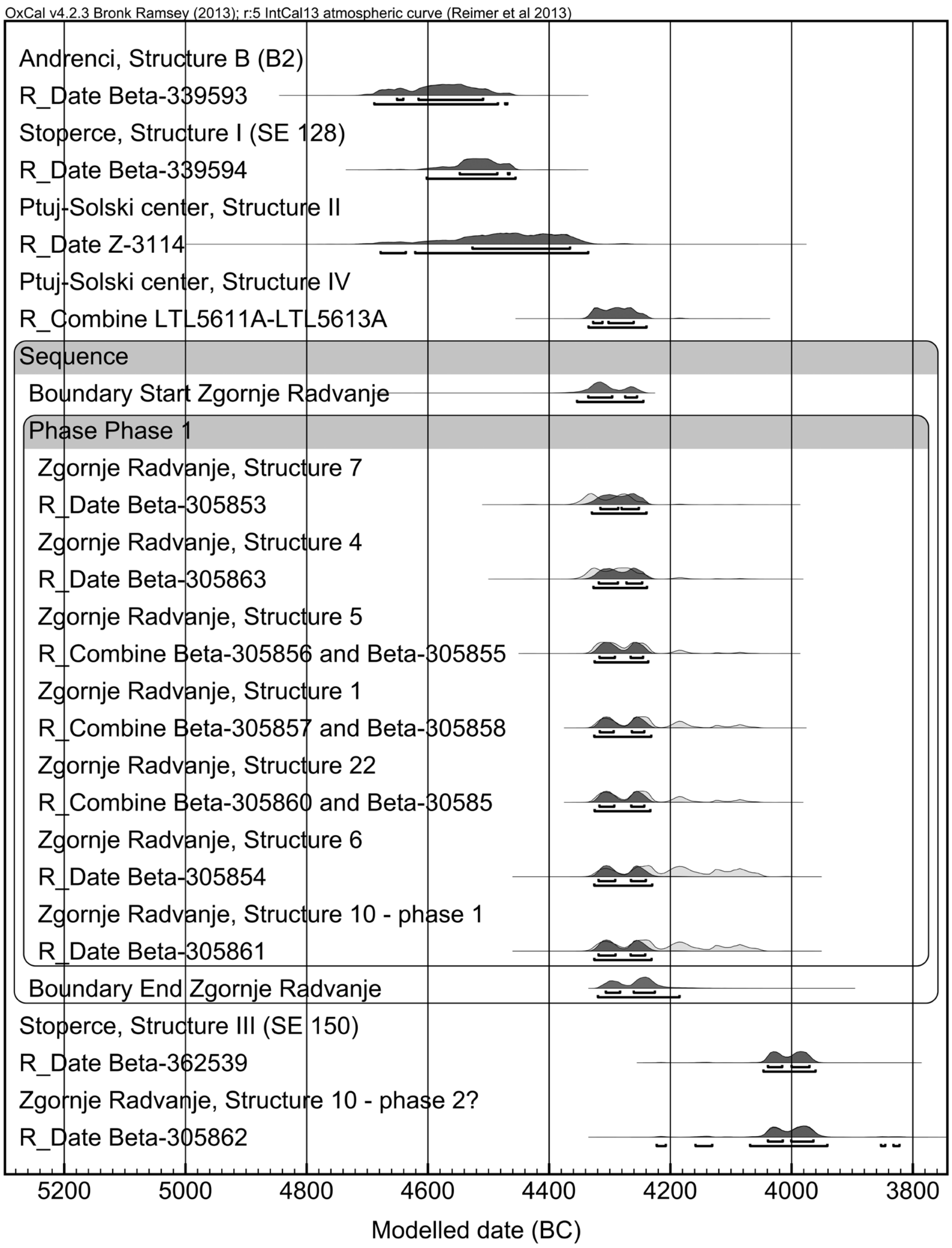


Fig. 25. Settlement chronology at Andrenci, Stoperce, Ptuj-Šolski center and part of Zgornje Radvanje.

Settlement	Amount of fragments before mending	Amount of fragments after mending	Total weight of pottery fragments (kg)
Andrenci	1050	/	/
Stoperce – settlement phase 1	1186	850	4,28kg
Stoperce – settlement phase 2	2522	1714	14,58kg
Ptuj-Šolski center	5908	4465	64,995kg
Zgornje Radvanje	26408	18086	291,677kg
Hoče-Orglarska delavnica	1584	895	33,947kg
All settlements together	38398	26010 + Andrenci	409,479 kg + Andrenci

Fig. 26. Size of studied pottery assemblages. The only data available from Andrenci is the quantity of pottery fragments that were found in the settlement.

with *Tomaž 1999.Pl. 17.4*; a pot with a concave body and cylindrical neck – Pl. 5.86 with *Tomaž 1999.Pl. 24.1, Pl. 25.1, Pl. 32.6*; a jug with a concave body decorated with incisions – Pl. 6.105 with *Tomaž 1999.Pl. 31.2–3*) and a ^{14}C-dated site at Ponikve pri Trebnjem which is dated to the same era as Structure II at Ptuj-Šolski center (*Ravnik, Tica in press*)[39] and settlement phases Moverna vas 4 and 5.

In addition to the similarity between pottery from Ptuj-Šolski center and pottery from the sites mentioned above, noticeable differences also exist. The former has frequent imprinted decoration more frequently, while the pot with a low convex body and a sharp transition between a medium cylindrical neck and shoulders, as well as footed dishes with a straight rim and hanging appliqués, which were identified in the region as typical of the Lasinja Culture, are not known at the above-mentioned sites. Is this merely a result of archaeological research, or do we have to look for an answer elsewhere?

Ptuj-Šolski center is located near the so-called 'western route' defined by Eszter Bánffy and based on many elements of southern origin seen on pottery. Sites further away from this route have fewer of these elements (*Bánffy 1994.294; 2002.42*). As already noted, these links are important, as they help to determine the transition from the Hungarian Late Neolithic to the Copper Age, as they link with changes that should have resulted from spread of new technologies (primarily copper) from the area of the central Balkans to Central Europe. Further research is needed to answer the above question, but, at this point, it is necessary to stress that there are noticeable similarities to pottery from several Copper Age cultural groups in the central Balkans, primarily with the early phases of the Salcuta Culture. Several correlations can be found (*Kramberger 2014.292, 308–309, 310–311*). However, the comparison with a uniquely formed pot with a low convex body and sharp transition between medium cylindrical neck and shoulders (Pl. 5.88; Fig. 34.1) has to be stressed here. No similar form has been found at other Slovenian sites (*cf.* Fig. 34.2).

The end of the 44th and 43rd century BC

As mentioned above, ^{14}C dates and settlement model date structures 7, 4, 5, 1, 22, 6 and 10 (Phase 1) at Zgornje Radvanje to the late 44th and 43rd century BC (68.2% probability) or, more specifically, between the second half of the 44th and the early 42nd century BC (95.4% probability) (Fig. 25). Pottery from these structures is typologically well comparable with pottery from Hoče-Orglarska delavnica (*cf.* Pl. 7–10 with Pl. 11–12), but slightly different from that found at Ptuj-Šolski center, mainly in elements where similarities with Ptuj-Šolski center, Structure I at Stoperce and Andrenci were found.

Namely, Zgornje Radvanje and Hoče-Orglarska delavnica yielded only footed dishes with a straight rim decorated with hanging tongue-like appliqués (Pl. 7.109, 112; Pl. 8.124; Pl. 9.142, 147, Pl. 10.159; Pl. 11.165). Different forms of feet are present (Pl. 8.137; Pl. 11.172; Pl. 12.180, 184; see also *Kramberger 2010.Pl. 1.1; Pl. 6.33*), the most common being high hollow feet, convex on top (Pl. 7.110; Pl. 8.123; Pl. 10.155; Pl. 12.183). Dishes and bowls were formed similarly to footed dishes.[40] They have applied handles (Pl. 8.126; Pl. 11.166; Pl. 12.186), lugs (Pl. 12.192), appliqués (Pl. 7.113; Pl. 11.168) or spouts. Semi-circular spouts with a partition (Pl. 9.145) and thrown spouts (Pl. 9.143; Pl. 10.154) appear with a protrusion/protrusions on the inside, and circular spouts with partition (Pl. 7.111; Pl. 11.170) and extracted spouts (Pl. 7.115; Pl. 12.181) are also present.

39 I am grateful to Mateja Ravnik that enabled me to get an insight to the dating and pottery and allowed me to mention the yet unpublished data at this stage.

40 Only bowls with a concave body, shoulders and rim differ (Pl. 11.168, see also *Kramberger 2010b.Pl. 1.6–7*).

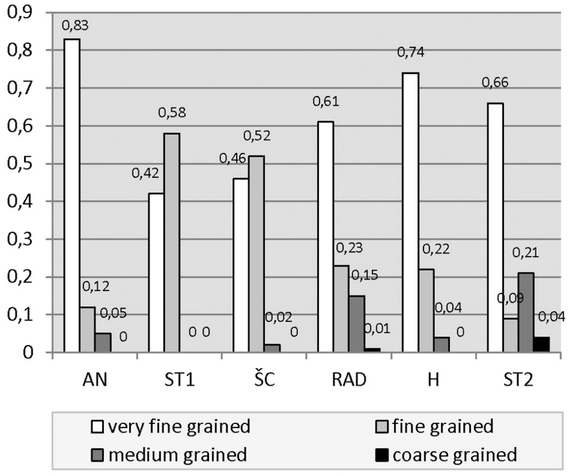


Fig. 27. Andrenci (AN), Stoperce – settlement phase 1 (ST1), Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica and Stoperce – settlement phase 2 (ST2). Percentage of different granularity groups of fabrics.

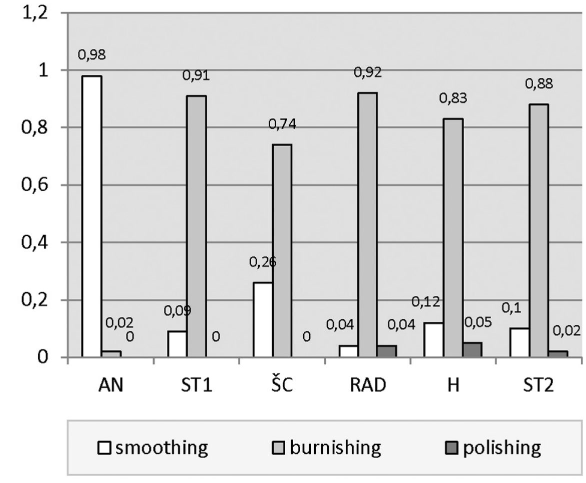


Fig. 28. Andrenci (AN), Stoperce – settlement phase 1 (ST1), Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica and Stoperce – settlement phase 2 (ST2). Percentage of finishing (surface treatment) techniques.

Jugs with a low concave body, low shoulders and a long, cylindrical (Pl. 7.116; Pl. 11.174; Pl. 12.182) or slightly sloping neck (Pl. 10.162) are similar in form to jugs found at Ptuj-Šolski center, but the shoulders are often extremely thickened (see also Pl. 8.128, *Kramberger 2010.Pl. 7.41, 45*). Jugs with identically formed upper parts, but a high concave body (Pl. 7.121; Pl. 8.136; Pl. 11.171; Pl. 12.185, probably also Pl. 9.144), and jugs with a high concave body and long strongly sloping necks (Pl. 8.127, 135; Pl. 9.149) (see also App. 2) are also present.

The most common pot forms are, similarly to Ptuj-Šolski center, pots with a high concave body, shoulders and a sharp transition to a short cylindrical neck (Pl. 8.131; Pl. 11.177–178; 12.187–188; see also *Kramberger 2010.Pl. 2.12; Pl. 3.13–15, 18; Pl. 7.48–49; Pl. 9.52; Pl. 10.58*), and pots with a high concave body, low shoulders and a long, sloping neck (Pl. 9.152; Pl. 11.176, 179; see also *Kramberger 2010.Pl. 7.46–47*). Pots with a high concave body, with no shoulders and a long, strongly sloping neck (Pl. 7.122; Pl. 9.146, 153; see also *Kramberger 2010. Pl. 8.50*) are also frequent, together with individual finds of pots with a low concave body (*Kramberger 2010.Pl. 2.11; Pl. 20.4*), a pot with a high concave body, shoulders and medium strongly sloping neck (Pl. 10.164), a pot with a concave body and an indistinct transition to a short slightly sloping neck (Pl. 7.114) and pots with a convex body and a long, slightly sloping neck (Pl. 12.189–190; see also App. 3).

Apart from pots, ^{14}C-dated structures at Zgornje Radvanje also yielded bottle-like vessels (Pl. 7.118, *Kramberger 2010b.Pl. 3.17, 9.55*). They are similar to the so-called Lasinja bottles – a characteristic of this period, which are also present at Zgornje Radvanje (Pl. 7.119) and Hoče-Orglarska delavnica (Pl. 12.191) – but incomparably larger (*Kramberger 2014.343–344, 346–348*). They were categorised as pots in the first publication (*Kramberger 2010.313, 314*), but compared to pots they are more closed and have appliqués instead of handles.

The pottery ladles were made in one piece, with a full (Pl. 8.132) or punctured attachment (Pl. 9.151; Pl. 10.160; Pl. 11. 175) for a handle. The latter is more common, often with one (Pl. 7.117; Pl. 8.141; see also *Kramberger 2010b.Pl. 9.53*) and sometimes more protrusions, which is characteristic of a period after the Lengyel Culture (*Ruttkay 1994. 223*).

Pottery similar to that found at Hoče-Orglarska delavnica and Zgornje Radvanje can primarily be found[41] at sites dated later as pertaining to the Lengyel Cul-

41 Some forms and ornaments have comparisons on sites that are dated to the 45th and 44th century BC (Phase 4 and 5 of Moverna vas – see *Kramberger 2010b.317–322*) and even sites that are dated to the middle of the 5th millennium BC (*cf.* Pl. 9.150 with Pl. 3.66). The datings of some sites which are based on comparisons of a few small pottery fragments do not seem completely convincing (see *Tomanič-Jevremov* et al. *2006.find no. 2–15* and compare find no. 3 with Pl. 8.133). However, we also have to mention that there are indeed some fragments at Ptujski grad which are characteristic of the pottery of the middle of 5th and first half of 5th millennium BC (*Tomanič-Jevremov* et al. *2006.find no. 2; Korošec 1951.Fig. 55; 1965.Pl. 11.4*)

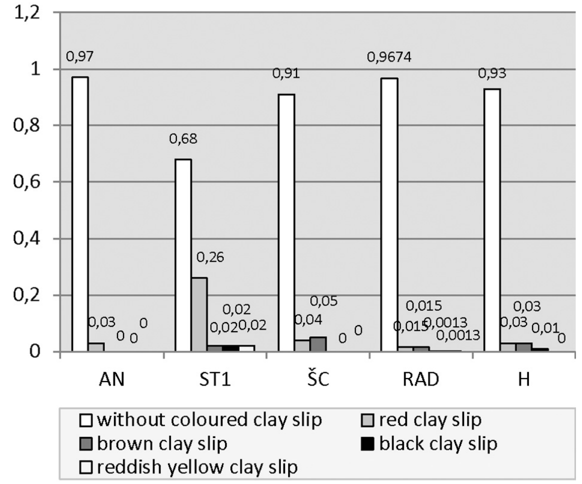


Fig. 29. Andrenci (AN), Stoperce – settlement phase 1 (ST1), Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica and Stoperce – settlement phase 2 (ST2). Percentage of different coloured clay slips.

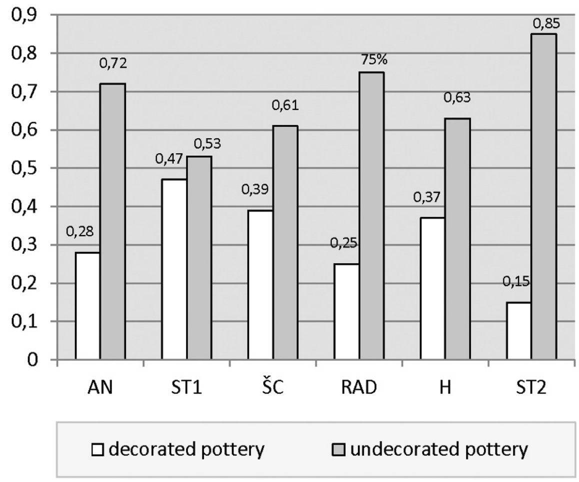


Fig. 30. Andrenci (AN), Stoperce – settlement phase 1 (ST1), Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica and Stoperce – settlement phase 2 (ST2). Percentage of decorated/ undecorated pottery.

ture. Most comparisons are from Lasinja sites in the region, in south-eastern Slovenia and in the Gorenjska region in Northern Slovenia; Zbelovo (*cf.* Pl. 19. 189–190 with *Pahič V. 1983.Pl. 5.1*; *cf.* Pl. 7.119 and Pl. 12.119 with *Pahič V. 1983. Pl. 15.10–11*) and Brezje pri Zrečah (*cf.* Pl. 7.119 with *Pahič 1956. Pl. 1.2*), located at Dravinjske gorice. The Drava plain offers good comparisons at, for example, Hardek (*cf.* Pl. 12.189–19 with *Žižek 2006a.find no. 31*; Pl. 7.115 with *Žižek 2006a.find no. 20*; Pl. 7.114 with *Žižek 2006a.find no. 23*), part of the pottery from Ptujski grad (*Tomanič Jevremov* et al. *2006b.178–182*) and some of the finds from Ormož-Škoršičev vrt (*cf.* Pl. 12.189 with *Tomanič Jevremov* et al. *2006a.find no. 21*). South-eastern and northern Slovenia offer well comparable pottery finds primarily from burials in Ajdovska jama (*cf.* Pl. 7.121 with *Horvat Mi. 1989.Pl. 6.435*; Pl. 11.179 with *Korošec Pa. 1975.Pl. 8.1*; Pl. 11.176 with *Horvat Ma. 1986. Pl. 3.2; cf. Kramberger 2010b.Pl. 3.17* with *Horvat Mi. 2009.Fig. 5.10*; *cf.* Pl. 7.119 with *Horvat Mi., Horvat Ma. 1987. Fig. 3*), finds from the 6th and 7th settlement phase of Moverna vas (*Budja 1995. Fig. 4*), pit PO 004 at Čatež-Sredno polje (*cf.* Pl. 7.121 with *Tiefengraber 2006b. find no. 5*), and partly finds from Spaha (*Velušček 2011.222–223*) and Dru-

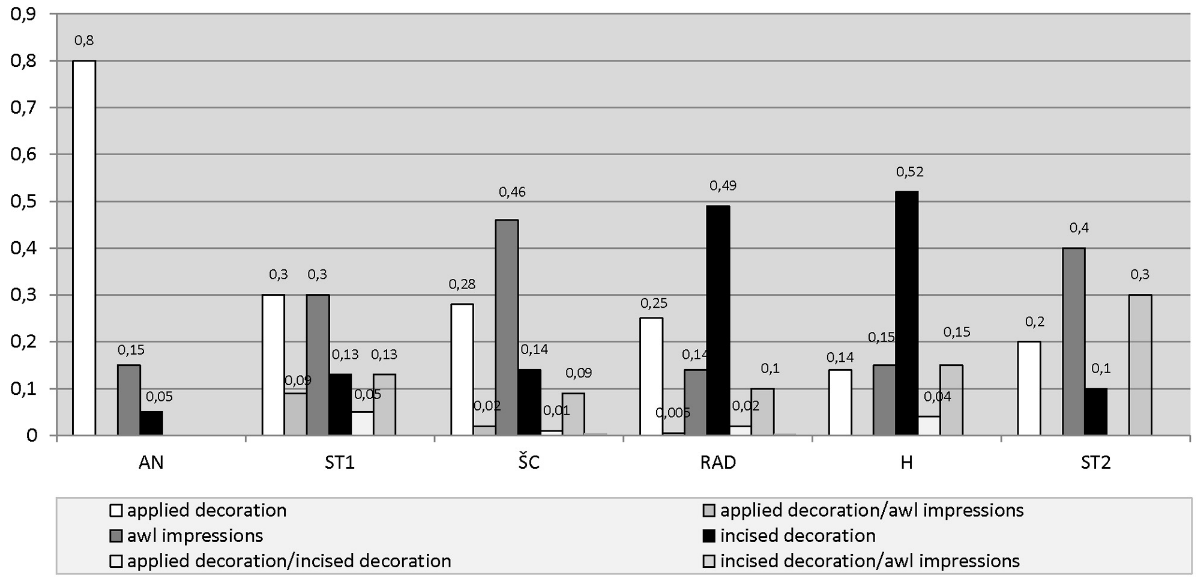


Fig. 31. Andrenci (AN), Stoperce – settlement phase 1 (ST1), Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica and Stoperce – settlement phase 2 (ST2). Percentage of pottery decoration techniques.

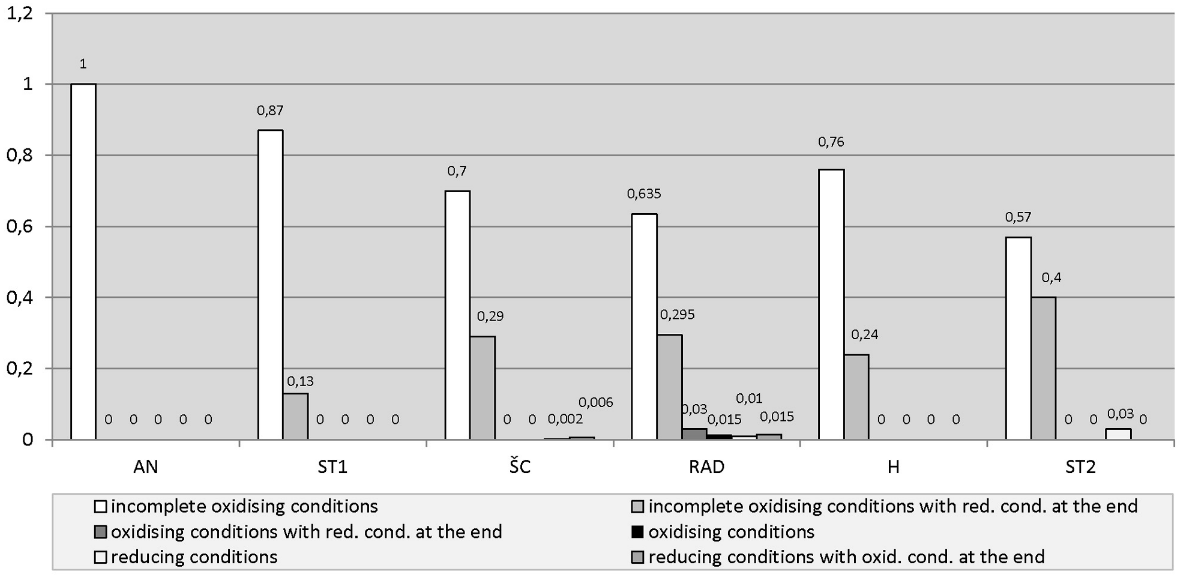


Fig. 32. Andrenci (AN), Stoperce – settlement phase 1 (ST1), Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica and Stoperce – settlement phase 2 (ST2). Percentage of types of firing of pottery (firing conditions).

lovka near Kranj (*Guštin* et al. *2005.47–50*; *cf.* also Pl. 7.119 with *Guštin* et al. *2005.find no. 32*).[42]

The best Austrian comparisons are from Raababerg near Graz (*cf.* Pl. 7.115 with *Obereder 1989.Pl. 15. 155–156*; *cf.* Pl. 9.143 with *Obereder 1989.Pl. 18. 183–184, Pl. 20.201–204*; *cf.* Pl. 9.145 with *Obereder 1989.Pl. 18.188, Pl. 20.205*; *cf.* Pl. 12.192 with *Obereder 1989.Pl. 9.97 and 149*), and also from Stillfried (*cf.* Pl. 7.113 with *Hahnel 1991.Pl. 1.2*) and Kanzel bei Graz (*cf.* Pl. 12.189–190 with *Artner* et al. *2012.Pl. 1.R30–R42, R69*).

