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A sculpted boulder named 'First Mother' or 'Foremother', found in front of the hearth of 'House XLIV/57' at Lepenski Vir (from Srejović D. 1969. Lepenski Vir. Nova praistorijska kultura u Podunavlju. Srpska književna zadruga. Beograd: V, 35).

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A child born to immigrant parents at Lepenski Vir

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ABSTRACT – *Our 2022 article challenged the traditional view of Lepenski Vir as a Mesolithic village that became Neolithic. Instead, genetic analysis suggests it was founded by Aegean farmers who occasionally admixed with local hunter-gatherers but maintained separate burials. New genomes released by Žegarac* et al. *(*2025*), including that of an infant boy with fully Aegean ancestry during the final phase of occupation, support the presence of entire immigrant families at the site. The discovery of neonates of mixed ancestry beneath house floors highlights complex interactions during the transitional phase. Additional kinship and identity-by-descent analyses offer deeper insight into early farmer-forager admixture processes.*

KEY WORDS – *farmer-forager interactions; Lepenski Vir; Iron Gates; ancient DNA; IBD sharing patterns*

Otrok, rojen priseljenim staršem na Lepenskem Viru

IZVLEČEK – *V članku iz leta 2022 smo izzvali tradicionalni pogled na Lepenski Vir kot mezolitsko naselje, ki naj bi postopoma prešlo v neolitsko. Genetske analize kažejo, da so naselje ustanovili kmetje z območja Egejskega morja, ki so se občasno mešali z lokalnimi lovci-nabiralci, pri tem pa ohranjali ločena grobišča. Novi genomski podatki, ki so jih leta 2025 objavili Žegarac in sodelavci, vključno z genomom dečka egejskega porekla iz zadnje faze poselitve, potrjujejo prisotnost celotnih priseljenih družin. Odkritje novorojenčkov mešanega porekla pod tlemi hiš poudarja kompleksnost interakcij v prehodnem obdobju. Dodatne analize sorodstvenih povezav, identitete in genetskega porekla ponujajo podrobnejši vpogled v zgodnje procese mešanja med prvimi kmetovalci in lovci-nabiralci.*

KLJUČNE BESEDE – *interakcije kmetovalcev in lovcev-nabiralcev; Lepenski Vir; Železna vrata; stara DNK; genetski vzorci sorodnosti po poreklu