The other side of Slovenske gorice yielded comparable sites at Sodolek (*cf.* Pl. 7.114 with *Kavur* et al. *2006.find no. 5*; Pl. 9.143 with *Kavur* et al. *2006. find no. 2*) and Šafarsko (*cf.* Pl. 7.116 with *Šavel 2006.find no. 27*; *cf.* Pl. 12.189–190 with *Šavel 1984.Pl. 4.1*), which are located on the right bank of the Mura River. Slightly fewer comparisons can be found at sites from the Prekmurje region in eastern Slovenia and Hungary. In Prekmurje, for example, pottery comparisons can be found at Popava 1 near Lipovci (*cf.* Pl. 12.189–190 with *Šavel, Karo 2012. find no. 481*; Pl. 7.119 and Pl. 12.119 with *Šavel, Karo 2012. find no. 819*; Pl. 12.192 with *Šavel, Karo 2012. finds nos. 49, 239–240, 507, 717, 729*), Turnišče (*cf.* Pl. 12.189–190 with *Tomaž 2012.finds nos. 7–8, 10, 14, 15 , 22, 139*; Pl. 12.192 with *Tomaž 2012.find nos. 435, 485, 487–488*), Bukovnica (*cf.* Pl. 11.176 with *Šavel 1994.Pl. 21.2*; *cf.* Pl. 12.189 with *Šavel 1994.Pl. 21.13*), Kalinovnjek near Turnišče (*cf.* Pl. 12.189–190 with *Kerman 2013a.find no. 408*; Pl. 12.192 with *Kerman 2013a.find no. 267*) and Gorice near Turnišče (*cf.* Pl. 9.152 with *Plestenjak 2010.find no. 15*). It is also necessary to mention some of the Hungarian sites, particularly Szombathely metro (*cf.* Pl. 7.121 with *Gábor 2004. Pl. 86*), Dobri-Alsó-mesö (*cf.* Pl. 12.189–190 with *Horváth, Katalin 2004.Fig. 25.3*; Pl. 12.192 with

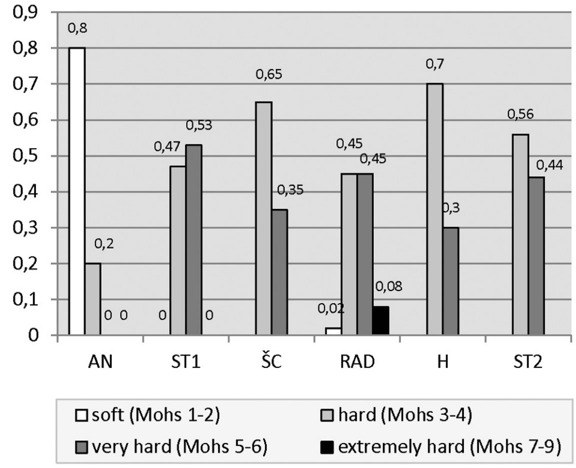


Fig. 33. Andrenci (AN), Stoperce – settlement phase 1 (ST1), Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica and Stoperce – settlement phase 2 (ST2). Percentage of hardness groups of pottery.

42 The miniature bottle from Drulovka has been explained as a representative find of the Sava Group of the Lengyel Culture, but it is not clear on what basis. Resnikov prekop, Čatež-Sredno polje, Dragomelj and other comparable Slovenian sites have not yielded miniature bottles; they are present only at sites of the Lasinja Culture.

Horváth, Katalin 2004.Fig. 6.5), Sormás (*cf.* Pl. 12.189–190 with *Straub 2006.Fig. 4.6*; Pl. 12.192 with *Straub 2006.Figs. 5.3, 8.2, 8.1, 3*), Nagykanizsa (*cf.* Pl. 12.189–190 with *Kalicz 1975. Pl. 9.4*), Zalaszentbalázs-Pustatető (*cf.* Pl. 12.189–190 with *Bánffy 1995a.Pl. 32.129*), Gellénháza-Városrét (*cf.* Pl. 12.191 with *Horváth, Katalin 2003. Figs. 22.7, 23.8*; Pl. 9.143 with *Horváth, Katalin 2003.Fig. 24.7*; Pl. 12.192 with *Horváth, Katalin 2003.Fig. 24.2*), Úyperint-Kavicsbánya (*cf.* Pl. 7.116 with *Károlyi 1992. Pl. 34.4*), Mosonszentmiklós-Pálmajor (*cf.* Pl. 7.113 with *Virág, Figler 2007.Fig. 8.1*), Kaposvár (*cf.* Pl. 7.113 with *Samogyi 2000.Fig. 13.3*), Zalavár-Basasziget (*cf.* Pl. 12.189–190 with *Virág 2003b.Fig. 3.5, Fig. 6.4*; Pl. 12.192 with *Virág 2003a.Fig. 4.1*), Letenye-Szentkerszdomb (*cf.* Pl. 12.189–190 with *Kalicz 1973. Fig. 19.6*), Tornyiszentmiklós (*cf.* Pl. 12.189–190 with *Barna 2003.Fig. 6.10*) and Nagykanizsa-Sanc (*cf.* Pl. 12.189–190 with *Kalicz 1991. Fig. 8.1*).

In Croatia, the best correlations come from Bukovje (*cf.* Pl. 7.119 with *Homen 1985.Fig. 1*), Beketinec (*cf. Kramberger 2010.Pl. 3.17* with *Homen 1990. Fig. 5.8*; Pl. 7.118 with *Homen 1990.Fig. 2.1*; Pl. 7.119 with *Homen 1985.Figs. 2–3*), Cerje Tužno-Krč (*cf.* Pl. 7.119 with *Marković 1994.Pl. 24.9*) and Jakšić (*cf.* Pl. 12.189–190 with *Marković 1985.Fig. 3*).

The second half of the 41st and the first half of the 40th century BC

Pottery from the Early Eneolithic pits at Stoperce, which, based on an absolute date from the hearth in Structure III, can be dated to the period between the second half of the 41st and the first half of the 40th century BC, are typologically homogeneous. The finds that connect Early Neolithic pits at Stoperce, structures 7, 4, 5, 1, 22, 6, 10 (Phase 1) from Zgornje Radvanje, Hoče-Orglarska delavnica and Ptuj-Šolski center are dishes with a straight rim (Pl. 4.70) on high hollow feet that are convex on top (Pl. 4.71), and decorated with tongue-like appliqués, together with dishes and bowls similar to them. On the other hand, differences can be seen in jug and pot forms and decorative motifs.

The pots and jugs most frequently have an S-shaped profile. These jugs (Pl. 4.74, 77) and pots (Pl. 4.72) differ from one another only in dimensions and the number of handles. Another form of pot has a high concave body, an indistinct transition to the upper part and a long, slightly sloping neck (Pl. 4.75). A jug from the same site is similar in form, but

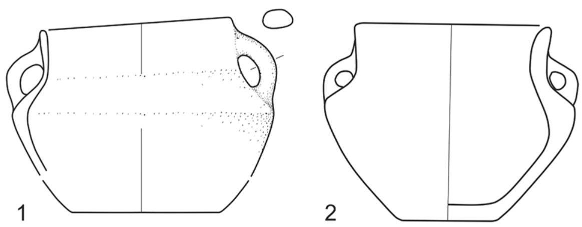


Fig. 34. Comparison to a pot with a low convex body. 1 Ptuj-Šolski center, Structure IV; 2 Salcuta (after* Radu 2002.357 – CANA 2B*).

has a distinct transition to the upper part (Pl. 4.76) (see also App. 2–3). As mentioned above, the decoration is noticeably different. The most common form consist of individual bunches of incisions that end with awl impressions (Pl. 4.73, 77). Another decoration that has to be mentioned consists of two lines of impressions on the shoulders of a closed vessel (Pl. 4.76) and the upper parts of the feet of footed dishes (Pl. 4.71). A foot of this type was also found in layer SE 1004 in Zgornje Radvanje (*cf.* Pl. 10.155), which may be linked to post-hole SE 1040 and its absolute date (see Fig. 25 and comments on dates from Zgornje Radvanje).

Again, comparable finds in terms of form and decoration can be found mainly at Lasinja Culture sites and related cultures in neighbouring countries. The best correlations are from Keutschacher See in Austria (*cf.* Pl. 4.71 and Pl. 10.155 with *Samonig 2003. Pl. 40.435*; Pl. 4.75 with *Samonig 2003.Pl. 13.133*; Pl. 4.74, 77 with *Samonig 2003. Pl. 13.138* and Fig. 25: Type B2), Pri Muri near Lendava (*cf.* Pl. 4.72 with *Šavel, Sankovič 2011. find nos. 92, 131–132*) and Brezje near Turnišče (*cf.* Pl. 4.71 and Pl. 10.155 with *Novšak* et al. *2013.find no. 97*), and finally in some of the finds from Hardek (*cf.* Pl. 4.75 with *Tušek 1999.Pl. 2.8*; Pl. 4.74, 77 with *Žižek, 2006.find no. 22*).

Chronologically concurrent sites and cultural groups

To summarise, the best comparisons with the pottery from Andrenci can be found in pottery from the later Lengyel Culture (phases Lengyel IIb and III) in western Hungary, Austrian Styria and Bukovnica and from later phases of the MOG Culture in Austria (phases IIa and IIb), while pottery from chronologically contemporary Structure I at Stoperce correlates with sites in central and south-eastern Slovenia. Pottery from slightly later structures at Ptuj-Šolski center is comparable to pottery from Rabenstein near Lawamünd and some sites in central and south-eastern

Slovenia, while pottery from Zgornje Radvanje, Hoče-Orglarska delavnica and settlement Phase 2 at Stoperce correlates with Lasinja Culture sites.

^{14}C dates from Structure B in Andrenci and Structure I at Stoperce are comparable with dates from the Late Lengyel site at Zalaszentbalázs-Szőlőhegyi mező in western Hungary, from Dragomelj, settlement Phase 3 of Moverna vas and some of the dates from Resnikov Prekop (see also *Mlekuž* et al. *2013. Pl. 1*) and Čatež-Sredno polje. This indicates that these sites were partly contemporary. The unpainted phase of the Lengyel Culture (Lengyel Phase III) was, by definition, concurrent with the 'Phase of unpainted pottery' MOG IIb in Austria, while Phase MOG IIa, which is characterised by multiple colour painting, was probably earlier (*Bánffy 1997.61*). However, scholars note that this does not correlate with the AMS ^{14}C dating (*Veluščček 2011.236*). This was furthermore confirmed with dates from Andrenci and Structure I at Stoperce, which are earlier than dates from MOG IIb and comparable to MOG IIa (Michelstetten, Oberbergern, Antonshöhe in Reichersdorf) (Fig. 35).

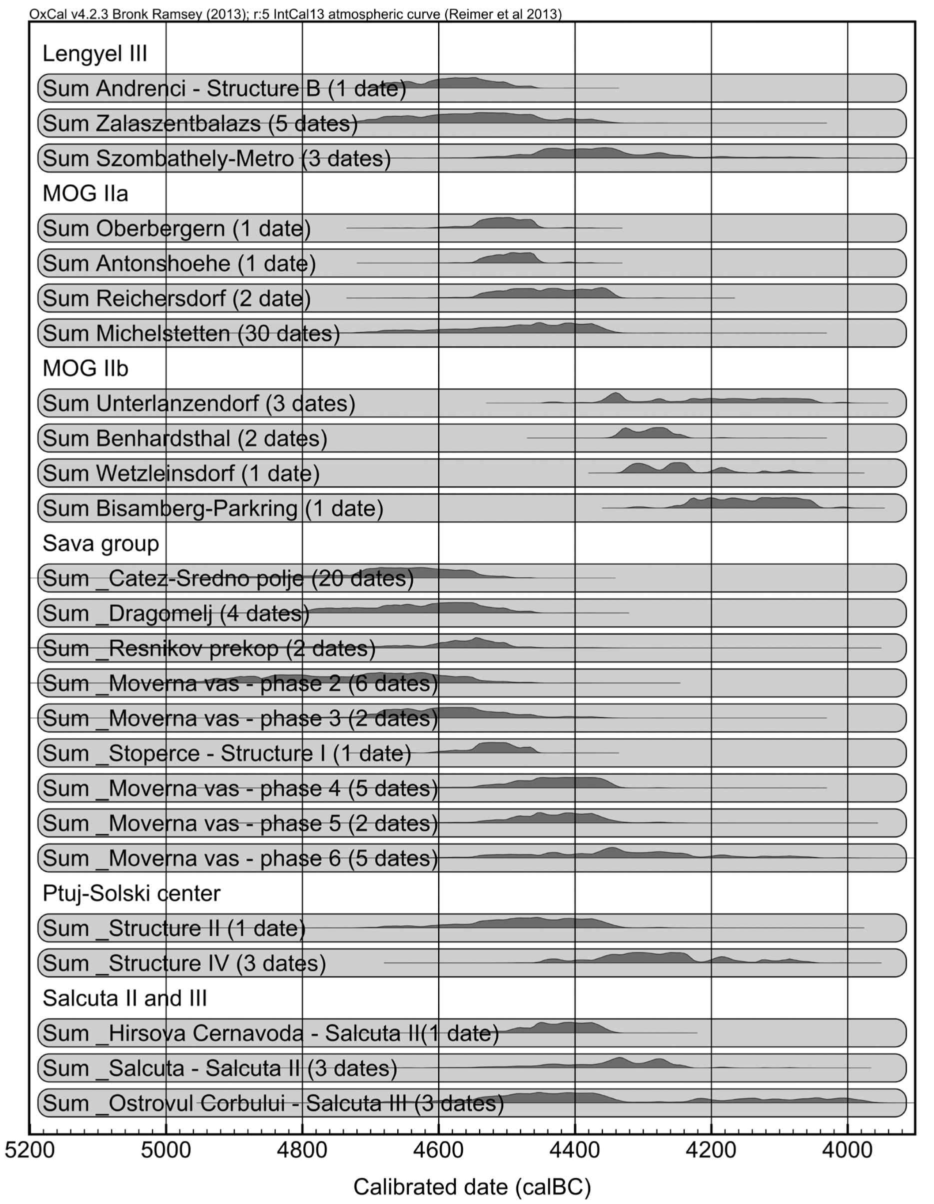


Fig. 35. Sum probability of dates from the sites of Lengyel Phase III (according to* Hertelendi 1995.105 *and* Gábor 2004.Fig. 26*), phases MOG IIa and IIb (according to* Stadler, Ruttkay 2007.Pl. 1–4*), the Sava Group and comparable sites in central and south-eastern Slovenia (according to* Guštin 2005.Fig. 2; Turk 2010.43; Turk, Svetličič 2005.69; Budja 1994.Fig. 5; Čufar, Korenčič 2006.Pl. 2; Sraka 2012.375*), earlier phases of the Salcuta Culture (after* Lazarovici, Lazarovici 2013.Fig. 5 *and* Rădoescu 2009.42*) and dates from Ptuj-Šolski center.

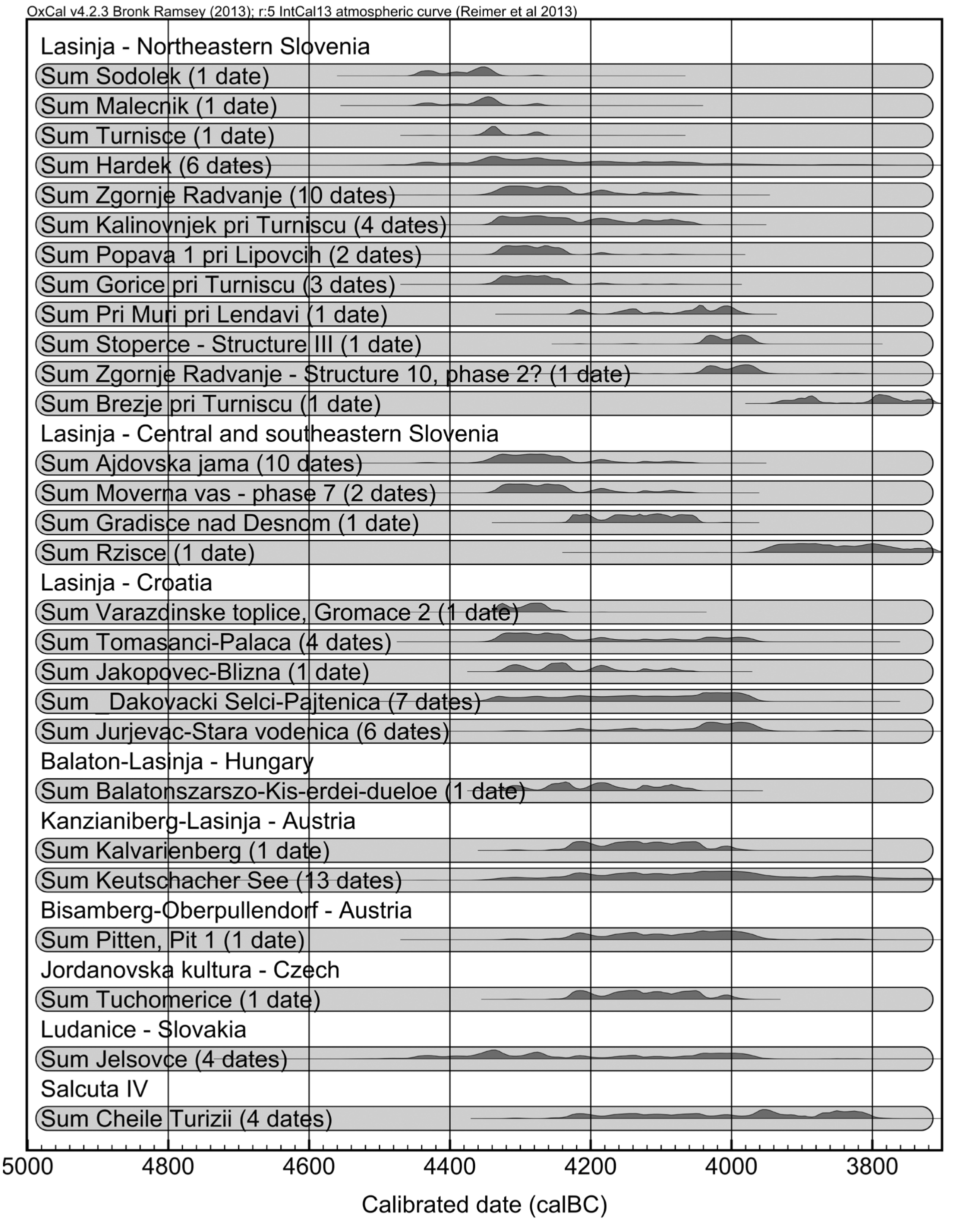


Fig. 36. Sum probability of dates from the Lasinja Culture sites in north-eastern Slovenia (according to* Guštin 2005.Fig. 3; Tomaž 2012.Fig. 59; Žižek 2006.Figs. 2 and 3; Kerman 2013.Fig. 46; Šavel, Karo 2012.Figs. 48 and 49; Plestenjak 2010.Figs. 86, 93-94; Šavel, Sanković 2011.Fig. 52; Meiert Grootes, Josée Nadeau 2013.126*), in central and south-eastern Slovenia (*Bonsall *et al.* 2007.Tab. 1; Mason, Andrič 2009.Tab. 1; Sraka 2013.375*) and in Croatia (*Bekić 2006.95; 2006a.27; Balen 2008.Fig. 3*); a single date of the Balaton-Lasinja Group in Hungary (*Oross *et al.* 2010.Fig. 12*); dates of the Kanzianiberg-Lasinja Group (*Fuchs 2002.117; Cichocki 2003.Tab. 1*), Bisamberg-Oberpullendorf Group in Austria (*Stadler, Ruttkay 2007.Tab. 4*); date of the Jordanovska Culture in the Czech Republic (*Sankrot, Zápotocký 2011.114*); dates of the Ludanice Group in Slovakia (*Görsdorf 1995.205–206*) and sum probability of dates from Salcuta Phase IV (according to* Lazarovici, Lazarovici 2013.Fig. 5*).

Structure II at Ptuj-Šolski center yielded a date that overlaps with the later MOG IIa, with earlier MOG IIb, with dates of the Late Lengyel Culture site at Szombathely metro in Hungary and dates of settlement phases 4 and 5 at Moverna vas (south-eastern Slovenia), which can probably be attributed to the Sava Group (*Veluščck 2011.226–227*). Dates from phases II and III of the Salcuta Culture, where, for example, a comparison of a pot with a rounded lower part was found, are also comparable (Fig. 35).

According to the results of the ^{14}C AMS analyses, structure II at Ptuj-Šolski center is earlier than structures 7, 4, 5, 1, 22, 6 and 10 (Phase 1) at Zgornje Radvanje, and perhaps also Structure IV at Ptuj-Šolski center, although typologically well comparable pottery has been discovered in both structures. These structures are earlier than Structure III at Stoperce, part of the site at Radvanje-Habakuk 2 (*Arh 2012*) and the date from the post-hole SE 1040 at Zgornje Radvanje. Dates from the mentioned structures at Zgornje Radvanje, as well as from Structure IV at Ptuj-Šolski center, are consistent with the earlier dates of the Lasinja Culture and its related cultures in neighbouring countries, while the dates from Structure III at Stoperce (SE 150), part of the site at Radvanje-Habakuk 2 and from post-hole SE 1040 in Zgornje Radvanje, correlate with later dates of the Lasinja Culture and its related cultures. It is important to note that sites with comparable pottery material have been shown to be chronologically concurrent (Keutschacher See, Pri Muri near Lendava and Brezje near Turnišče) (Fig. 36).

Conclusion

Comparative analyses of pottery found at the studied settlements and beyond, as well as comparisons of radiocarbon dates show that, based on the presented settlements of the 5th millennium BC in northeastern Slovenia, it is possible to identify three cultural groups, *i.e.* the Sava, the (Late) Lengyel and the Lasinja Culture. According to the current chronology of the 'the central and southern Slovenian Neolithic and Early Eneolithic' and ^{14}C dates known so far, these settlements date to between the Younger/Late Neolithic and the Early Eneolithic (*Velušček 2011.225–23*).

Andrenci in western Slovenske gorice represents the extreme south-western site of the Lengyel Culture, while the more or less concurrent Structure I from Stoperce at Haloze belongs to the Sava Group. They are dated to between the end of the 47th century and the first half of the 45th century BC, which is consistent with the earlier dates of the Late Lengyel Culture in western Hungary (Zalaszentbalázs-Szőlőhegyi mező) and dates of MOG IIa in Austria.

The settlement at Ptuj-Šolski center dates to between the end of the 46th and 43rd century BC.[43] The comparative analyses of the pottery are not completely consistent with the relative chronological incorporation of Ptuj-Šolski center into the wider Lengyel Culture (*Guštin 2005.13, Fig. 1*) or Late Lengyel Culture (*Kavur 2010.71*). The pottery found in structures (I, II and IV) shows elements of the Sava Group in central and south-eastern Slovenia, as well as elements already attributed to the Early Eneolithic Lasinja Culture. Comparable pottery assemblages are deemed to have been produced in the early phase (Phase I) of the Lasinja Culture in Austria (*Tiefengraber 2004. 219*).

These phases were followed by the 'Classical' Lasinja Culture. The studied sites passed through two phases: structures 7, 5, 1, 22, 6 and 10 (Phase 1) at Zgornje Radvanje, part of the settlement at Radvanje-Habakuk 2 (*Arh 2012.Fig. 10*) and the settlement at Hoče-Orglarska delavnica represent the older phase, namely the end of the 44th and 43rd century BC (68.2% probability), with dates corresponding to earlier (!) dates of the Lasinjska Culture and related cultures in neighbouring areas. Structure IV at Ptuj-Šolski center was more or less contemporaneous, although pottery from this structure is well comparable with material from Structure II on the same site, while its decoration and forms differ slightly from the material found at Zgornje Radvanje and Hoče-Orglarska delavnica. Differences in decorative techniques, motifs and forms could therefore be regional or chronological, but the latter can be confirmed or disproved only with new ^{14}C dates and new pottery assemblages.

The Late Lasinja Culture is presented by pits from the second settlement phase at Stoperce, individual pits in part of the site Radvanje-Habakuk 2 and, according to the ^{14}C date, post-hole SE 1040 at Zgornje Radvanje. This settlement dates to the end of the 5th and the beginning of the 4th millennium BC, where the dates correlate with the later (!) dates of the Lasinja Culture and related cultures in neighbouring countries.

Translation: dr. Nives Kokeza

43 One of the two dates from Structure II was, as already stated, not included in further analyses, as five different samples were mixed in one sample prior to dating.

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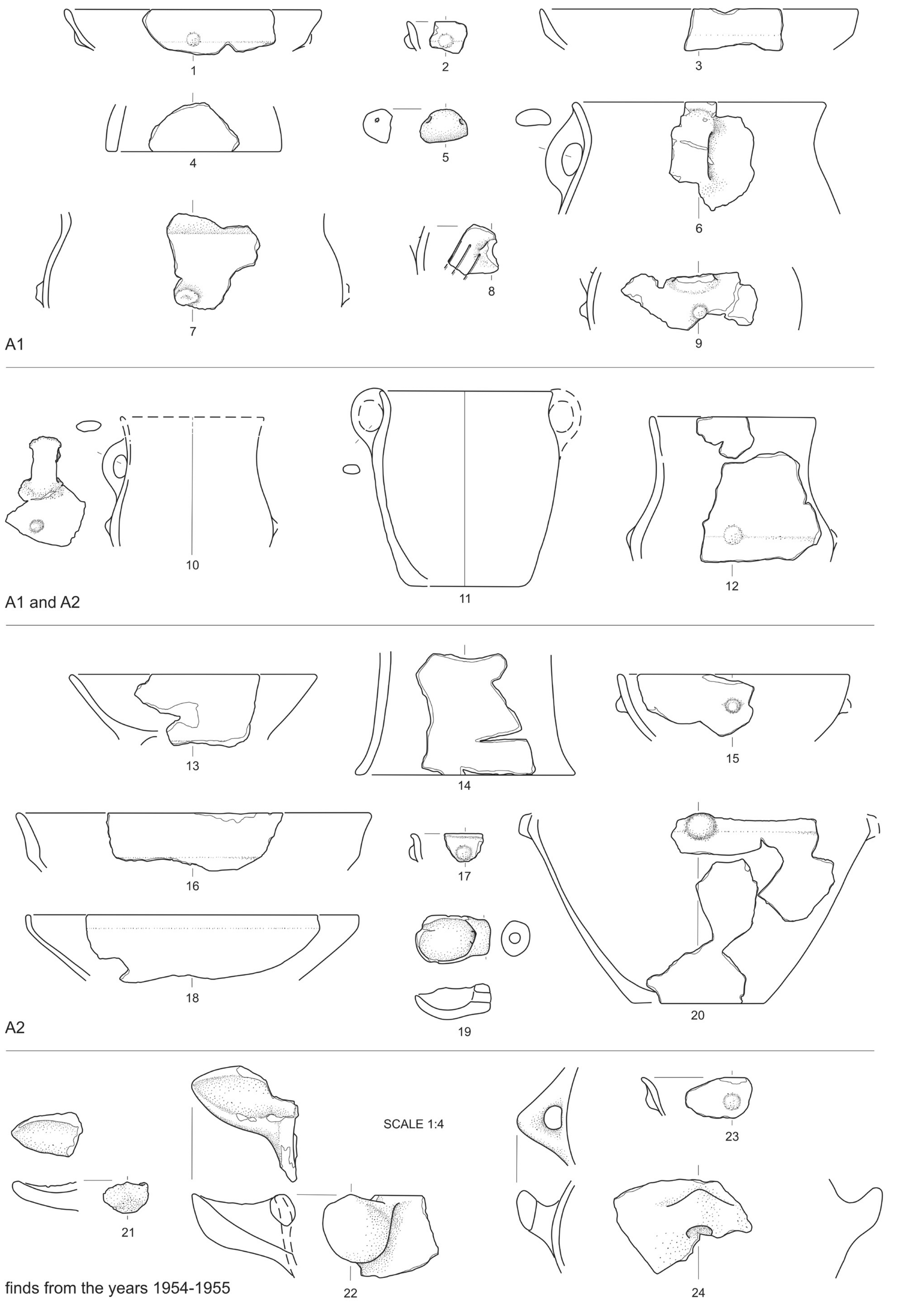
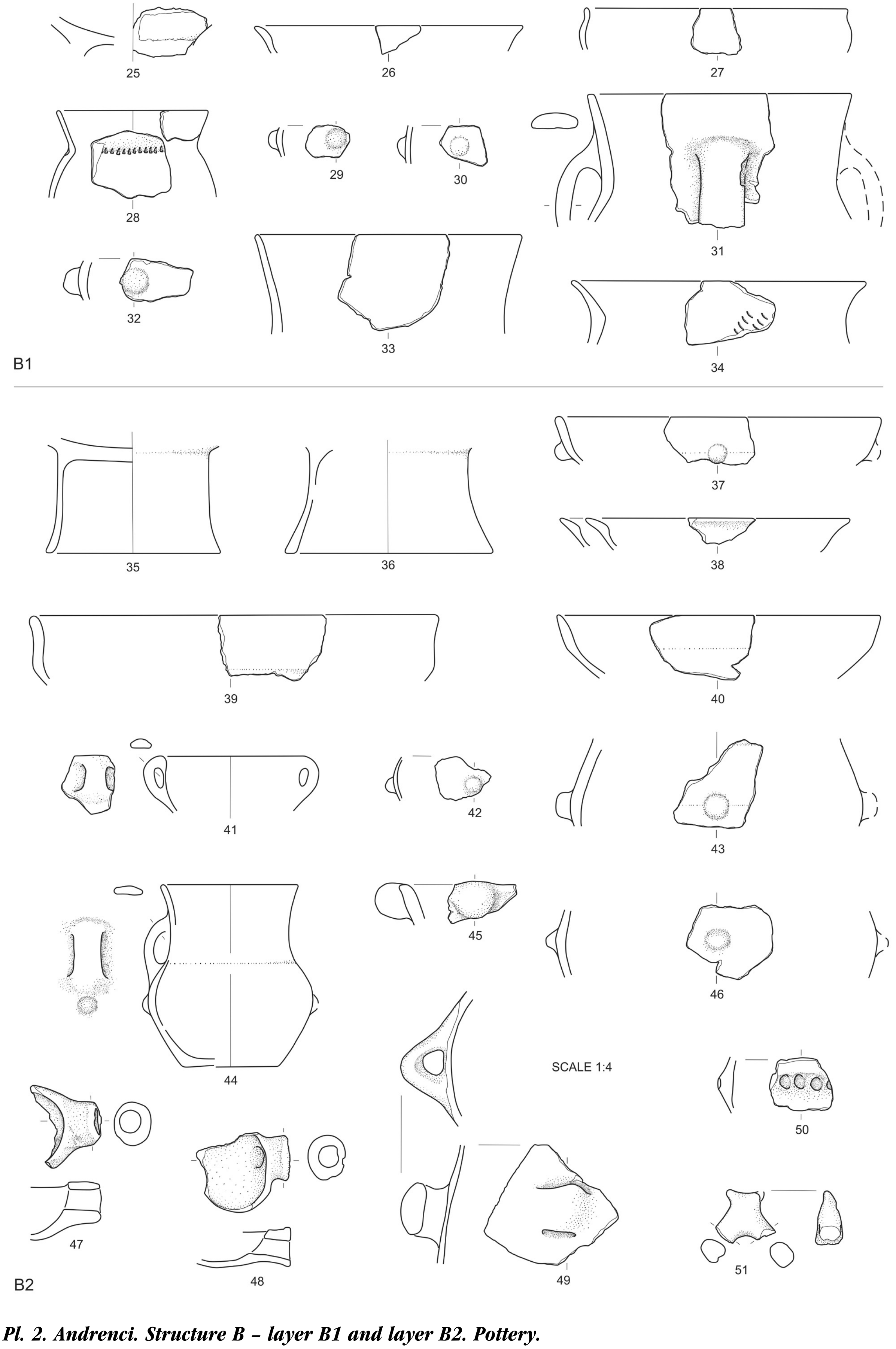
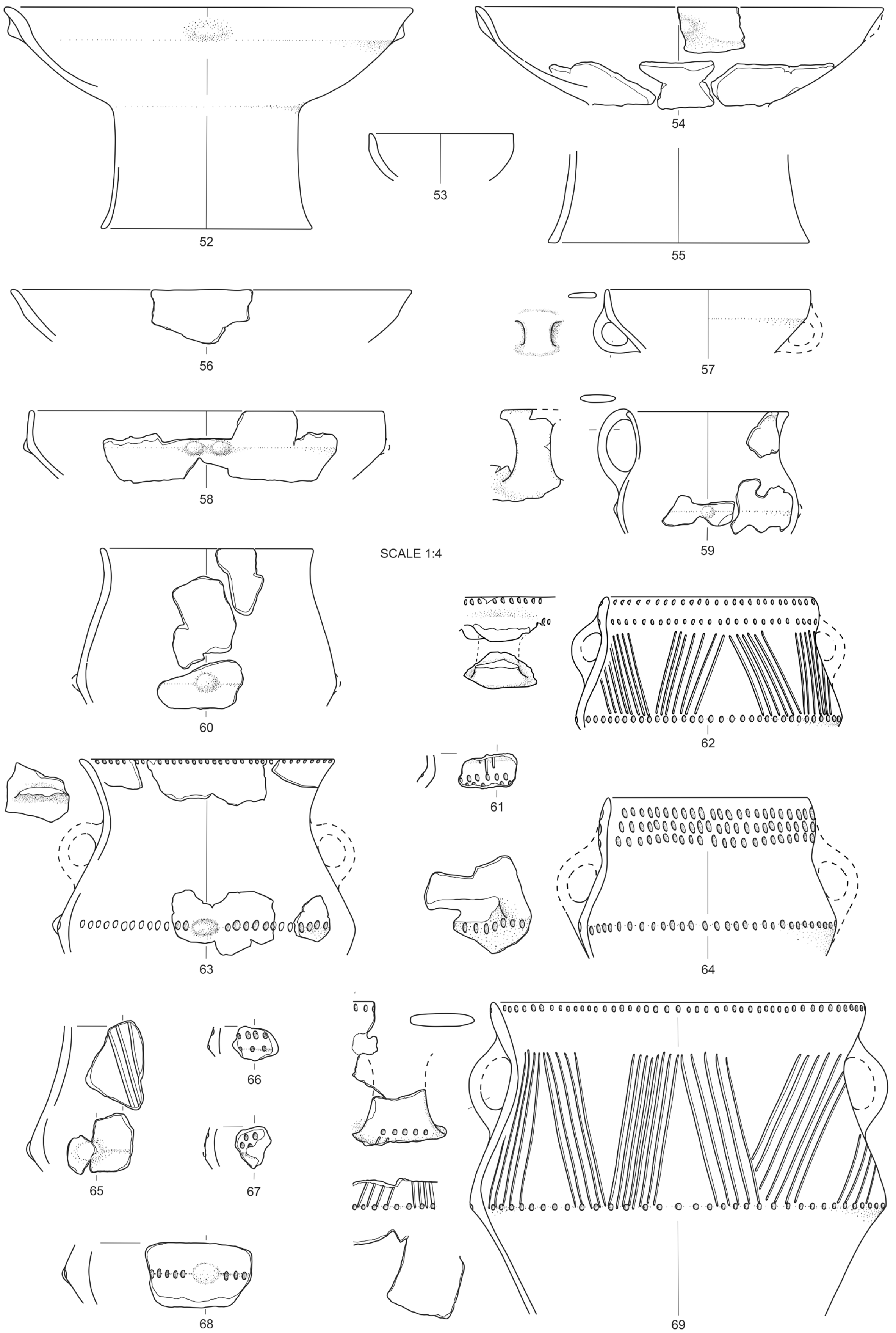


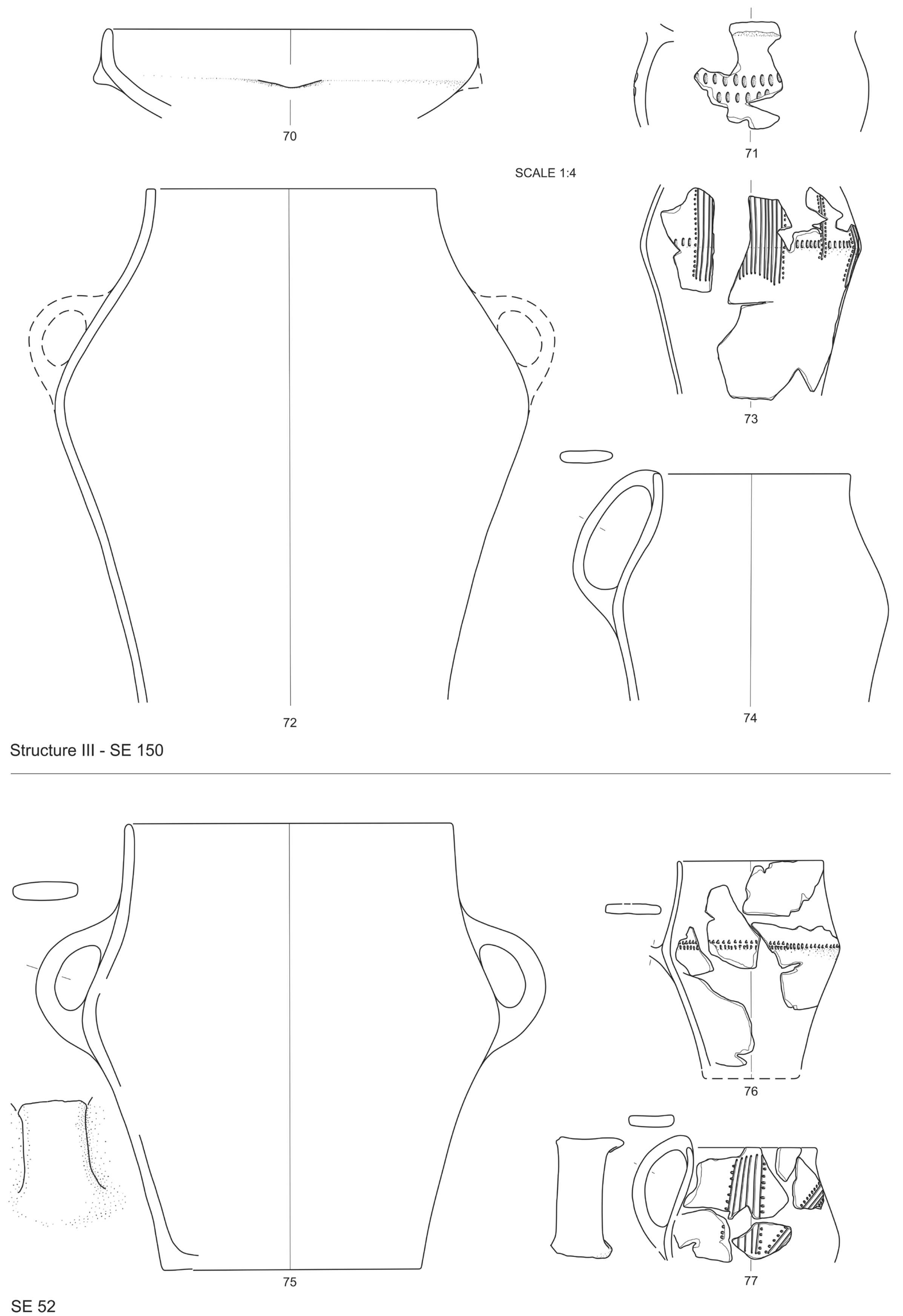
Pl. 1. Andrenci. Structure A – layer A1, layer A2 and finds from 1954–1955. Pottery.



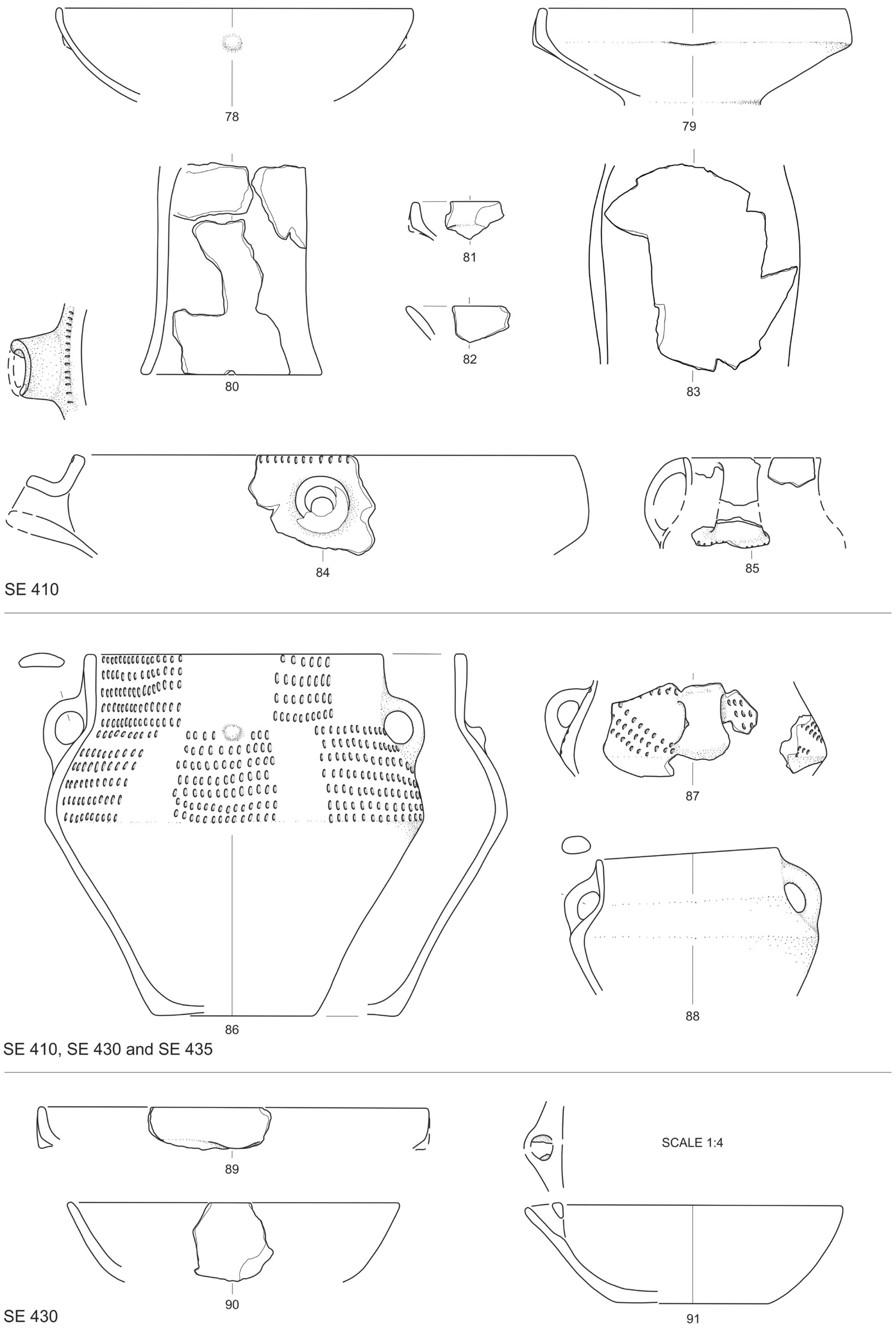
Pl. 2. Andrenci. Structure B – layer B1 and layer B2. Pottery.



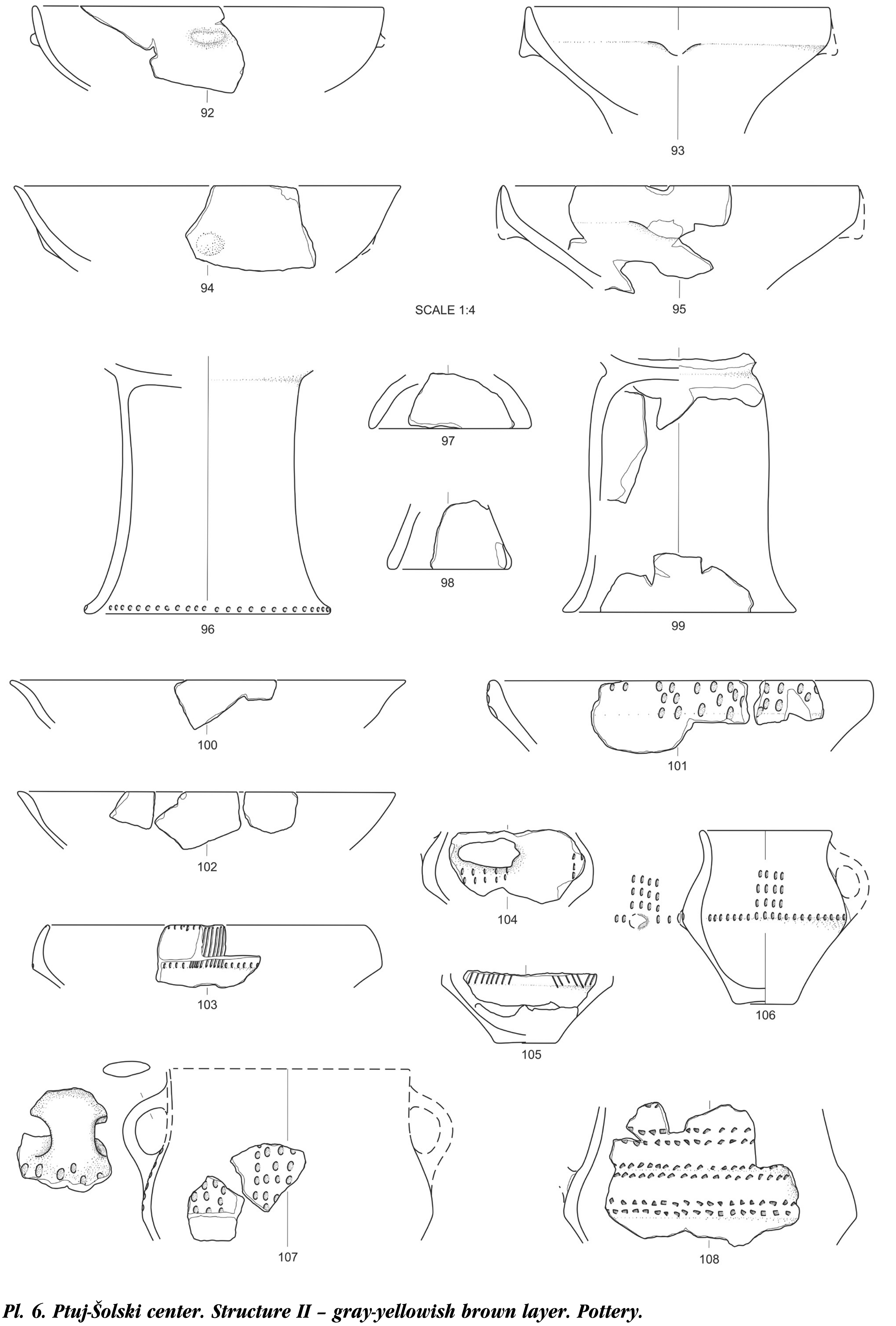
Pl. 3. Stoperce. Structure I - layer SE 128. Pottery.



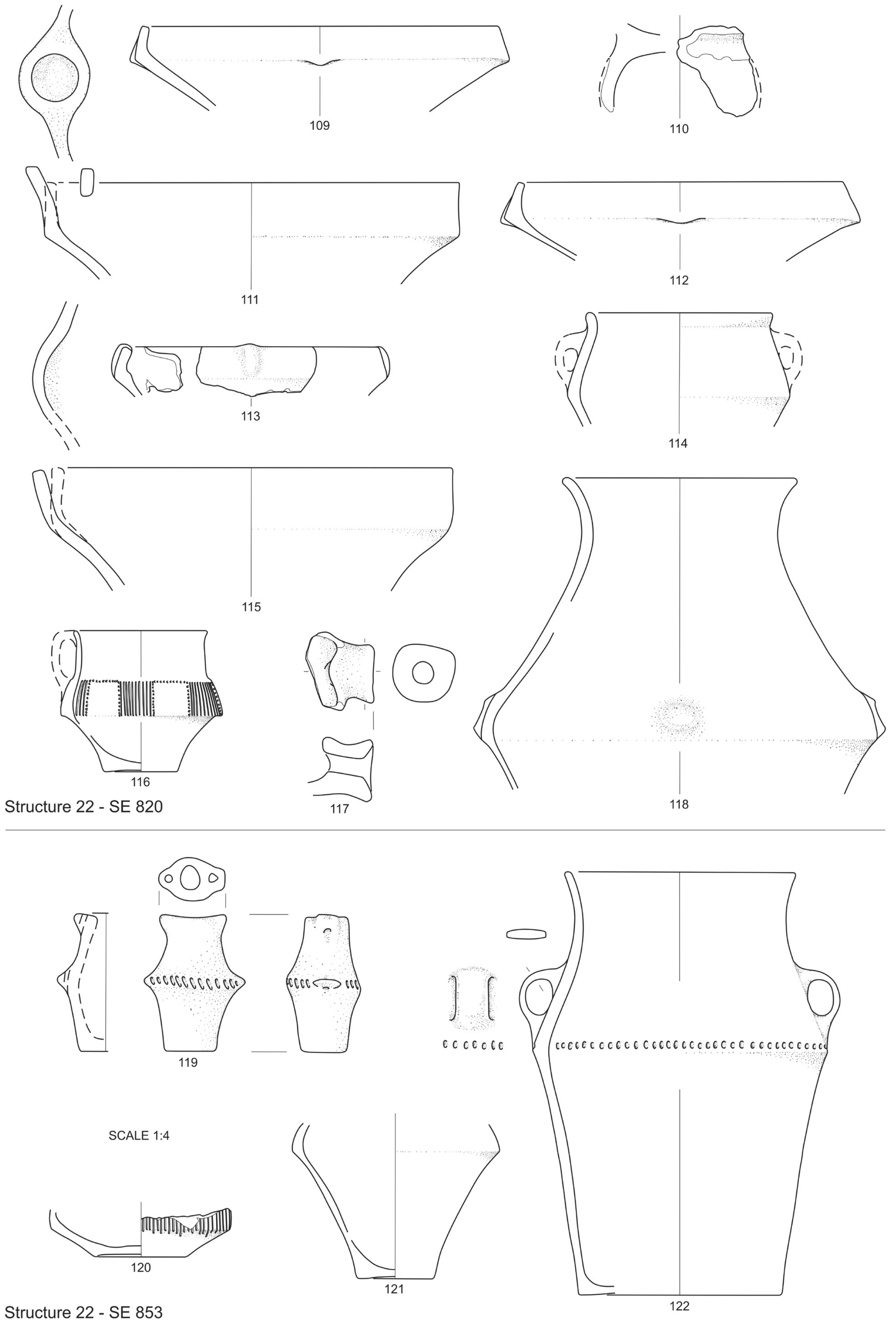
Pl. 4. Stoperce. Structure III – layer SE 150. Pit SE 52. Pottery.



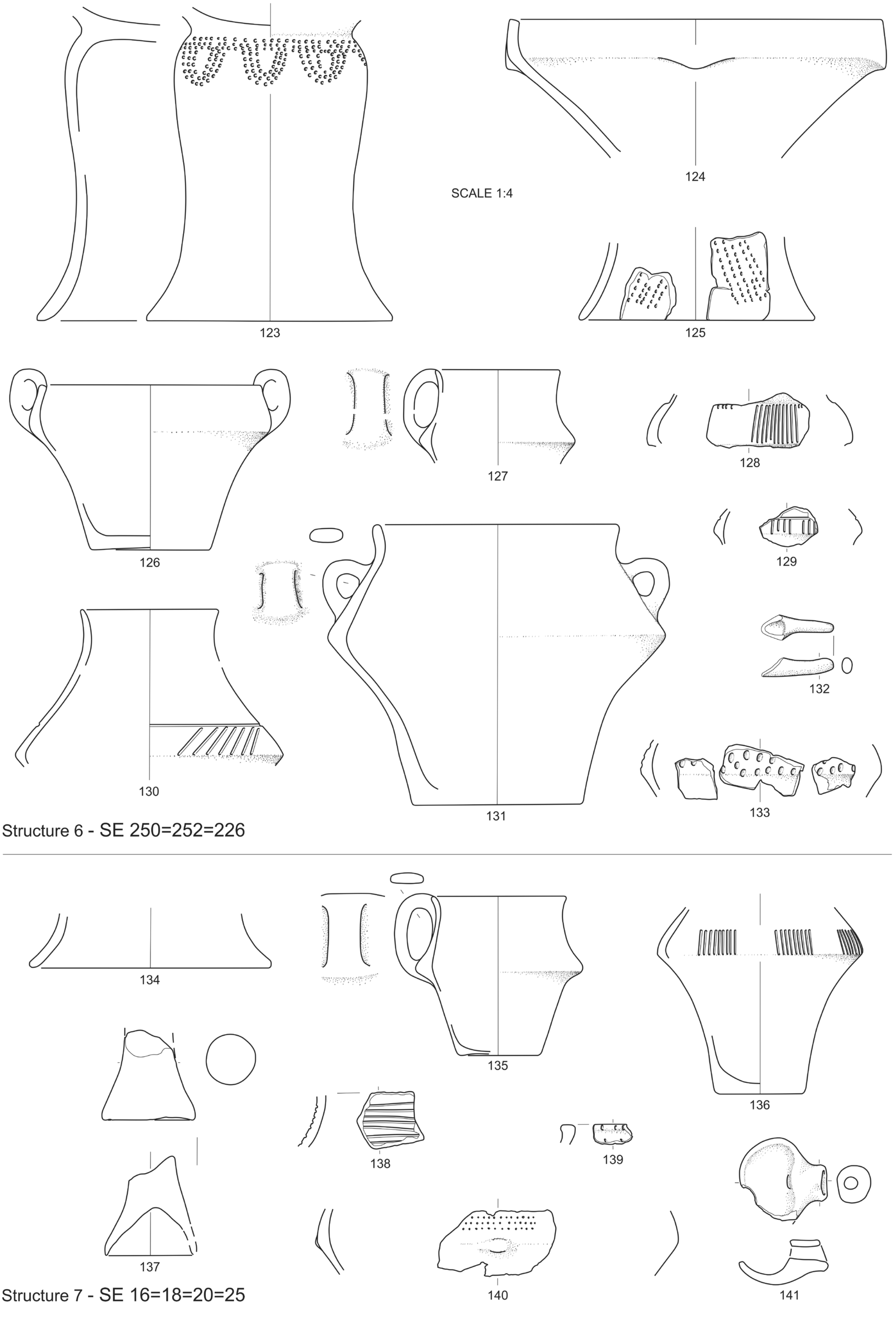
Pl. 5. Ptuj-Šolski center. Structure IV – layers SE 410, 430 and 435. Pottery.



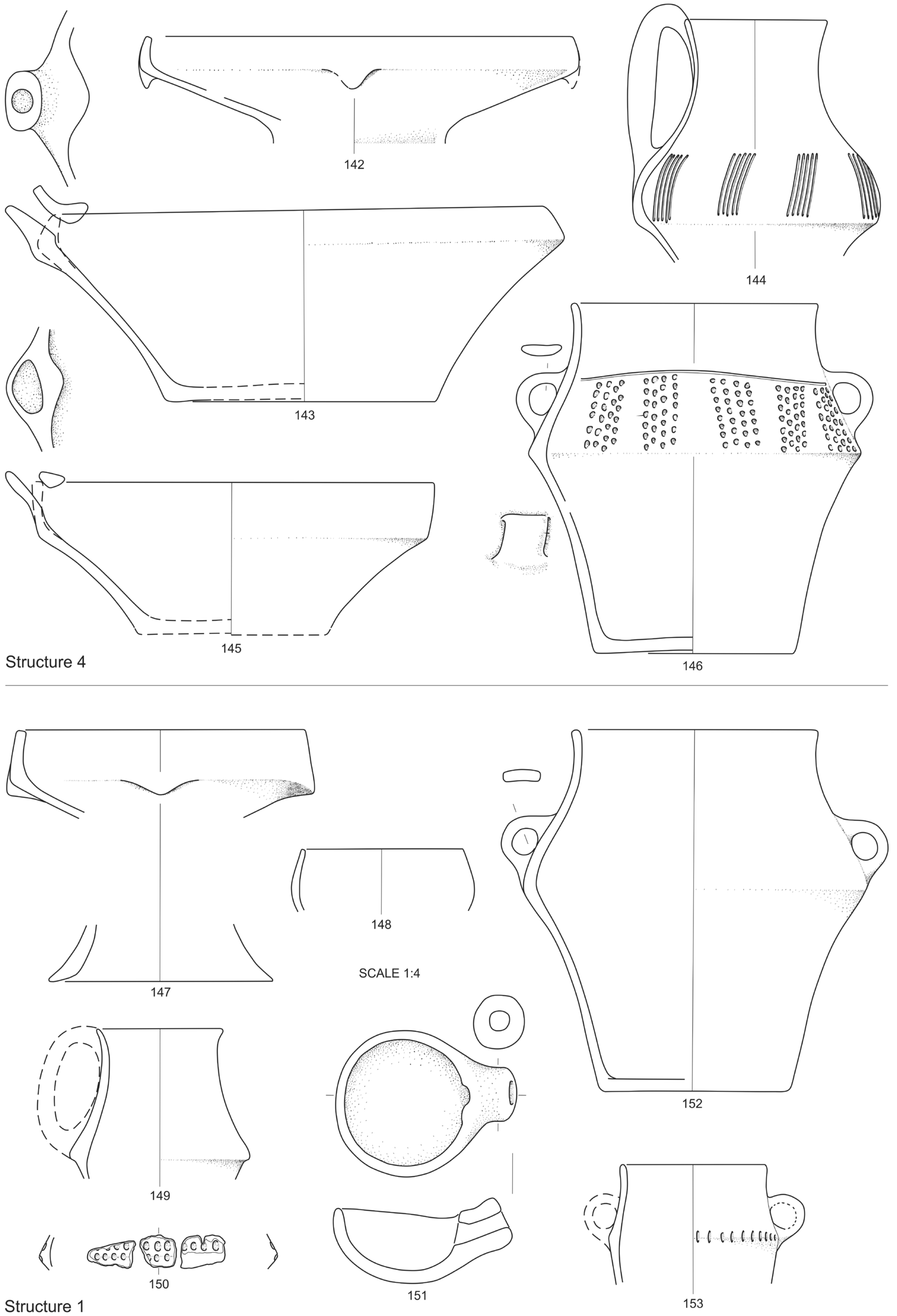
Pl. 6. Ptuj-Šolski center. Structure II – gray-yellowish brown layer. Pottery.



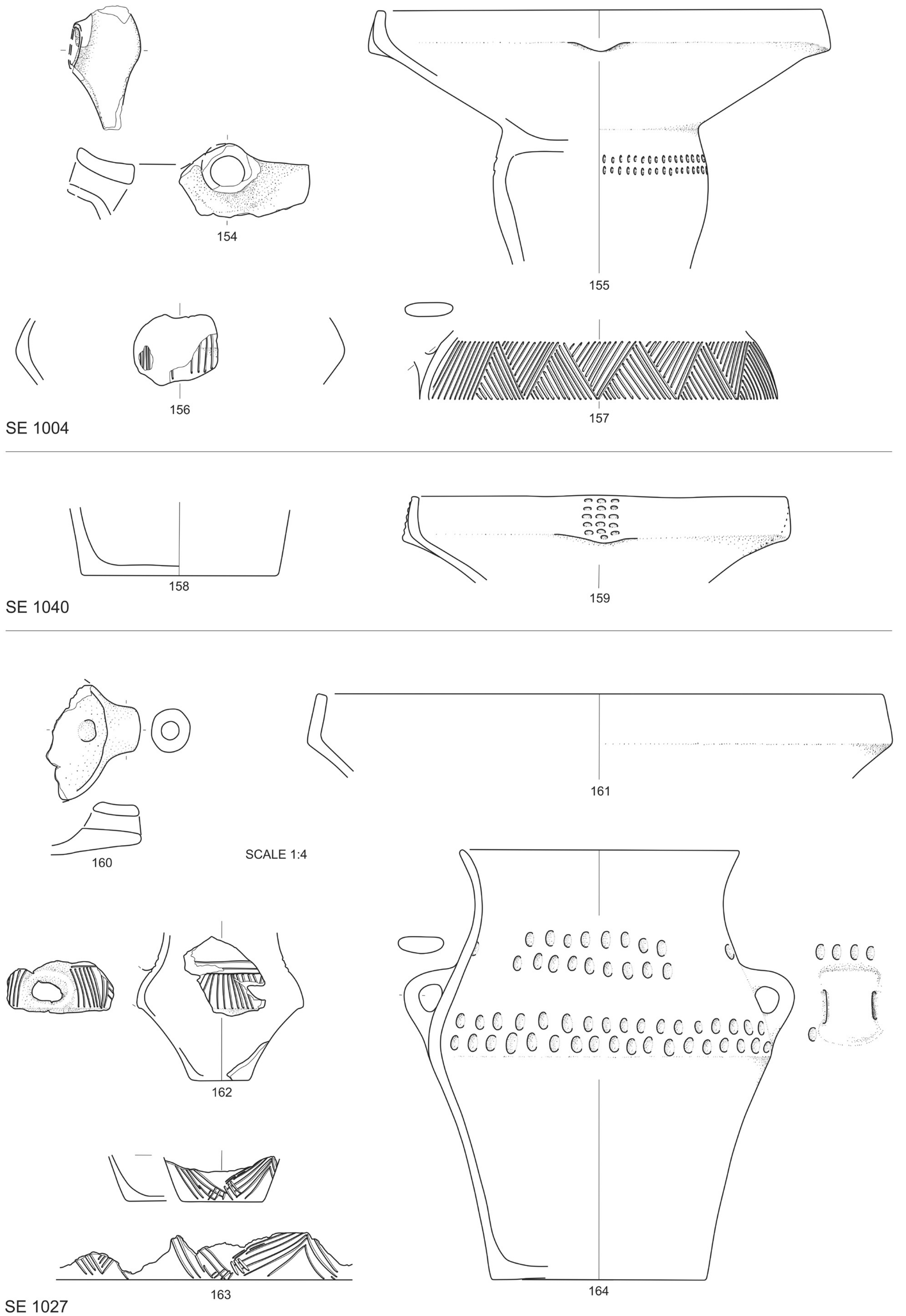
Pl. 7. Zgornje Radvanje. Structure 22 – SE 820 and SE 853. Pottery.



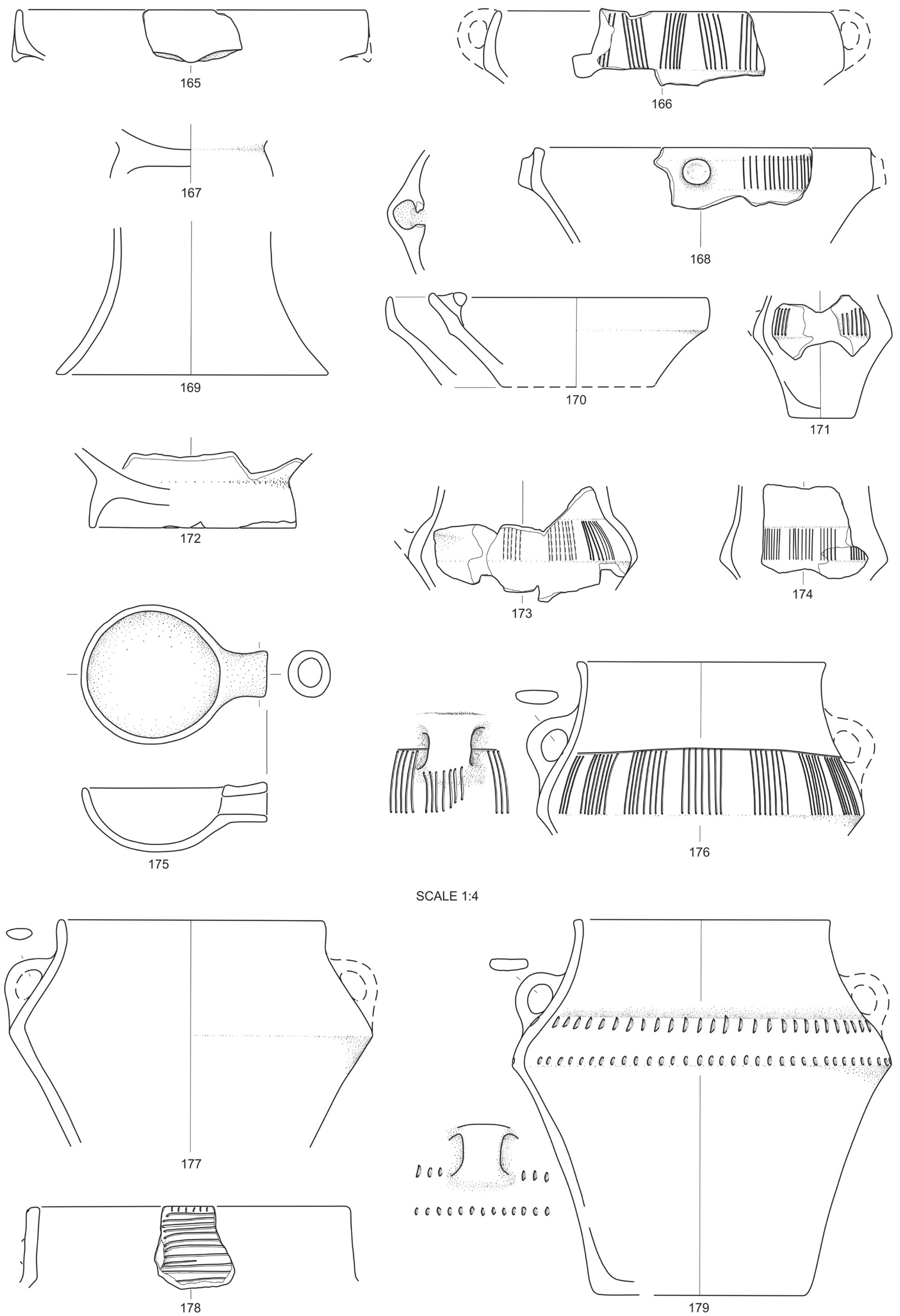
Pl. 8. Zgornje Radvanje. Structures 6 (SE 250 = 252 = 226) and 7 (SE 16 = 18 = 20 = 25). Pottery.



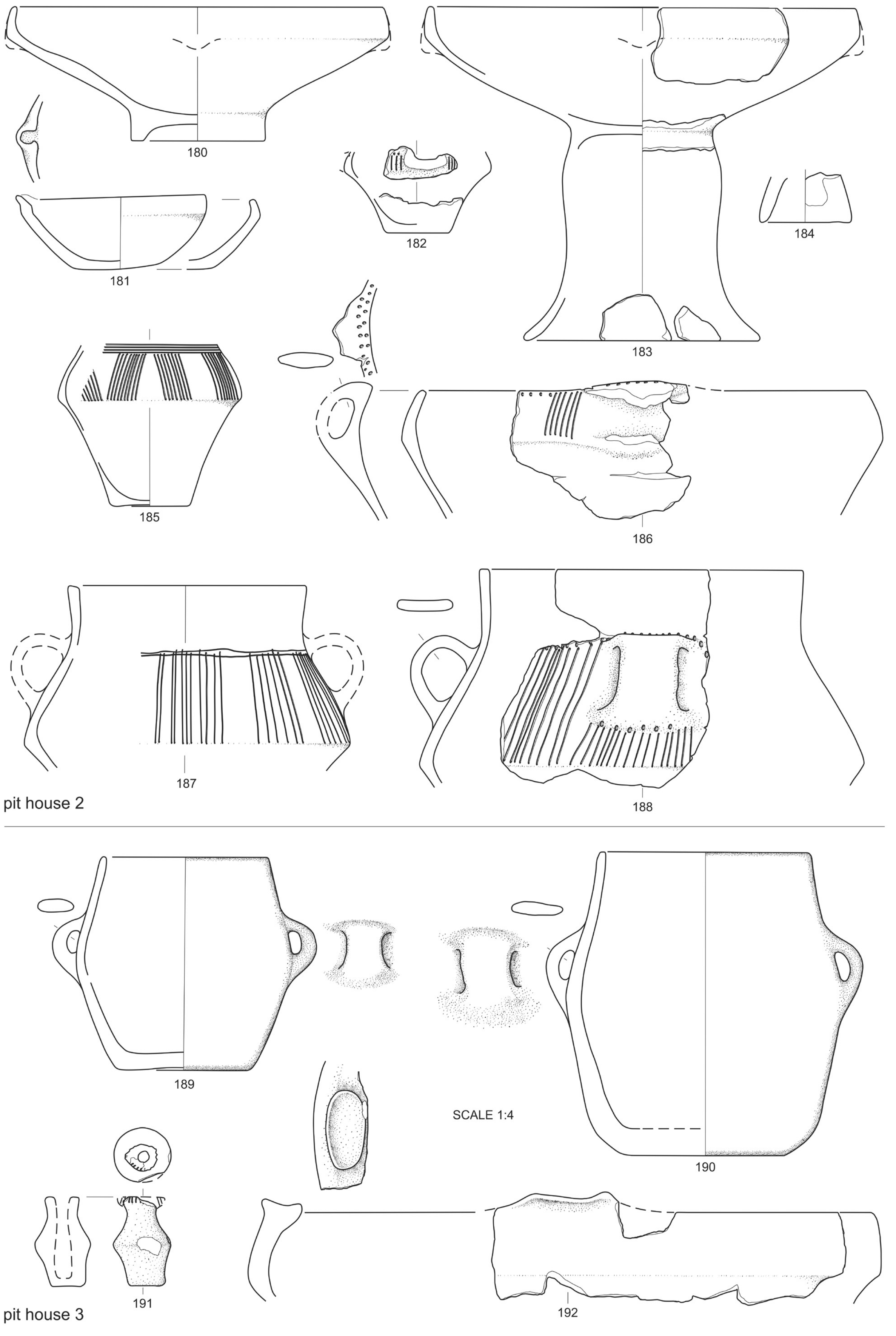
Pl. 9. Zgornje Radvanje. Structure 4 – SE 1128 (142–143, 145–146), SE 1102 (144). Structure 1 – SE 623 (147, 153), SE 625 (148), SE 599 (149–152). Pottery.



Pl. 10. Zgornje Radvanje. Structure 10 – SE 1004 (154–157), SE 1040 (158–159) and SE 1027 (160–164). Pottery.



Pl. 11. Hoče-Orglarska delavnica. Pit-house I. Pottery.



Pl. 12. Hoče-Orglarska delavnica. Pit-houses II and III. Pottery.

Appendix

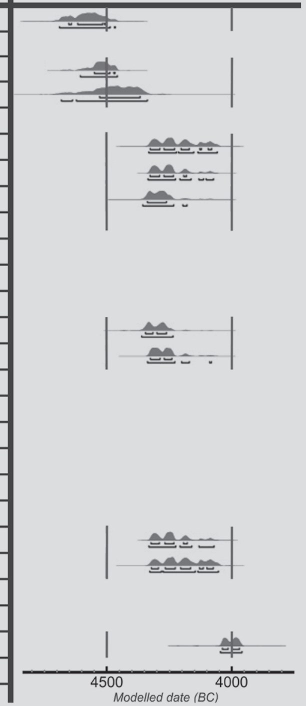
Fabric	Macroscopic description	Granularity	Quantities of different fabrics					
			AN	ST1	ŠC	RAD	H	ST2
LM01	A13;C21;E31;E21	1	1	/	/	/	/	
LM02	A13;C23;E31;E21	1	1	3	133	628	54	23
LM03	A13;C23;E31;E23	1	/	/	5	29	4	2
LM04	A21;A13;C21;E31;E21	1	31	/	/	/	/	/
LM05	A21;A13;C23;E31;E21	1	/	2	/	39	5	6
LM06	A21;A13;C31;C23;E31;E22	1	/	/	/	13	3	/
LM07	A21;A13;C32;C23;E31	1	/	1	/	24	54	2
LM08	A21;A13;C31;C22;E41;E31;E22	1	/	/	/	1	/	/
LM09	A31;A21;A13;C21;E31;E21	1	88	/	/	/	/	/
LM10	A31;A21;A13;C31;C22;E31;E21	1	/	12	112	177	20	22
LM11	A31;A21;A13;C31;C22;E31;J31	1	/	/	/	23	1	/
LM12	A31;A21;A13;C31;C22;E32;E22;J31	1	/	/	/	40	/	/
LM13	A31;A21;A13;C31;C22;E41;E32;E23	1	/	/	/	5	/	/
LM14	A31;A21;A13;C32;C23;E31	1	/	/	/	6	16	/
LM15	A41;A31;A13;C31;C22;E31;E21	1	/	1	/	6	2	7
LM16	A41;A31;A13;C21;E31;E21	1	1	/	/	/	/	/
LM17	A51;A31;A13;C31;C22;E31	2	/	/	/	1	/	/
LM18	A31;A21;B13;A13;C21;E31	2	/	/	/	/	/	1
LM19	A22;A13;C31;C22;E31;E21	2	/	7	132	55	6	/
LM20	A22;A13;C31;C22;D31;E31;E21	2	/	/	/	1	/	/
LM21	A22;A13;C31;C22;E31;E22	2	/	/	58	/	/	/
LM22	A22;A13;C31;C22;E32;E22	2	/	/	/	4	/	/
LM23	A31;A22;A13;C21;D33;E31	2	7	/	/	/	/	/
LM24	A31;A22;A13;C21;E32;E22	2	1	/	/	/	/	/
LM25	A31;A22;A13;C22;E31	2	10	/	/	/	/	/
LM26	A31;A22;A13;C31;C22;E31	2	/	/	43	50	7	5
LM27	A31;A22;A13;C31;C22;E31;E21;J31	2	/	/	/	36	/	/
LM28	A31;A22;A13;C31;C22;E31;E22;J31;J23	2	/	/	/	6	/	/
LM29	A31;A22;A13;C31;C22;E32;E22	2	/	11	/	/	/	1
LM30	A31;A22;A13;C31;C22;E32;E22;J31	2	/	5	/	29	/	/
LM31	A31;A22;A13;C32;C23;E31	2	/	1	/	71	19	1
LM32	A31;A22;A13;C32;C23;E31;J31	2	/	/	/	6	/	/
LM33	A23;A13;C22;E41;E31;E22	2	/	/	/	2	/	/
LM34	A23;A13;C31;C22;E31;E21	2	/	1	/	17	8	/
LM35	A23;A13;C32;C23;E31;E21	2	/	1	/	4	5	/
LM36	A23;A13;C31;C22;E32;E21	2	/	/	48	/	/	/
LM37	A23;A13;C31;C22;E32;E23;J21	2	/	/	/	3	/	/
LM38	A23;A13;C32;C23;E31;E21	2	/	/	/	12	1	/
LM39	A31;A23;A13;C22;E31;E22;J21	2	/	/	/	19	/	1
LM40	A31;A23;A13;C22;E41;E31;E21;J31;J21	2	/	/	/	15	/	/
LM41	A31;A23;A13;C31;C22;E21	2	/	/	1	40	/	/
LM42	A31;A23;A13;C32;C22;E31;E22;J21	2	/	/	/	/	/	1
LM43	A31;A23;C31;C22,D31;E41;E31;E23	2	/	/	/	1	/	/
LM44	A32;A21;A13;C31;C22;E21	3	/	/	/	26	/	/
LM45	A32;A21;A13;C31;C22;E31;J31;J21	3	/	/	/	15	/	/
LM46	A32;A21;A13;C32;C22;E21	3	/	/	/	11	/	/
LM47	A32;A22;A13;C21;E31	3	7	/	/	/	/	/
LM48	A32;A22;A13;C31;C22;E31	3	/	/	1	61	3	12
LM49	A32;A22;A13;C31;C22;E31;J31	3	/	/	/	6	/	/
LM50	A32;A22;A13;C31;C22;E32;E21;J31	3	/	/	/	44		/
LM51	A32;A22;A13;C31;C22;E33	3	/	/	/	/	/	4

Fabric	Macroscopic description	Granularity	Quantities of different fabrics					
			AN	ST1	ŠC	RAD	H	ST2
LM52	A32;A22;A13;C32;C23;E31	3	/	/	/	27	4	/
LM53	A32;A23;C22;E32;E21	3	/	/	10	17	1	/
LM54	A32;A23;C41;C31;C22;E32;E21	3	/	/	/	2	/	/
LM55	A32;A23;C22;E32;E21;J31;J22	3	/	/	/	2	/	3
LM56	A33;A22;C31;C22;E31	3	/	/	/	6	/	/
LM57	A33;A23;C22;E31	3	/	/	/	3	/	/
LM58	A33;A23;C22;E31;E21;J31	3	/	/	/	12	/	/
LM59	A41;A32;A22;A13;C31;C22;D31;E32	3	/	/	/	5	/	/
LM60	A42;A31;A21;A13;C31;C22;E31;E21;J31	4	/	/	/	15	/	/
LM61	A42;A31;A21;A13;C22;E31	4	/	/	/	/	/	2
LM62	A42;A31;A21;A13;C32;C22;E31	4	/	/	/	/	/	2

App. 1. Pottery fabrics and their representation in the Late Neolithic pottery assemblages at Andrenci (AN) and Stoperce 1 (ST1) and Early Eneolithic pottery assemblages at Ptuj-Šolski center (ŠC), Zgornje Radvanje (RAD), Hoče-Orglarska delavnica (H) and Stoperce (ST2). Fabric codes, firstly define type of a particular grain (A – quartz, B – calcium carbonate, C – mica, D – charred organic substance, E – iron oxides, J – undefined white grains), followed by its size (1 – <0.25mm, 2 – 0.26 to 0.50mm, 3 – 0.51 to 2.0mm, 4 – 2.01 to 3mm and 5 – >3mm), and finally their frequency (1 – <5 grains per mm², 2 – 5 to 10 grains per mm² and 3 – >10 particles per mm²).

V11	V12	V13	V10	V9	V6	V8	V7	V3	V4	V1	V2	V5	jug form / context
X													**ANDRENCI, Structure B**
	X												ANDRENCI, Structure A
		X											**STOPERCE, Structure I**
			X										**ŠOLSKI CENTER, Structure II**
				X	X	X							ŠOLSKI CENTER, Structure I
					X								**ZGORNJE RADVANJE, Structure 10 (phase 1)**
						X		X		X			**ZGORNJE RADVANJE, Structure 22**
							X	X		X			**ZGORNJE RADVANJE, Structure 4**
							X			X			ZGORNJE RADVANJE, Structure 9
							X			X			ZGORNJE RADVANJE, Structure 17
							X	X					ORGLARSKA DELAVNICA, „Pit-house II“
								X					ORGLARSKA DELAVNICA, „Pit-house I“
								X		X			**ZGORNJE RADVANJE, Structure 7**
								X					**ZGORNJE RADVANJE, Structure 5**
								X					ZGORNJE RADVANJE, Structures 11-15 (SE 786)
								X					ZGORNJE RADVANJE, Pit SE 986
								X	X				ZGORNJE RADVANJE, Pit SE 213
								X					ZGORNJE RADVANJE, Pit SE 245
								X	X				ZGORNJE RADVANJE, Structure 20
								X		X			ZGORNJE RADVANJE, Structure 3
										X			**ZGORNJE RADVANJE, Structure 1**
										X			**ZGORNJE RADVANJE, Structure 6**
										X			ZGORNJE RADVANJE, Pit SE1407=SE 1419
											X	X	STOPERCE, Pit SE 52
												X	**STOPERCE, Structure III**
												X	STOPERCE, Pit SE 45

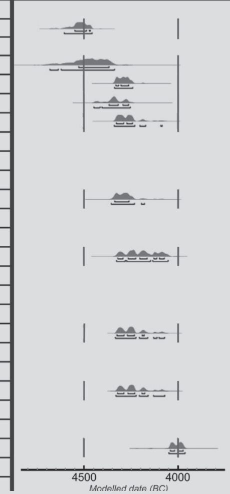
Radiocarbon dates (cal BC)



App. 2. Combination table of jugs in the studied Late Neolithic and Early Eneolithic settlement contexts. Bold letters highlight ^{14}C AMS dated contexts.

context \ pot form	L24/1	L23/1	L13/3	L7/1	L14/2	L15/1, 2	L20/1	L25/1	L10/5	L12/1	L12/2	L12/3	L12/4	L12/5	L5	L4	L13/1, 2	L1/1	L22	L11/4	L11/2	L2/1
ANDRENCI, Structure A	X	X																				
STOPERCE, Structure I			X	X	X	X																
ŠOLSKI CENTER, Structure I						X	X			X				X								
ŠOLSKI CENTER, Structure II									X	X					X							
ŠOLSKI CENTER, Structure IV								X	X	X	X				X							
RADVANJE-HABAKUK 2, Structure 1 (SE 214)																			X			
ZGORNJE RADVANJE, Structure 5									X	X	X	X			X	X		X				
ZGORNJE RADVANJE, Structure 20											X	X	X		X	X	X					
ORGLARSKA DELAVNICA, „Pit-house II“												X	X			X						
ZGORNJE RADVANJE, Structure 2														X		X			X			
ZGORNJE RADVANJE, Structure 4														X		X		X				
ZGORNJE RADVANJE, Structure 11-15 (SE 786)														X	X	X	X	X				
ORGLARSKA DELAVNICA, „Pit-house I“														X	X	X						
ZGORNJE RADVANJE, Structure 6														X								
ZGORNJE RADVANJE, Structure 3															X	X	X					
RADVANJE-HABAKUK 2, Pit 10 (SE 221)																X						
RADVANJE-HABAKUK 2, Pit 13 (SE 219)																X						
ZGORNJE RADVANJE, Structure 22																X	X	X				
ZGORNJE RADVANJE, Structure 17																X	X					
ZGORNJE RADVANJE, Structure 9																X				X		
ZGORNJE RADVANJE, Structure 1																X						
ORGLARSKA DELAVNICA, „Pit house III“																			X			
ZGORNJE RADVANJE, Structure 19																		X	X			
STOPERCE, Structure III																			X		X	
STOPERCE, Pit SE 52																			X	X		X

Radiocarbon dates (cal BC)



App. 3. Combination table of pots in the studied Late Neolithic and Early Eneolithic settlement contexts. Bold letters highlight ^{14}C AMS dated contexts.

A hoard of astragals discovered in the Copper Age settlement at Iepureşti, Giurgiu County, Romania

Raluca Kogălniceanu [1], Ana Ilie [2], Monica Mărgărit [3], Angela Simalcsik [4] and Valentin Dumitraşcu [5]

1 "Teohari Antonescu" County Museum, Giurgiu, RO
raluca.kogalniceanu@gmail.com
2 "Princiary Court" Museum Complex, Târgovişte, RO; ana_arheo@yahoo.com
3 Valahia University, Târgovişte, RO; monicamargarit@yahoo.com
4 Centre of Anthropology, Romanian Academy – Iaşi branch, RO; angellisimal@yahoo.com
5 "Vasile Pârvan" Institute of Archaeology, Bucharest, RO; validumitrascu@yahoo.com

ABSTRACT – *This article presents the discovery of 25 abraded and perforated ovicaprid astragals in a burned house at the Gumelniţa Copper Age settlement at Iepureşti in Southern Romania. They were analysed in terms of their processing, of the taphonomic processes that affected them (burning), and of their spatial distribution. These astragals were also analysed in the wider context of more or less similar discoveries made mainly south and east of the Carpathian Mountains, in Romania, but also south of the Danube, in Bulgaria.*

IZVLEČEK – *V članku predstavljamo odkritje 25 odrgnjenih in preluknjanih gležnjic/astragalov ovce/koze v požgani hiši na bakrenodobni naselbini kulture Gumelnita pri kraju Lepuresti v južni Romuniji. Preučili smo obdelavo, tafonomske procese (žganje) in prostorsko razporeditev teh najdb. Gležnjice/astragale smo preučevali tudi v širšem kontekstu bolj ali manj podobnih najdb, ki so jih izdelovali v glavnem južno in vzhodno od Karpatov v Romuniji, a tudi južno od Donave v Bolgariji.*

KEY WORDS – *abraded and perforated astragals; Copper Age; Gumelniţa settlement; spatial analysis; contextual analysis*

Introduction

The Iepureşti site is located in Southern Romania, approx. 30km southwest of Bucharest, between the villages of Stâlpu and Iepureşti, Giurgiu County, at an altitude of approx. 65m (altimetric reference system – Baltic Sea) (Fig. 1). It is located on the middle course of the Neajlov River, on its flood plain. Today, the river flows approx. 500m north of the site, but is very active, changing its course every three or four years (*Ilie 2011.38*). It is quite possible that the site was located on its banks in the past (*Morintz 2011*).

The archaeological investigations at this site began in 2007 and continued each year, expanding outside the site, in its immediate surroundings (*Schuster* et al. *2009; 2010; 2011; 2012; Markussen, Vornicu 2011; Kogălniceanu* et al. *2012*). Four sections (4 x 4m) were opened on the northern margin of the site in order to establish the stratigraphy. The research was extended into the meadow with a trench of 11 x 1.5m in order to identify a possible defense system. The 2 x 1m test pits around the site following magnetic surveys were aimed at understanding the use of space outside the settlement.

Although the investigations in the four sections mentioned above have not been completed, we can assert that the site is the result of prehistoric human activities. The first layer (the most important in terms of the archaeological features investigated: houses, debris areas, *etc.*) is attributed to the Gumelniţa – Kodjadermen – Karanovo VI cultural complex

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(hereafter: G-K-KVI). The second layer was represented by a series of pits, attributed to the Early Bronze Age Glina culture.

The G-K-KVI cultural complex is known for tell settlements with several layers of habitation and was important for the production and circulation of large copper and gold artefacts. Chronologically, it evolved between 4600 and 3900 calBC (*Bem 2001b; Reingruber, Thissen 2009; Brehard, Bălăşescu 2012. 3169*). Although, based on pottery styles, the existence of regional expects and internal modifications is accepted (three evolution phases have been distinguished), much is still unknown about the social and territorial organisation of these communities due to the state of field research and published results.

The site is located on a levee and has the appearance of a small mound (Fig. 2), a characteristic common to a large number of G-K-KVI sites on the Găvanu-Burdea Plain considered to be tell settlements (*Andreescu, Mirea 2008; Bem* et al. *2001; Ilie 2011*). In spite of this, the stratigraphy of this site is different from that of the tells located along the Danube (Olteniţa, Căscioarele, Pietrele, Ruse, Hârşova, Borduşani) which are characterised by important depositions that vary between 3–12m of the habitation layers, and also from that of the tells on the Găvanu-Burdea Plain. The ongoing research at the G-K-KVI sites in the Bucşani and Vităneşti-Lăceni micro areas (*Haită 2001a; 2001b*) suggests a different type of behaviour, the sites being formed by multiple settlements in the same place interposed by alluvial levels which mark periods of abandonment.

In this context, the excavations at Iepureşti diversify the image of this period concerning the habitation types of Gumelniţa communities on this plain north of the Danube. The discovery in the last four years of excavation (2010–2013) of 25 astragals (see Tab. 1 and Figs. 3–4) in the G-K-KVI layer must be regarded as diversifying our understanding of social organisation, both through the type of site and through the types of artefacts specific to certain types of site. The finds come from at least 13 individuals of *Ovis aries* or *Capra hircus* and underwent modifications consisting of drilling, abrading and burning.

Morphology and modifications of the finds

The astragal is a short, compact bone located in the ankle joint. The family *Bovidae* (including sheep and goat) has a distinctive astragal with a double-pulley at the extremities and four distinct facets. It

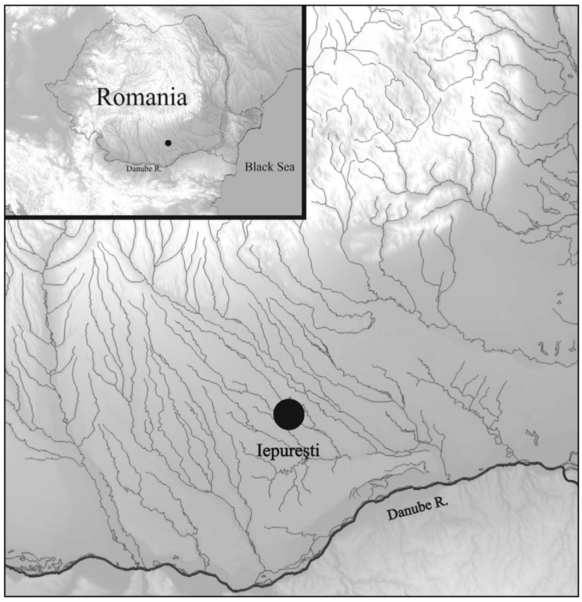

Fig. 1. Location of the site.

has a characteristic shape (cube-like) with four sides and a depression on the dorsal surface (Fig. 5). The astragal ossifies relatively early in the maturation process, making it difficult to distinguish between sub-adult and adult animals. The only indicator of age is the porosity of the bone surface observable in very young individuals (*Reitz, Wing 2008*).

The 25 sheep/goat astragals, complete (17) or fragmentary (8), are extremely burned (Fig. 6a, e, i), and vary in colour, from black to white, except for two examples (Tab. 2). In order to modify the anatomical morphology, the astragals were abraded on the four sides, which helped to reduce the protuberances specific to this type of bone, which finally gave the pieces an approximately rectangular form (Fig. 6b, d, g, h, j, l). A perforation was made in the centre by boring alternately from each side. The dimensions are uniform, being determined both by the selection of a single species, and by the similar processing technique (see Tab. 2).

At the beginning of our analysis, we started, *a priόri*, from several assumptions concerning the technique used to make these pieces. These suppositions were later confirmed or disproved by microscopic study. The plantar side of all the examples was abraded, acquiring a perfectly flat aspect, unlike the dorsal, lateral and medial sides, whose morphology was modified to varying degrees. The abrasion scratches are oblique to the axis of the piece and parallel with each other, but are hard to detect even at a magnification of 200x due to the deterioration of the surface caused by burning. We supposed that the

Fig. 2. Aerial image of the site (image from ANCPI).

rectilinear edges might have been created through previous processing (*e.g.*, cutting by sawing) but we have not been able to identify any marks of this nature. Our conclusion is that they were transformed exclusively through an abrasive action of linear friction.

Other observations were formulated regarding the central perforations made, with just one exception, at the level of the depression on the dorsal side. It is not by chance that this area was used, as it is the thinnest surface and therefore the surface easiest to perforate. We could have supposed that these pieces were elements destined to be attached to something, and that the abrasion was made at the same time as the perforation to eventually create an ornament. Yet, as a second hypothesis, we also considered a function in two stages, *i.e.* the piece might have been used as a polisher in an abrading action on a highly abrasive surface (ceramics, perhaps), using a new side as the different faces were worn out, until their final exhaustion (until the piece could not be held for abrading). During a second stage, the piece might have been perforated and converted into a bead, part of a necklace. Yet again, an examination by microscope showed that the abrasion followed the perforation, as it had destroyed its edges, and also that the pieces were suspended for a long time on a thread, as the scratches from the perforation process have been preserved in only a few cases (Fig. 6c, f, k). The conclusion is that, regardless of the function they had, the items were perforated at the beginning of the process of technological transformation.

Concerning the burning of the astragals, the criteria used for analysis were as follows:

- the colour of the exterior surface of the bone;
- the pattern of cracking of the external bone;
- the presence/absence of warping.

A general observation is that the astragals were burned in a dry state, and that the burning was uneven. The analysed pieces are not deformed or contracted; there are no fissures deep in the bone; they are not white-coated, and the colour inside the bone is yellow-brownish.

The bone wall displays a variety of colours (according to the RGB scale), varying from dark brown

No.	Piece no.	Year of discovery	Section	Square	Depth (m) (in relation to a 'o' point)	Side
1	373	2010	S2	C3	−1.13	R
2	396	2010	S2	C3	−1.01	L
3	404	2010	S2	B4	−1.18	R
4	408	2010	S2	A–D/3–4	−0.90 −1.10	R
5	422	2011	S2	B4	−0.96	L
6	423	2011	S2	B4	−0.96	L
7	424	2011	S2	B4	−0.96	L
8	425	2011	S2	B4	−0.96	R
9	428	2011	S2	C4	−0.98	L
10	430	2011	S2	B3	−1.08	L
11	431	2011	S2	B4	−1.07	R
12	432	2011	S2	B4	−1.18	R
13	433	2011	S2	C4	−1.18	R
14	437	2011	S2	B3	−1.03	L
15	439	2011	S2	B4	−1.09	R
16	441	2011	S2	B4	−1.09	L
17	486	2011	S2	B4	−1.19	R
18	489	2011	S2	B4	−1.19	L
19	490	2011	S2	C4	−1.17	L
20	560	2011	S2	A–D/3–4	–	R
21	562	2012	S2	A–D/3–4	–	L
22	638	2012	S2	C3	−1.26	L
23	690	2012	S2	C4	−1.29	R
24	751	2013	S2	A4	−1.47	L
25	753	2013	S2	A4	−1.48	R

Tab. 1. List of discovered astragals, indicating the year of discovery, the location within the excavation, the depth and whether they were left or right side.

(200°C) through black (300°C) and grey-brown (400°C) to light brown (500°C), dark grey (600°C) and light grey (700°C). In two cases a temperature of 800°C (dark beige) and even 900°C (light beige) were reached (these values are on the threshold of calcination). In conclusion, the burning temperature can be ascribed to an interval between 200°C and 700°C (*Walker* et al. *2008*). In ten cases, the temperature did not exceed 400–500°C (nos. 373, 396, 404, 431, 433, 437, 489, 490, 562, and 690) (Fig. 7a). In another eleven cases (nos. 422, 423, 424, 425, 428, 430, 432, 439, 441, 486, and 560), the temperature reached 600–700°C (Fig. 7b). The bone wall indicates higher temperatures, of 800–900°C, in two cases (nos. 638 and 408), where the presence of whitish areas indicates temperatures close to those required for calcination (Fig. 7c).

There is one additional observation concerning astragal no. 408. This fragment, unlike the others, seems to have undergone uniform burning. It appears white-coated, meaning that there is a whitewash layer of

Fig. 3. Image of astragals **in situ.**

approx. 1mm that 'coats' the rest of the dark-coloured bone tissue. In addition, the external surface is dotted with quite deep fissures that form a network. All these traits are characteristic of burning of fleshed or recently de-fleshed remains ('green' bones). Nonetheless, we remain reserved concerning the

Fig. 4. All 25 astragals found in Section 2.

state of bone at the time of burning because there is only half of it present in the sample.

Cracks were recorded in nine out of 25 astragals (nos. 373, 408, 422, 424, 437, 490, 560, 638, and 690). The pattern of cracks is not uniform (as it usually is on long bones), but appears as a network (similar to the patterns that would appear on cranial vault bones). With the exception of astragal no. 408, which has both surface and profound cracks (Fig. 8a), in all the other cases the cracks are superficial (Fig. 8b), *i.e.* they extend for a maximum of 1mm into the bone tissue (although they are visible to the naked eye). Only two astragals (nos. 751 and 753) of the 25 appear to be unburned. In these two cases, the colour of the external bone wall is not typical of unburned (animal or human) bone: while bone that is not touched by flames would generally be reddish or reddish-beige, the astragals nos. 751 and 753 are greyish-beige (Fig. 9). It is possible that these astragals were close to a heat source, but were not been touched directly by the flames.

Context of discovery

Due to the location of the site in the flood plain of the Neajlov River, the archaeological layers underwent significant pedogenetic degradation, which makes the reading of traces of Chalcolithic human activity difficult. The 23 burned astragals, as well as the two unburned ones, were not found in a vessel or assembled in a more restricted area, but dispersed over an area of $2.5m^2$, and at different depths. We tried to analyse the characteristics of their dispersal and to answer several other questions to determine if they were part of a hoard.

	Abrasion				Perforation		Morphometry				
Piece no.	Dorsal side	Plantar side	Lateral side	Medial side	Depression on dorsal side	Another location	Length (mm)	Medium width (mm)	Medium thickness (mm)	Perforation diameter (mm)	Observations
373	x	x	x	x	x		23	14	8	5	Complete, burned
396	x	x	x	x	x			indet.			Fractured, burned
404	x	x	x	x	x		27	16	9	5	Fractured obliquely, burned
408	x	x	x	x	x			indet.			Fragment, burned
422	x	x	x	x		x	25	13	7	4	Complete, burned
423	x	x	x	x	x		26	14	8	5	Complete, burned
424	x	x	x	x	x		–	15	9	5	Fractured, burned
425	–	–	–	–	–			indet.			Two small fragments, burned
428	x	x	x	x	x		25	15	8	5	Complete, burned
430	x	x	x	x	x		27	16	7	4	Complete, burned
431	x	x	x	x	x		24	14	9	4	Complete, burned
432	x	x	x	x	x		26	16	9	4	Complete, burned
433	x	x	x	x	x		25	17	11	4	Complete, burned
437	x	x	x	x	x		25	17	9	4	Complete, burned
439	x	x	x	x	x		28	14	8	4	Complete, burned
441	x	x	x	x	x		29	19	9	5	Complete, burned
486	x	x	x	x	x		26	15	7	5	Complete, burned
489	x	x	x	x	x		24	15	8	4	Complete, burned
490	x	x	x	x	x		27	16	6	4	Complete, burned
560	x	x	x	x	x		26	15	9	5	Complete, burned
638	x	x	x	x	x		35	16	11	4	Slightly fractured, burned
690	x	x	x	x	x		–	16	7	–	Fractured, burned
562	x	x	x	x	x		–	15	8	–	Fractured, burned
751	x	x	x	x	x		25	16	7	4	Complete, unburned
753	x	x		x	x		25	16	10	3.5	Complete, unburned

Tab. 2. List of morphometric data and modifications suffered by the astragals.

In the eastern part of section S2 (Fig. 10), although the archaeological deposits have not yet been excavated completely, two overlapping G-K-KVI features have been identified and investigated: a burned house (H4) and an area of debris beneath it.

The H4 house was investigated over an area of approx. 4m². In the field, it was identified based on the density of burned wattle and daub pieces that pigmented the area, although the dimensions of these pieces were not usually greater than 2–4cm. A series of vessels was found at the top of this burned and greatly degraded wattle and daub area. Based on these, the house was culturally attributed to the G-K-KVI complex. Two Early Bronze Age pits (Pit 1 and 2) had disturbed the investigated surface of the house (Fig. 17).

The thickness of the destruction of the house was approx. 15–20cm (Fig. 11). A layer characterised by an impressive quantity of pottery fragments, animal bones and even wattle and daub pieces was identified beneath it, at the same location, and starting at a depth of –1.25/–1.30m in the uphill grid squares (B–D) and –1.35/–1.40m in the downhill grid square (A). We considered this as representing a debris area. The two unburned astragals were found in this feature.

One question is to which feature the 23 burned astragals can be attributed: to the burned house or the debris area below it (taking into consideration the fact that there are no technological differences between the burned and unburned pieces)?

The burned astragals found in 2010 were discovered immediately below the burned vessels found in the

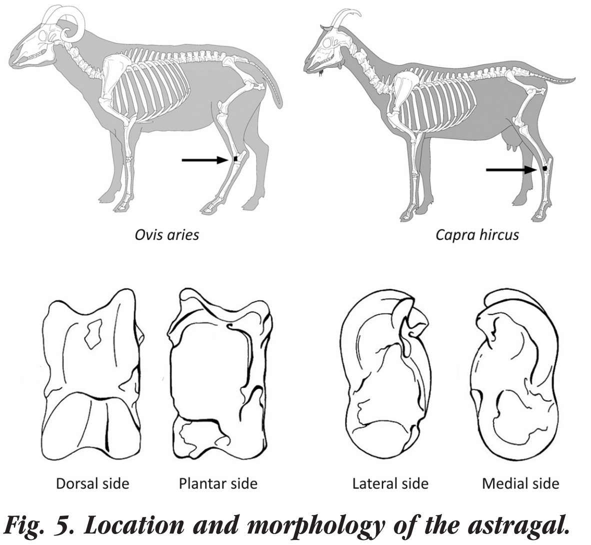

Fig. 5. Location and morphology of the astragal.

upper part of the burned wattle and daub layer of the house H4. The burned astragals discovered in 2011 and 2012 were found either in the reddish level interpreted as the last remains of house H4, and also below it, at the interface with the layer interpreted as the debris area. As a final remark on this subject, it can be said that most of the finds were located between –0.95m and –1.20m (Fig. 12).

Analysis of the astragals' spatial distribution and context of discovery

As the astragals were not found in a vessel or concentrated in a more restricted area, but were found dispersed over a 2.5m² area, we tried to analyse the characteristics of their dispersal, and to answer several other questions in order to determine if they are part of a hoard or not.

How similar are the pieces in terms of shape, size, and how were they modified?

From a technological perspective, all the astragals underwent the same treatment. All of them were perforated through the centre, followed by a flattening of the surface through abrasion (resulting in a rectangular section). The uniformity in terms of shape and size also derives from the source of the bones being *Ovis aries* or *Capra hircus* only. We believe that these choices in terms of technology and species are not random, and that the desired outcome was a unified ensemble, with a strong visual impact, and that they were probably kept together.

While the first two types of modification (drilling and abrasion) were intentional (at least the drilling), their burning was, we think, accidental. An argument to support this assertion is the variations in colour among the pieces and even on single pieces.

What does their spatial distribution tell us?

We looked at their spatial distribution both vertically and horizontally. From the point of view of the depth at which the astragals were discovered, we immediately noticed two anomalies (see Tab. 1; Fig. 12). Before anything else, we should draw attention to the fact that the research area lies on a slight slope from south to north, and in Section 2 the difference between the southern part (grid squares D) and the northern part (grid squares A) is approx. 0.25m.

Although the depth mostly increased over the four years of excavations, the altitude data for the first year has bigger values than expected. This might be

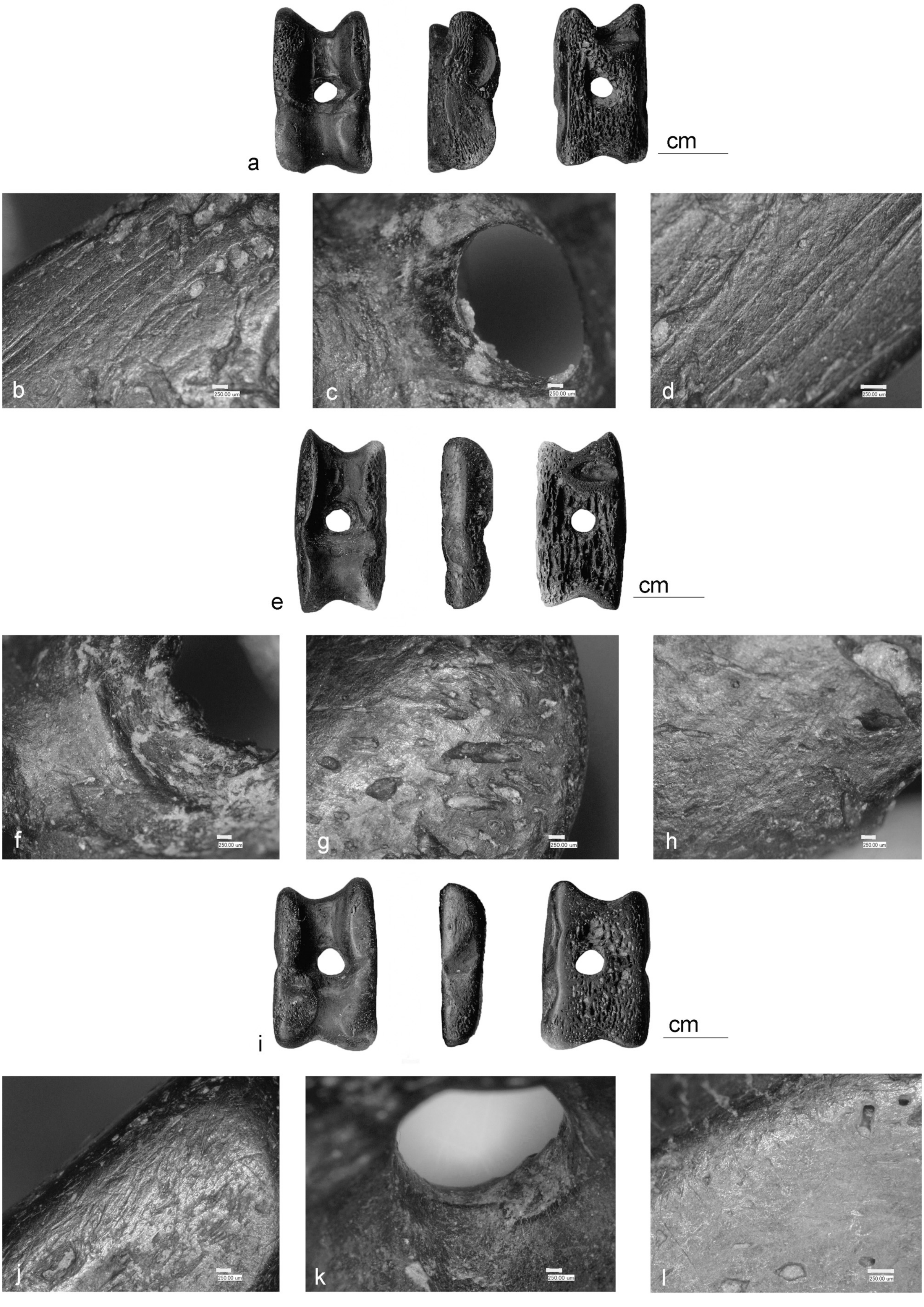

Fig. 6. a, e, i – abraded and perforated astragals from the Iepureşti settlement; b, d, g, h, j, l – details of the abraded surface (magnification: 50x; 100x; 50x; 75x; 50x; 100x); c, f, k – details of the perforation made by rotation (magnification: 50x; 50x; 50x).

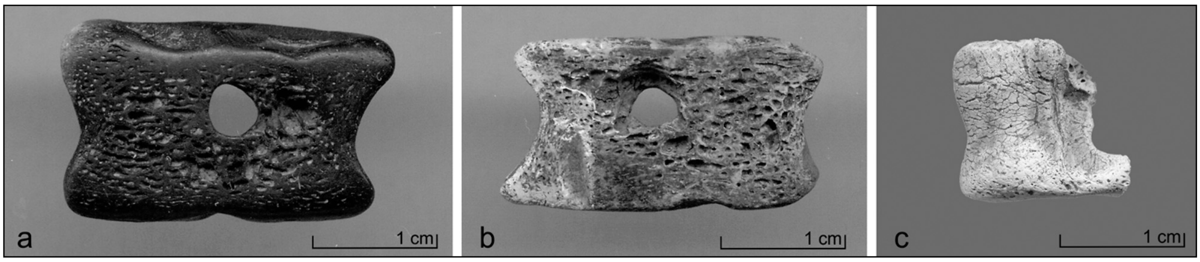

Fig. 7. Variations in the colour of the astragals.

due to the gradual erosion of the terrain at the initial point '0', which also led to the changing of its location the following year, and implicitly to a recalculation of the depths. We also noted that the depth of the last two astragals to be found appeared to be outliers in the series of data. This, together with the fact that so far they were the only unburned ones, made us question their association with the same group of astragals as the others. An argument in favor would be the fact that the astragals found during the last two years (burned and unburned), small in number and at a greater depth, are all located on the periphery of the main group. In addition, it can be seen that the house level curves downward in the area where squares A4 and B4 meet (Fig. 11), so it is not surprising that the last two astragals found precisely in that area were at a greater depth than the others. Since we do not find these arguments (depth and peripheral position) to be enough to exclude the two burned astragals from the possible hoard, they also might not constitute by themselves strong enough arguments to exclude the unburned astragals.

We also looked at the horizontal distribution pattern (if any) of the artefacts under discussion. A first step was to check if the data is normally distributed. In our analysis, we included the last two astragals to see if they show up as outliers. We did not include the piece we located by approximation, but we always checked to see how it fits within the whole. The mean and median centres produced close values (Fig. 13), which is one of the conditions for the data to be considered normally distributed.

The next step was to try to see if the features (in our case, the astragals) are dispersed or concentrated. We used standard distance for this (Fig. 14). Fourteen features (66.66%) are located within a distance of 0.59m from the mean centre if the calculations consider one standard variation. When we consider two standard variations, 95.24% of the features (20 out of 21) are located within a standard distance of 1.18m from the mean centre. Taking into account the small number of features considered, we could say they seem to be more concentrated than dispersed.

Following the above, we wanted to check if the features are not only concentrated, but also display any directional trend (Fig. 15). The calculated directional distance showed that 61.90% of features (13 out of 21) and 95.24% of them (20 out of 21), taking into account one and two standard deviations, display a NNE-SSW directional trend (26.09° from North).

In both of the above cases, the two unburned astragals were within the standard distance and the directional trend, but only when two standard deviations were considered. The same applies to the astragal located by approximation.

The spatial distribution of the maximum temperatures recorded from each astragal (Fig. 16) seems to suggest that most of them might have been in the same position when the house was burnt. This supposition is based on the grouping of the astragals that were burned at a maximum 700°C, and the fact that the others that burned at lower temperatures (400–500°C) seem to cover an area to the south-west of the previous group. This would indicate that, for

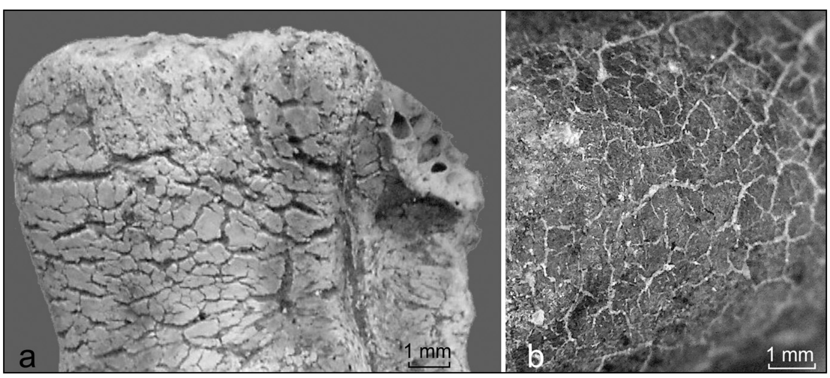

Fig. 8. Types of crack observed on the astragals.

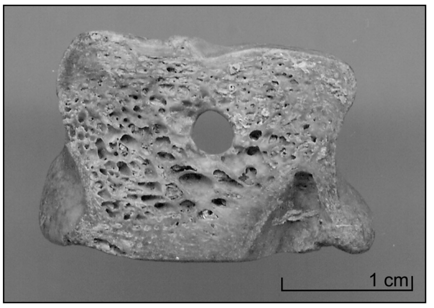

Fig. 9. Astragal with colour indicating the vicinity of heat, but not direct burning.

some reason, higher temperatures developed in a small area of less than 1m^2, while lower temperatures affected the materials around this hot spot.

An analysis of their spatial distribution and their almost uniform dimensions suggest that, in spite of their dispersal over an area of 2.5 m^2, they were part of a hoard, they were kept together somewhere in the house and were dispersed when the house collapsed. As to where they might have been kept, the higher density of findings in the area of vessel no. 4 (Figs. 17 and 18) might suggest that they were contained in it. However, a few issues concerning this hypothesis should be mentioned.

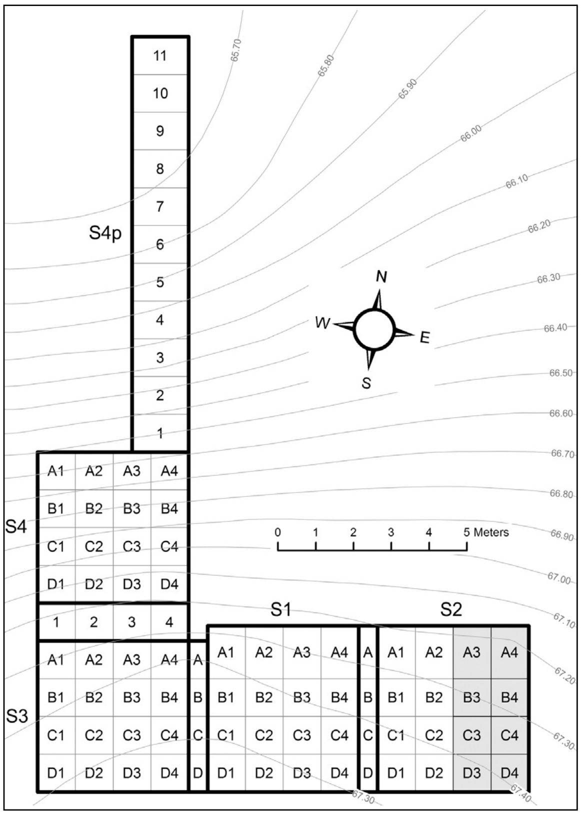

Fig. 10. Excavation plan drawn on top of the level curves – the grey squares represent the area where the astragals were found.

Firstly, if the astragals were kept inside the large vessel mentioned above (31cm high, with a rim diameter of 17cm), and the vessel fell from a height or simply fell on its side during the destruction of the house, then the astragals should have been less dispersed. On the other hand, the location of the group of astragals that was affected by higher temperatures close to the central part of vessel no. 4 might suggest a direct connection between the astragals and the vessel. Nonetheless, this connection might have resulted during or after the collapsing of the house, and not necessarily before. After all, astragals were found in the areas of the bottom or of the rim of the vessel that seem to have been less affected by fire.

We also considered the possibility that the astragals were kept in one of the other vessels from the group found in the vicinity (vessels 3 and 5) (Fig. 17). These are smaller recipients, with a larger rim diameter relative to their height, attributes which would have allowed the astragals to fall out much more easily. Nonetheless, given the location of these vessels, the direction of the astragals' distribution should have been more SE-NW, not SW-NE as recorded. But this scenario should not be entirely excluded, since variables that should be taken into account are missing, such as, for example, whether the vessel was located on the floor and flipped onto its side or was on a shelf and fell down, or if the floor was horizontal or slightly inclined, *etc*.

If the astragals were kept in a pouch, they should have been found either gathered in a very small area (if the pouch was on the floor or burned after reaching the floor) or very dispersed (if the pouch was burned while still hanging on the wall or on some kind of shelf).

As all the astragals had a central perforation that was supposedly used to keep them on a string, we could assume that they might have been kept in the house on a string hung from a nail in the wall. This hypothesis is supported by the impression evidence analysis of the pieces and to some degree by their dispersal pattern.

Are they the result of production in situ?

We considered the possibility that they might have been part of a workshop for making bone artefacts. According to a general schema, the presence of a workshop could be supported by the identification of all the products and sub-products that accumu-

Piece no.	Burning temperature	State of bone before burning	Uniformity of burning	Cracks
373	200–500°C	Dry	Not uniform	Fine cracks on the surface. The cracks' pattern is random, forming a network.
396	200–400°C	Dry	Not uniform	No
404	200–400°C	Dry	Not uniform	No
408	700–900°C	Green (?)*	Uniform (?)	Network cracks on the entire surface. Some are fine, but most of them are deep.
422	400–600°C	Dry	Not uniform	Fine cracks on the surface
423	400–700°C	Dry	Not uniform	No
424	500–700°C	Dry	Not uniform	Fine cracks on the surface. The cracks' pattern is random, forming a network (present mainly in the vicinity of white areas)
425	300–700°C	Dry	Not uniform	No
428	200–600°C	Dry	Not uniform	No
430	300–700°C	Dry	Not uniform	No
431	200–400°C	Dry	Not uniform	No
432	300–700°C	Dry	Not uniform	No
433	200–400°C	Dry	Not uniform	No
437	300–500°C	Dry	Not uniform	A few fine cracks on the surface forming a network around the perforation.
439	300–700°C	Dry	Not uniform	No
441	200–700°C	Dry	Not uniform	No
486	300–700°C	Dry	Not uniform	No
489	200–400°C	Dry	Not uniform	No
490	200–400°C	Dry	Not uniform	A few fine cranks on the surface at one end of the piece (the part having brownish-grayish coloration).
560	200–700°C	Dry	Not uniform	Fine cracks on the surface. The cracks' pattern is random, forming a network (present only in the vicinity of white areas).
562	300–500°C	Dry	Not uniform	No
638	300–800°C	Dry	Not uniform	Fine cracks on the surface. The cracks' pattern is random, forming a network (present only in the vicinity of white areas).
690	300–500°C	Dry	Not uniform	Fine surface cracks on the ridges of the proximal articulation.
751	Unburned bone. The colour of the bone indicated nonetheless that it might have stayed close to a heat source, without being touched directly by the flames.			
753	Unburned bone. The colour of the bone indicated nonetheless that it might have stayed close to a heat source, without being touched directly by the flames.			

* There are some reserves concerning this determination. The bone is not complete (only approximately 50%) which prevents us from making definite observations.

Tab. 3. Data concerning the burning of the astragals.

late at the end of a technological chain, developed for the production of a certain artefact. In addition to this, the presence of a considerable number of pieces in various stages of fabrication together with the tools needed for the work would be essential characteristics of a workshop. Starting from these premises, we tried to determine if, in the case of the astragals from Iepureşti we could speak of a workshop. Unfortunately, both technological interventions identified on the astragals (abrasion and drilling) have as a result very small flakes of raw material. This makes it impossible to recover any resultant debris. In these conditions, we tried to identify tools used for drilling, such as flint drills, or flakes adapted to such activities. Their absence leads us to conclude that in this case there was no workshop or production on the spot. This question once answered, we directed our attention to a much-debated aspect concerning the use of astragals.

What were the functions of these pieces?

The significance of these pieces has raised a lively debate in the literature due to their presence over a long span of time (from the Neolithic to modern times) and around the globe (Europe, Asia, Africa, America and Australia).

A first hypothesis concerning the function of the astragals is their domestic use. The result of intense friction against a strongly abrasive body might be an indication of its use for pottery decoration or

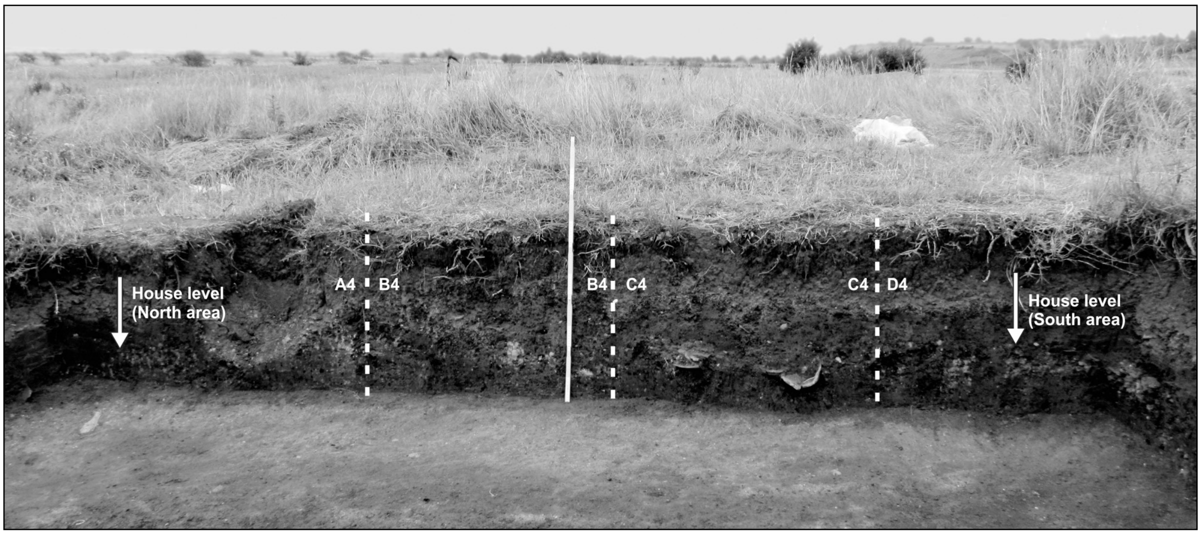

Fig. 11. Profile of the eastern wall of Section S2.

leather working (*Riedel, Tecchiati 2001*) which would imply that the abrasion marks are of a functional rather than a technological nature. Our own experimental studies demonstrated the great efficiency of these pieces in the process of pottery finishing while clay was still wet in order to give it a mechanical shine (present on many G-K-KVI vessels, especially small and medium sized). It was also noted that the astragal piece was completely worn down after its use on one small vessel. The same experiments showed that if the astragal was rubbed on a stone in order to obtain a flat surface, the finishing process was faster. In this last case, we can assume that the abrasion marks illustrate a stage in a technological chain whose purpose is to transform the shape of the piece in order to create a standardised final product.

Another hypothesis concerning the function of the astragals is their use in various games. Numerous such cases have been recorded around the globe and for various historical periods (pre-history, Ancient Greece and Rome, the Middle Ages, modern Iran and Mongolia, America, or among indigenous Australians) (*Marckevich 1981.170–172; Lewis 1988; 1990; Elster 2003; Korzakova 2010; Choyke 2010; Amandry 1984; Gilmour 1997; Eisenberg 1989; Bartosiewicz 1999; Dandoy 1996*).

In the case of some primitive populations, astragals have been used as possession markers (*Perego 2010*). The study of the animal bones from Iepureşti showed that animal husbandry was more important than hunting, implying that the possession of domestic animals and the affirmation of this possession before the community (raising social status) might also have played an important part. The only argument against this interpretation of the astragals is the percentage of various domestic species as determined by the archaeozoological analysis: 73% cattle, 16% sheep or goat, and 11% pig[1].

For cases where deposits of astragal have been found, Richard Holmgren (*2004*) proposed a possible commercial value, that of primitive currency. As shown by the same author, it is impossible to know if the exchange of astragals was limited to a simple gift, took place while playing various games (with no commercial value: the winner took the pieces of the other players), or was a genuine commercial exchange in the absence of a different currency.

We cannot ignore the use of astragals as amulets, as votive depositions, or in various ritual practices, such as divination (*Zidarov 2005; Prummel* et al. *2011. 84*).

Their exceptional symbolic importance was imprinted in the collective mind. In classical antiquity, for example, astragals were copied in clay, bronze, glass or marble (*Amandry 1984; Dandoy 2006*). In Ancient Egypt, at Amarna, a piece showing an astragal of faience was found; two ivory astragals were identified in Tutankhamen's grave (*Gilmour 1997; Dandoy 2006*), and a stone astragal dating from the Bronze Age was found at Gonur Depe in Turkmenistan (*Moore 1993*). In the North Balkan region, a clay astragal was found at the Neolithic site at Târ-

1 The analysis of the animal bones is ongoing, so these percentages are not final, but only for orientation purposes.

gu Frumos (*Ursulescu, Boghian 1997–1998.17*), and a gold one in the G-K-KVI necropolis at Varna (*Poplin 1991; Slavchev 2010*). Smaller than normal astragals, this last one has the same morphology as the pieces polished on the medial and dorsal faces. It also had a plantar-dorsal perforation. This piece was considered proof of an old ritual known among the Hittites, and in Ancient Greece and India, namely a ritual game part of royal ideology whereby the destiny of the king and the protection offered to him by the gods were established by the decision of the dice (*Marazov 1991*).

The astragals from Iepureşti in a wider spatial and temporal framework

In the Northern Balkans, such pieces have been dated to the Middle and Late Neolithic. The earliest case known so far is two astragals from pit house 40 at Măgura/*Buduiasca/TELEOR 003*, attributed to the Dudeşti culture (*Andreescu* et al. *2006.217*). Another early discovery is the ovicaprid astragals found at Cheia/*Vatra satului* interpreted as pottery polishers and attributed to the Hamangia culture (*Voinea, Neagu 2009.97*).

The polished astragals, mostly from cattle or deer, discovered in the Precucuteni II and III settlements at Ghigoeşti-Trudeşti (*Marinescu-Bîlcu 1974.46–50*), Isaiia (*Ursulescu* et al. *2004.151; Vornicu 2013.84*), Târpeşti (*Marinescu-Bîlcu 1974.46–50*) and Târgu Frumos (*Ursulescu, Boghian 1996.44; Vornicu 2013. 201–203*) have also been interpreted as polishers. In some of cases, these were discovered in large numbers in the same feature, like the 20 astragals (some from sheep, most from cattle) found in Pit 2 at Târgu Frumos. The deliberate character of the deposition is suggested by the grouping of the astragals inside the pit. Along with the polished pieces, quite a large number of unpolished astragals were discovered in the same features, both at Isaiia and at Târgu Frumos (*Vornicu 2013*).

The analysis of the published discoveries of astragals with traces of human intervention on them found in the G-K-KVI cultural environment (especially north of the Danube) led to the identification of the following variables: context, type and degree of bone morphology modification (polishing, drilling), number of pieces/context, and the animal species from which the astragals were taken.

Such discoveries in G-K-KVI cemeteries are rare. One case is the 13 ovicaprid astragals found in Grave 4

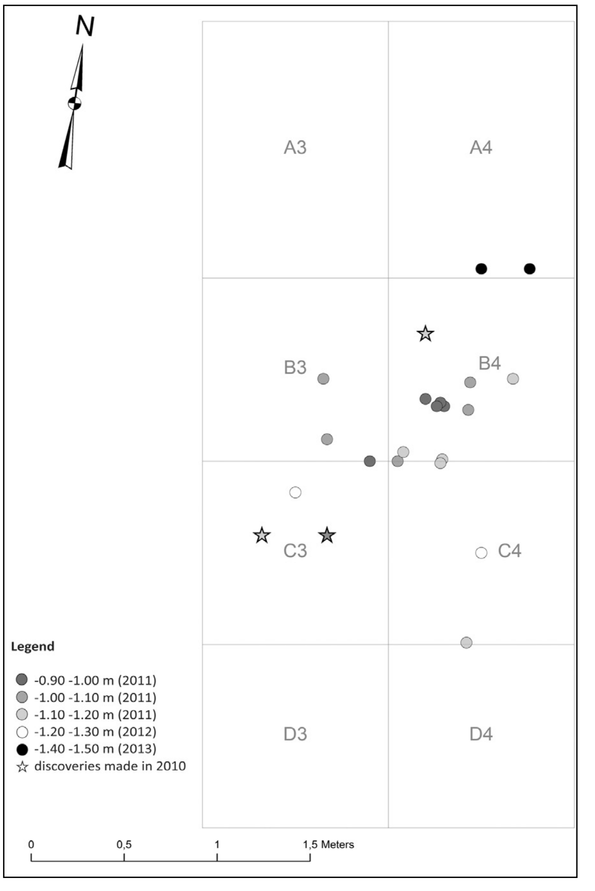

Fig. 12. Distribution of depths at which the astragals were found.

at Devnia. As five of them were polished and one perforated, they were interpreted as part of a bracelet or necklace (*Todorova-Simeonova 1971.5–6*). A famous discovery is the gold imitation of a perforated astragal found in Grave 36 at Varna (the richest grave in the cemetery) (*Slavchev 2010.196*).

In the case of the G-K-VI settlements, the analysis led to the observation of several distinct situations; unperforated astragals were involved in hearth, oven and house foundation rituals.

At Hârşova, a rectangular pit (0.6 x 0.35m) was made on the occasion of the reconstruction of a hearth (C. 506) from House 49 from the Gumelniţa A2 level. Several astragals were deposited in the pit; unfortunately, no data on the number of pieces, animal species or interventions on the bones were published (*Popovici* et al. *1998–2000.18*). A similar case was recorded in House 9 at Bucşani – *La Pod* (Gumelniţa B1 level). Here, when the oven was being built, two polished sheep astragals together with a flint blade and a schematic clay anthropomorphic figurine were deposited in one of the construction levels (*Bem 2001a.164*).

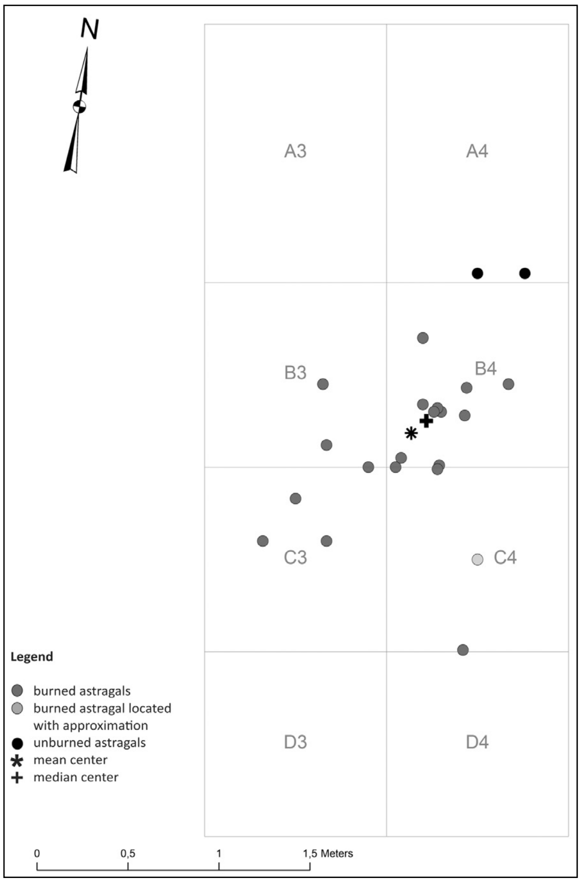

Fig. 13. Location of the mean and median centers of the astragals' distribution.

We found only one other somewhat similar situation, which is the discovery made in House 4 at Hotnitza (level III), where a house foundation ritual was recorded. The practice of depositing objects in house foundation rituals is not usually encountered in this cultural area. In the southern part of the house, laid simultaneously with the floor and plastered within it, the leg bones (phalanx, astragals, hooves) of 23 animals (16 cows, two ovicaprids, three pigs, one deer and one auroch) were found; 32 of these were astragals (*Chokhadzhiev, Chokhadzhiev 2005.11; Chokhadziev 2009.68, Fig. 13*). We do not have data on any human intervention on the bones.

The same interpretation (*i.e.* house foundation ritual) could also be proposed for the situation at Gumelniţa, where a deposit of small sheep astragals (from young individuals?) polished on one side was discovered at the base of the upper level (Gumelniţa B1) (*Dumitrescu 1966.59*).

Discoveries of astragals inside buildings are more numerous. Thus, in a burned building of level III at Pietrele (Gumelniţa A2), interpreted, based on the exceptional inventory, as a sanctuary, 13 astragals were deposited to the left of the entrance, together with a prismatic idol and two herbivore hooves. At least one of the astragals was decorated with incised lines (*Berciu 1956.512*). No data were published concerning the animal species from which the astragals were taken, or whether they had been modified in any way, such as by drilling or polishing. It was only mentioned that they had been "worked on carefully".

Other discoveries of pig and cattle astragals deposited together were made in the burned Houses 2 and 4 at Căscioarele (Gumelniţa B1 level). Some had been polished, but no other data were published (*Dumitrescu 1965.225*). The first house was interpreted as a flint axe workshop (*Marinescu-Bîlcu 1965*), while the second was called the "fisherman's house" (*Marinescu-Bîlcu 2002*). In both cases, the inventory was rich, diverse, and included exceptional elements (due to the character of the artefacts, or their number: moulds for casting axes, 100 clay weights, 13 flint axes, *etc*.).

Another polished and perforated piece was found at Drăgăneşti-Olt in the filling of pit house 2, in association with pottery, partially burned deer bones, a miniature mask representing a horse head and other several clay artefacts (*Nica* et al. *1977.10, Fig. 3/3a–b*). Four polished ovicaprid astragals, one perforated, were found in a vessel in House 5, and one polished cattle astragal was found in House 6 at Mălăieştii de Jos/*La Mornel*. Both houses had been destroyed by fire (*Frînculeasa* et al. *2011*). Two or four[2] ovicaprid astragals, of which at least two were abraded and one perforated, were found at Măriuţa/*La Movilă* (Gumelniţa B1), in a deposit including numerous bone and antler tools, grinding stones, axes, *etc*. (*Parnic, Păun 2003–2004.57–58; Mărgărit* et al. *in press*). Three polished (?) astragals were found in a house at Năvodari/*Insula La Ostrov* (*Marinescu-Bîlcu* et al. *2003.210*). We presume that the deposit of seven polished astragals discovered at Hârşova (of which six were ovicaprid) (*Haşotti 1997.105*), as well as a deposit consisting of 20 perforated ovicaprid (young individuals) astragals, of which three were decorated with incisions and at least two with ochre, and interpreted as necklaces (*Popovici, Rialland 1996.54–55*) were also found inside houses.

2 The number varies according to the source used.

Astragals showing traces of abrasion, and sometimes perforation, were recorded (separately or in groups of two or three) in other contexts such as in middens, foundation trenches, *etc*. at Urlaţi (two perforated and polished pig astragals in a midden pit; *Frînculeasa* et al. *2008.97*), Chitila/*Fermă* (*Nicolae* et al. *2003.78–80*), Măriuţa/*La Movilă* (three abraded astragals in a refuse area; *Mărgărit* et al. *in press*), Cuneşti/Măgura Cuneştilor (*Mărgărit* et al. *2013*), Însurăţei/*Popina I* (six polished astragals in a refuse area located between two houses; *Pandrea 2002.172*), Borduşani (10 polished ovicaprid astragals, one of which is perforated, found in foundation trenches and in the archaeological strata; *Voinea 1997.75*), Năvodari (two polished astragals found in a pottery complex; *Marinescu-Bîlcu* et al. *2000.66; Marinescu-Bîlcu* et al. *2001.160*), and others.

This enumeration of known situations suggests that the perforated pieces appear quite rarely. We do not know if this image is real or it is due to a shortcoming in the publication of materials. With the exception of the cases already mentioned (Mălăieşti, Urlaţi, Chitila, Drăgăneşti and Hârşova), there are no data on other discoveries of perforated astragals. The lot discovered at Iepureşti can be now added to this list. In all these cases, although the number of pieces is different, the common element is the provenance of the bones from (young) ovicaprid individuals (with the exception of the piece from cattle found at Chitila). The same can be said for the discovery made at Devnia.

It should also be noted that during the Copper Age, in the cultural areas neighbouring the G-K-KVI cultural complex, such pieces are quite rare, perforated or otherwise. Two astragals were discovered in the IIb and IIc layers at Priscul Cornişorului (Sălcuţa culture) (*Berciu 1961.233*).

A recent revaluation of the bone and antler artefacts from sites located in the area of contact between the Gumelniţa and Cucuteni cultures (Stoicani-Aldeni aspect) (*Beldiman* et al. *2012*) did not lead to the identification of any modified astragals. The picture of this area may be false, due to the small number of recent archaeological investigations.

The discoveries of cattle and ovicaprid astragals in the numerous Cucuteni A settlements investigated are rare, and usually refer to a small number of pieces. The usual interpretation of such finds is that of polishers. Two ovicaprid astragals with traces of polishing were discovered at Hoiseşti/La Pod (*Bodi*

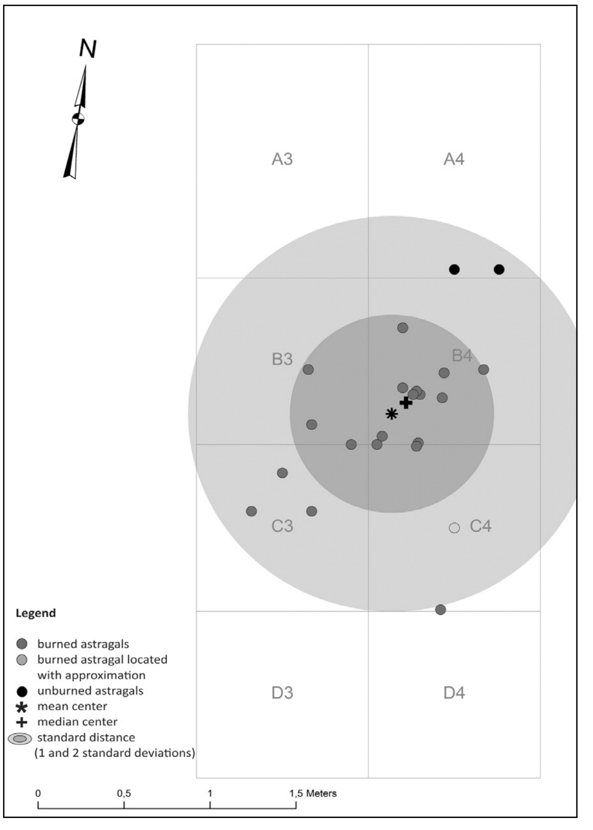

Fig. 14. The calculation of the standard distribution to determine the degree of concentration of finds.

2010.117, 120–121). In all, this site yielded 23 astragals from various species, both wild (*Capreolus capreolus* – 5, *Sus scrofa ferus* – 9, *Bos primigenius* – 2) and domestic (*Bos Taurus* – 1, *Sus scrofa domesticus* – 1, *Ovis aries* – 2, *Ovis/Capra* – 3) (*Cavaleriu, Bejenaru 2010.224*). Eight polished cattle astragals were discovered at Poduri/Dealul Ghindaru, in a refuse area (*Bejenaru* et al. *2010*). Several more or less polished cattle astragals, some burned, were discovered at Tîrpeşti (*Marinescu-Bîlcu 1981*). A polished astragal from a domesticated ox was found at Drăguşeni/*Ostrov* (*Bolomey, Marinescu-Bîlcu 2000.75*). Several astragals, some polished, were discovered at Dumeşti/*Între Pâraie*, in House 3 (pottery workshop) on the floor of the larger room (*Alaiba 2007.20–23*). Five ovicaprid astragals, of which one is perforated, were discovered in a vessel at Bonţeşti (*Dumitrescu 1933.97*).

Although many sites have been investigated and published in the past (Hăbăşeşti – *Dumitrescu* et al. *1954*; Izvoare – *Vulpe 1957*), or others more recently excavated that benefited from archaeozoological studies (Preuteşti/*Haltă – Ursulescu, Ignătescu 2003*; Truşeşti/*Ţuguieta – Petrescu- Dîmboviţa* et al. *1999*; Ruginoasa/*Dealul Drăghici – Lazarovici, Lazarovi-*

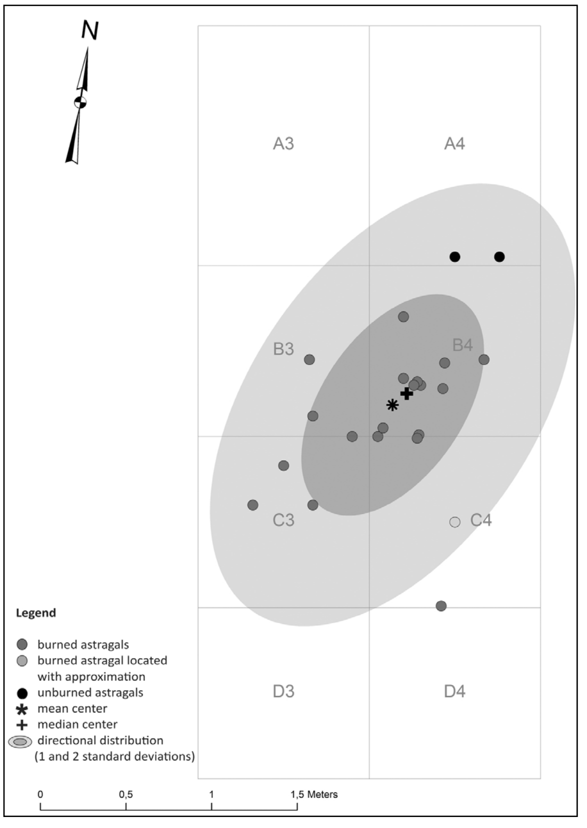

Fig. 15. The calculation of the directional distance in order to observe any trend in the dispersal of finds.

ci 2012; Cucuteni/*Cetăţuie – Petrescu-Dîmboviţa, Văleanu 2004*), the presence of astragals is very rarely recorded, and the pieces do not bear traces of abrasion, polishing, drilling or decoration.

Several notable exceptions, both from Cucuteni A settlements, should be mentioned. One was encountered at Poduri/*Dealul Ghindaru*, where 25 astragals of mature individuals (21 cattle, three deer, one ovicaprid) were discovered beneath the floor of a house. Some of the pieces have processing traces and were pigmented with ochre. A green colouration from contact with copper was noted on some of them. The discovery was interpreted as the final destination of dice-type artefacts deposited in the foundation of the house to bring good luck to the building (*Bejenaru* et al. *2010*). Although the ritual practice of placing objects in the foundations of buildings or combustion structures is frequent, the use of astragals for this purpose is unusual. On the other hand, related to the discovery at Poduri, we must note that the main meat component in the food in that site was from cattle (which also constitute the main component of the foundation deposit).

Another rare discovery was recorded at the site at Şoimeni-Ciomortan/ *Dâmbul Cetăţii*[3]: a perforated ovicaprid astragal and another one decorated with incisions were discovered in two different features (*Kavruk* et al. *2010.185; 2013.128; Beldiman, Sztancs 2010.143, 153*).

So far, these two contexts appear to be unique to the Cucuteni culture. They could be explained by the special position that the two sites occupied in the network of social and economic relations. In the case of the first site, the richness and multitude of discoveries associated with rituals led the archaeologists to consider it a 'Troy' of Cucuteni culture (*Monah* et al. *2003*). In the case of the second site, there was the possibility of controlling access routes between the areas east of the Carpathians and those inside the mountain arch, which included the possibility of controlling the distribution of salt extracted in Moldavia (*Cavruc 2005.333–336*).

The Cucuteni A–B phase is represented by only two discoveries (probably due to the limited number of

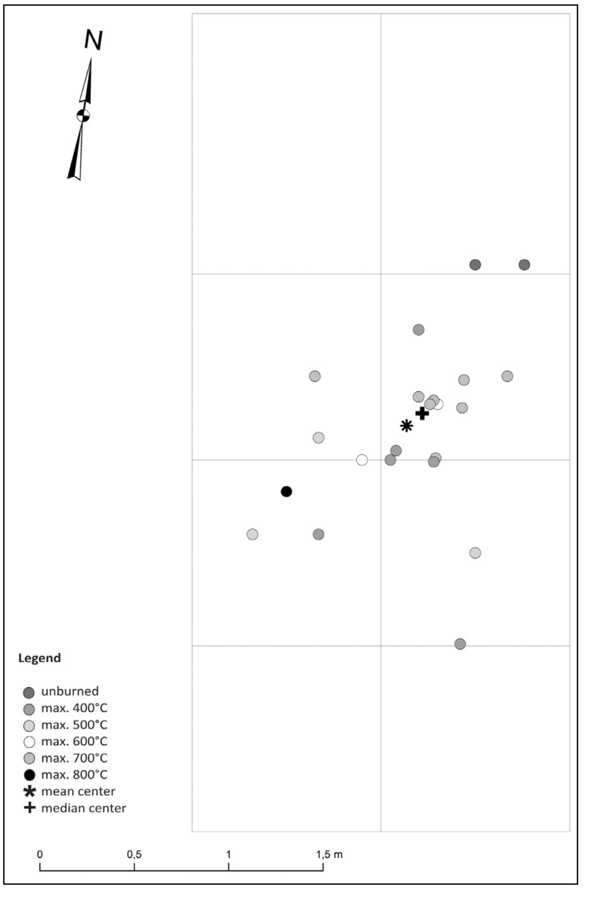

Fig. 16. Spatial distribution of the highest temperatures of burning recorded from the astragals.

3 The site is also known in literature under the name of Păuleni-Ciuc/*Dâmbul Morii*.

investigated contexts): five polished ovicaprid astragals were found at Traian/*Dealul Fântânii* (*Bem 2007.179*), and two deposits of 22 small astragals, one of them found in a globular vessel covered with a river stone, were discovered at Huşi/*Centrul oraşului* (*Niţu, Bazarciuc 1980.19*).

Several other discoveries have been recorded for the last phase of the Cucuteni culture (phase B). A polished pig astragal and a sheep astragal were discovered at Feteşti/*La Schit* (*Oleniuc 2012.61, 62*). Another astragal was discovered under a small vessel in the shape of a truncated cone, turned upside down, in House 7 at Roma/*Balta lui Ciobanu* (*Popovici* et al. *1992.16*) – no data is available on the species or on processing. Sixteen perforated (?) ovicaprid astragals were found in a vessel at Brânzeni III in association with a flint knife and a piercing tool. They were interpreted as pieces of a game that also involved small clay cones (*Marckevich 1981.171*). A spectacular discovery is that of a deposit consisting of 497 astragals (489 from ovicaprid individuals and 8 from pig, one of which was polished) found at Ghelăieşti. Some of the ovicaprid astragals showed several types of human intervention on them: traces of the butchering process and of the rubbing of the astragal against another object, incisions (on some of them), and perforations (on two pieces). The minimum number of individuals that these astragals came from is 253 ovicaprids and 7 pigs. The group of astragals is characterised by a wide variation in the dimensions of the individual astragals (*Necrasov 1999.192*). The deposit was found in House 5 in a large storage vessel with a curved shoulder and crater neck (*Cucoş 1999.48–49*). Another astragal, with one of the sides strongly abraded and with the upper margins slightly denticulated was found in house 23 of the same site (*Cucoş 1999.69*). Some of the astragals might have been used as amulets or simple adornments, the rest of them were most probably used as stone tools and pottery polishers (*Cucoş 1999.69*).

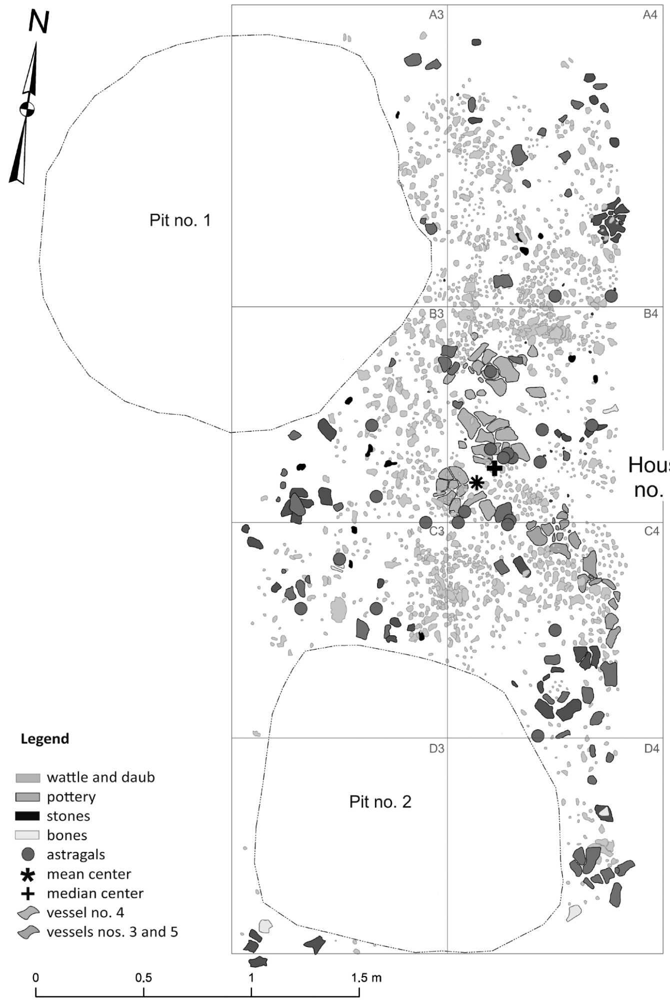

Fig. 17. Iepureşti 2010, Section S2, □A–D/3–4. Plan of the excavated portion of House H4 disturbed by two Early Bronze Age Pits. The locations of astragals and the vessels in which they might have been kept are marked on this plan, as well as the mean and median centres of the astragals 'distribution.

The simple enumeration of contexts can illustrate, but does not assure, the identification of the ways this category of artefacts was employed. We do not exclude the possibility that, according to context, the function might have changed, or that the pieces might have received multiple cultural/symbolic values. The cultural values associated with these artefacts can also vary from one culture to another, as appears obvious from the comparison between the discoveries made in the Cucuteni area and those made in the G-K-KVI area. In the Cucuteni A environment, there is a pre-Cucuteni tradition of using preponderantly cattle astragals which are hardly processed or not at all. In spite of a tradition (Dudeşti and Hamangia) in which the astragals seem to have been employed in a manner similar to the later Cucuteni one, an individualisation takes place in the G-K-KVI environment, a transformation of this artefact that underwent a rich symbolic investment. This transformation is very well illustrated by the variety of contexts in which they were discovered and by the preferred animal species (ovicaprid).

Conclusions

Fig. 18. Vessel no. 4 in situ and reconstructed.

In traditional societies, the sacred and the profane are perceived as being intertwined, and practical, daily activities have a mythical connotation. In these societies, objects are invested with symbols that, according to the moment or area, can be simplified, amplified or modified. Several classes of artefacts can be identified for the G-K-KVI cultural complex. The most visible category is that of prestige goods, including copper axes, certain shapes of stone or bone ax, gold and *Spondylus* artefacts, *etc*. They are usually encountered over large areas and are appropriate for long-distance trade. A second category would be that of identity goods, such as adornments and anthropomorphic figurines. Another group is comprised of symbolic goods, such as objects used in foundation rituals (pottery, flint and stone tools, adornments, figurines, astragals, *etc*.).

Astragals form a category of artefacts that can be easily obtained through the selection of these bones when animals are sacrificed. Nonetheless, their availability is limited by the existence of only two such bones per animal. Obtaining and processing them does not imply important efforts; even an untrained person can perform these actions in any household. Our own experiments (and another traseological analysis (*Meier 2013*)) which focused on the use of astragals for polishing vessels and processing leather would indicate that these artefacts were not used as tools in such activities.

The specific archaeological contexts of discovery for the G-K-KVI cultural complex suggest that the astragals, mostly ovicaprid, in some cases had a symbolic importance, being used in foundation rituals for houses or combustion structures. They were deposited in graves very rarely, although this aspect changed in the ensuing periods when astragals were used preponderantly in funerary contexts, public areas and, more rarely, private spaces (*Minniti, Peyronel 2005; Carè 2013*). Nonetheless, the smaller or larger number of pieces per context, and the association of pieces with different degrees of processing or from different species suggest their use for various purposes/practices.

From an economic perspective, recent studies (*Bréhard, Bălăşescu 2012*) suggest, in spite of the decreasing importance of small horned animals in Gumelniţa culture, the development a specialised form of exploiting ovicaprids, especially of sheep, for meat. While cattle were usually associated with masculinity, as suggested by a series of gold or clay representations (vessels with horned protomes, masks, bucrania), the ovicaprids might have been connected with older traditions in which they played important social and economic roles. With time, in virtue of this importance, certain parts of the animal became sacred, employed in house protection rituals, or perhaps even for personal protection in the case of perforated pieces. The archaeological situations suggest that these objects might have been invested with symbolism whether they were processed or not.

In these conditions and having in mind the scarcity of archaeological information available, the attention paid to these artefacts when they are found could yield new clues about how they were used in a social setting. The discovery made at Iepureşti is part of a universal tradition of using perforated and abraded astragals as old as the Neolithic. A common local animal species (that probably played an important economic role) was used for all the studied pieces. Standard blanks that made a strong visual impact were selected, especially if we presume they formed parts of a necklace.

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Book review

Julian Thomas

The Birth of Neolithic Britain: An Interpretive Account. xi+508 pages, 105 figures. 2013. Oxford: Oxford University Press; ISBN 978-0-19-968196-9 hardback

The Birth of Neolithic Britain is the fourth major work by the acclaimed Julian Thomas, one of the leading proponents of interpretive archaeology or archaeology informed by philosophy, anthropology and discussions in the arts and social sciences in general. After exposing the assumption and prejudices of archaeologists' narratives of the Neolithic and presenting innovative explanations of the shift from hunting-gathering to farming as well as other issues in *Rethinking the Neolithic* (1991; reworked and updated version *Understanding the Neolithic* in 1999), questioning Western conceptualisations of time, identity, materiality with the help of archaeological case studies in the 'Heideggerian' *Time, Culture and Identity* (1996) and further contextualised archaeology as part of a (post)modern worldview in *Archaeology and Modernity* (2004), this book seems to be a relevant continuation of Thomas's work. This is probably the first significant work on Neolithisation since Graeme Barker's global overview *The Agricultural Revolution in Prehistory* (2006, Oxford: Oxford University Press), this time with a focus on Europe and particularly Britain.

The book is divided into thirteen lengthy chapters organised and titled in a way which adds clarity to the structure of the text: (1) Introduction: The Problem, (2) The Neolithisation of Southern Europe, (3) The Neolithisation of Northern Europe, (4) The Neolithisation of Europe: Themes, (5) The Neolithic Transition in Britain: A Critical Historiography, (6) Mesolithic Prelude?, (7) Times and Places, (8) Contact, Interaction, and Seafaring, (9) Architecture: Halls and Houses, (10) Architecture: Timber Structures, Long Mounds, and Megaliths, (11) Portable Artefacts: Tradition and Transmission, (12) Plants and Animals: Diet and Social Capital, and (13) Conclusion: A Narrative for the Mesolithic-Neolithic Transition in Britain. While not claiming to be a complete survey of Neolithic archaeology in Britain, much less Europe, the extent of the bibliography alone, comprising some 1400 references, is an indicator that this is a detailed study, dealing with a diverse variety of geographical regions, themes, approaches and explanations related to the Neolithisation process. Fundamentally, this book represents a critical overview of the diverse narratives and empirical data used to explain the complex process of transformations from predominantly hunting and gathering to predominantly farming lifeways in Britain and Europe.

Chapters 1–4, dealing with Neolithisation in different parts of Europe are, as the author suggests, intended to present the "*progressive transformations*" of the Neolithic through time, the diversity of Neolithic societies across Europe and provide "*... comparative case studies against which the British evidence can be set*" (p. 7). In the first three chapters, the author comments on a wide variety of empirical evidence and presents his own explanations of the data, starting with the Franchthi cave in Greece and progressing through the continent to the megalithic monuments of Brittany. In chapter 4, the author presents "*... unifying themes that characterized the opening of the Neolithic in various parts of Europe*" (p. 101) starting with an overview of how the Neolithic was and is defined and Neolithisation conceptualised, then focusing on the different perspectives of migrationism and genetic evidence, the transmission of knowledge and skills, Mesolithic lifeways, the 'Neolithic frontier', subsistence strategies and feasting, houses and 'house societies' *etc*. In chapter 5, the author focuses exclusively on Britain with a 'critical historiography' in which he reviews the history of research of the British Neolithic, beginning with Sir John Lubbock, and considers the work of major authorities on the subject: Childe, Piggott, Hawkes, Clark, Humphrey, Whittle, Dennell, Kinnes, Hodder and, reflectively, himself. He then comments extensively on the migrationist and diffusionist arguments of Cooney, Sheridan and Rowley-Conwy, whom he labels 'revisionists'. Chapter 6 sets the stage for the rest of the book by presenting the evidence of Mesolithic lifeways. In the earlier part of chapter 7, the author dedicates a lot of attention to the results of the Bayesian modeling approach to ^{14}C calendar chronologies (*Whittle A., Healy F. & Bayliss A. 2011. Gathering time: dating the Early Neolithic enclosures of Southern Britain and Ireland*, cited in the Bibliography) and reviews the dating evidence from early British Neolithic sites. The rest of the book, constituting roughly one third of the

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whole volume, comprises a detailed consideration of the empirical evidence and ideas about a range of themes, starting with contact, interaction and seafaring in chapter 8, followed by architecture (halls, houses, timber structures, long mounds and megaliths), portable artefacts (ceramics, stone tools), landscapes, plant and animal remains. Of special notice here is the hypothesis that "*... livestock in general, and cattle in particular, may have been one of the principal factors that attracted hunters and gatherers to the Neolithic way of life*" (p. 430). "*The formation of more bounded social groups accumulating discrete herds of cattle suggests an increasingly competitive social milieu*", which expressed itself in "*feasting, gift-giving, strategic marriages, and the struggle for prestige*", but also in "*inter-personal violence ... linked to the emergence of endemic raiding, acquiring livestock and labour by foul means as well as fair*" (p. 418). Cattle can thus be regarded as Neolithic 'social capital'. Considering the emphasis on practices related to cattle herding, this book would benefit from more discussion of lipid analyses and dairying (*e.g.*, the work of Richard P. Evershed, Mark S. Copley and Lucy J. E. Cramp).

Innovative ideas and novel explanations of the empirical evidence from Europe and Britain can be found in every chapter, and it would not be fair to isolate a one in particular here. Generally, the explanations can be characterised as coming predominantly from a well-argued, indigenist neolithisation perspective, although the author specifically denies his is an 'indigenist' (p. 419), and it is true that he presents a balanced and well-argued account in which the distinction between 'indigenist' and 'migrationist' perspectives cease to be valid. The overall picture this narrative presents is of a "*mosaic*" of different lifeways in which various social entities, such as the "*LBK social network*" (p. 47), or different identities are conceived as permeable and fluid concepts. We notice a very pragmatic use of social-theory-informed archaeology, so that the text is not overburdened with philosophical discussions. Actually, there are almost no references to philosophical, sociological or anthropological works. Certain narrative elements bear a resemblance to an archaeological 'school of thought' which could be called 'Symmetrical' or 'Relational' archaeology: "*... while Neolithic societies in Europe were extremely diverse, they were generally characterized by a new kind of relationship between humans and non-humans ... Although post-glacial hunters had been deeply embedded in and attuned to their material world, there was a qualitative difference in the ways in which Neolithic people used material things to articulate social relationships, to extend human presence, and to frame and channel social interaction. We might say that while Mesolithic societies were principally composed of relationships amongst people, and that they operated in worlds of animals and things, Neolithic societies became heterogeneous meshworks in which people, things, and animals were mutually implicated to a greater degree*" (p. 421–422). This passage perhaps best illustrates the way in which neolithisation is explained in the book.

Interestingly, books dealing with neolithisation, and this one is no exception, usually review only the earliest Neolithic evidence in individual regions, even if on an widening geographical scale, this means considering evidence separated by several millennia. Neolithisation, or the transformation from hunter-gatherer to farmer's lifeways, is therefore seen as a universal global phenomenon, which it certainly is, and is approached from a comparative perspective. However, much could be gained also from a more 'historical' consideration of roughly contemporary evidence. In this book, for instance, there could be more consideration of the circular enclosures of the Lengyel, Stroked Pottery, Michelsberg, Chasséen, Funnel Beaker and other cultures, some of which are contemporary with the early British Neolithic and are sometimes seen as precursors to the early Neolithic enclosures in Britain. Furthermore, this book adheres to the conventional model of European neolithisation, at least in the structure of the first few chapters, beginning in Greece and ending in Britain. In his review of the book, Detlef Gronenborn (*Antiquity 88(341) 2014: 989–990*) notices the lack of consideration of recent archaeogenetic research, which he says, "*... may demonstrate a hesitance within British Neolithic archaeology to accept the growing evidence which indicates that, for several millennia, some regions of Europe experienced major population changes*". Rather than focusing on the still sketchy and interspersed archaeogenetic evidence, some of which is nevertheless presented in the book (p. 109–113), we would rather focus on a different issue, related perhaps to Gronenborn's observation cited above. While we personally applaud the enthusiasm with which Thomas writes about the Gathering Time project of Alasdair Whittle and his colleagues and agree with its impact on the "*post-Gathering Time era of Neolithic studies*" (p. 3), we noticed a comparable lack of consideration of other, perhaps no less revolutionary approaches to Neolithic studies. For example, no mention is made of the recent work by Stephen Shennan and his team at University College London (http://www.ucl.ac.uk/euroevol) dealing with the Neolithic from a more demographic and cultural evolutionary perspective and pointing to links between population fluctuations and cultural change. We could characterise Gathering Time as a bottom-up approach and the EUROEVOL project as a top-down approach in the utilisation of ^{14}C data and ultimately in Neolithic studies. However, both kinds of approach are needed, we think, if we are to understand the complex process of neolithisation from a multiscalar perspective. Furthermore, there is a lack in the book of at least a comment or a critique of the research on the impact of climate changes on the demographics and lifeways of Neolithic communities, mainly in continental Europe (Bernhard Weninger and others, also Detlef Gronenborn) but also Britain (*e.g.*, *Bonsall C. et al. 2002. Climate change and the adoption of agriculture in north-west Europe*, cited in the Bibliography).

There is no question, however, that the Birth of Neolithic Britain is a big step forward in understanding the transformations from hunting/gathering to farming regionally, continentally and globally. It represents a holistic synthesis of the current understanding of the neolithisation process in Britain and should be on the bookshelf of every student and researcher interested not only in the British but the European Neolithic as well.

Marko Sraka
University of Ljubljana

Stella Souvatzi and Athena Hadji (eds.)

Space and Time in Mediterranean Prehistory (Routledge Studies in Archaeology). xvi+304 pages, 36 figures, 2 tables. 2014. London: Routledge; ISBN 978-0-415-83732-3 hardback

The collection of papers *Space and Time in Mediterranean Prehistory* is an outcome of the collaboration between Stella Souvatzi, who regularly writes on spatiality within social archaeological themes such as households, as in her recent book *A Social Archaeology of Households in Neolithic Greece*, and Athena Hadji, whose Berkeley PhD thesis was entitled on *The Construction of Time in Aegean Archaeology*. The editors invited researchers from a predominantly interpretative (post-processual) archaeological tradition who deal with Mediterranean prehistory and included a few selected revised contributions to the similarly named session at the 16th Annual Meeting of the European Association of Archaeologists in the Hague. The collection of papers contains 15 chapters by archaeologists, anthropologists and an architect.

This timely volume is an anticipated continuation of the critique of space and time as passive and homogenous backdrops to human life, and treats them as socially constructed, as well as inseparable from human lives and experience. It not only restates the urgency of a theoretical discussion of the conceptualisation of space and time in archaeology, but attempts, perhaps for the first time in archaeology, to treat them as inseparable and as essential to understanding past social relations at different scales. The volume is also innovative in its focus on the whole of the prehistoric Mediterranean, which is too often fragmented in narratives along national, linguistic, academic and other boundaries. The volume stems from "*... the ever-growing interest in space and spatiality across the social sciences; the comparative neglect of time and temporality; the lack in the existing literature of an explicit and balanced focus on both space and time; and the large amount of new information coming from the prehistoric Mediterranean*", which serves "*... as an empirical archaeological background for the application and detailed analysis*" (Preface, p. xv).

The first chapter, written by the editors, serves as a theoretical introduction to the volume and reviews some focal points of research into Mediterranean prehistory, which is then further developed in the following chapter by Robert Chapman. Although not complete in its coverage of the theoretical discussions, the editors' introduction separately presents the conceptualisation of both space and time first in the social sciences in general and then within theoretical archaeology. The volume is an engaging and diverse collection of papers, and the reader can find plenty of useful information and thought-provoking ideas. The editors point to diverse and interesting topics and concepts applied to Mediterranean prehistory in this volume (p. 19–20): houses, households, settlements and communities (Stavrides, Harkness, Watkins, Düring, Marketou, Márquez-Romero & Jiménez-Jáimez and Athanasiou), urban space and planning (Athanasiou), architecture and the built environment (Harkness, Meegan and Márquez-Romero & Jiménez-Jáimez), the social production of space and the dialectical relationship between people and space (Stavrides), embodied space, movement (Harkness, Meegan and Skeates), cultural diversity and differences, social transitions, meaning, identity and memory (Skeates, Miller Bonney, Marketou, Murrieta-Flores and Yasur-Landau and Cline), the concepts of time in terms of social memory, identity and continuity, the transmission of social knowledge and reproduction of architecture (Meegan, Watkins, Düring, Miller Bonney Murrieta-Flores, Márquez-Romero & Jiménez-Jáimez and Yasur-Landau & Cline) as well as residential mobility, discontinuity, abandonment and destruction (Skeates and Marketou). Many contributors deal with similar topics and concepts, but approach them from different spatio-temporal scales. The editors (p. 19) recognise the importance of time perspectivism and of "*... a multiscalar approach to both space and time that will explore linkages between a whole range of spatial an temporal relationships*", critique the overuse of the large-scale, long-term approach and express the "*... lack of a sense of short-term and small-scale social action and the bewildering and contradictory complexity of everyday lived reality*". However, many contributors retain the large-scale, long-term approach, even if enriched by perspectives offered by local contexts, by selecting case studies from across the Mediterranean region or the millennia-long periods of prehistory (Watkins, Düring, Bonney). Some articles are more descriptive (Marketou, Yasur-Landau & Cline) with the addition, of course, of a theoretical commentary.

A critical weakness of the volume is the lack of more contributions from archaeologists more affiliated

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with what it is known as archaeological science, since space and time are central concepts for archaeology in general. The volume would certainly benefit from being more of a bridge between theory and practice in archaeology. When discussing time, the authors, informed of the development in anthropological theory, go further than most other theoreticians; for example, they present a critique of the established dichotomy of linear versus cyclical time, one identified with Western thought and the other with 'traditional' or 'primitive' societies, as well as the dichotomy of objective and subjective time (p. 6). But they do not problematise the related dichotomy of abstract and substantial time or measured time (chronology) and experienced time, which was established by proponents of interpretative archaeology Michael Shanks and Christopher Tilley in their book *Social Theory and Archaeology* (Albuquerque: University of New Mexico Press) and which continues to polarise the treatment of time and perpetuates "*The Two Cultures*" (*cf.* C. P. Snow's 1959 lecture) divide in archaeology. Substantial versus abstract time is of course a valid observation, but it tends to alienate proponents of social archaeology on the one and archaeological science on the other hand. The editors as well as the contributors (with a couple of exceptions: Skeates, Murrieta-Flores) do not attempt to bridge this gap. Most of the articles are written from a phenomenological perspective, which is not contradictory to, and would benefit from, 'scientific' approaches, such as a variety of spatial GIS analyses and temporal Bayesian modelling of calendar chronologies.

Nevertheless, this collection of papers is innovative in that it specifically tries to link the top-down with the bottom-up, the large-scale with the small-scale, the long-term with short-term, and most importantly, structure with agency. As expected, the contributors achieve this with varying success. The diversity of themes and views conveyed by individual papers preclude further summary in the context of this short review. We would, however, like to highlight the excellent paper by Patricia Murrieta-Flores (chapter 11). The author of the paper *Space and Temporality in Herding Societies* (p. 196-213) discusses prehistoric pastoralism and transhumance since the Chalcolithic in the Sierra Morena mountain range of the Iberian Peninsula and integrates space and time through GIS analyses. Time is introduced into the spatial GIS analysis with the help of cost-time models and by accounting for the different types of pasture available during different seasons. The analyses show patterns of regular distances between settlements in travel time. Furthermore, by mapping megaliths, she is able to show that they are located along preferred herding routes. According to the author, "*For herders, to travel through the landscape is also to travel through time, as movement resonates with the seasonal changes of the landscape*". Furthermore, "*Through time, the monuments as works of the ancestors might have served as material reminders of the deep past, of a temporality that extended beyond the seasonal cycle, where every movement acquired time depth, becoming the reiteration of the actual movements of the ancestors*" (p. 209). The monuments along the herding routes thus connect the immediate here-and-now experience of the traveling herder with social memory, the deep past and the ancestors, who perhaps tracked the same routes. In a way, the herder travels both through space and time. We believe this paper is the closest to the ideal to which the volume aspires, namely the multiscalar integration of spacetime with social archaeology, and goes a step further with the much needed bridging of the divide between social archaeology and archaeological science.

In the last chapter, which serves as a discussion (p. 262–291), Stephanie Koerner provides a useful commentary on the major themes and concepts in the volume and 'contextualises' the volume within the framework of a broader interdisciplinary discourse of space and time and how these relate to concepts such as structure and agency. The discussion is a challenging yet compelling philosophical text, which adds the finishing touches to the whole volume by stressing the relevance of issues explored in the volume not just for archaeology, but for the social sciences in general. *Space and Time in Mediterranean Prehistory* is an exciting and innovative collection of papers that should be read by students and researchers interested in the prehistoric Mediterranean, conceptualisations of space and time and those interested in social archaeology and anthropology in general.

Marko Sraka
University of Ljubljana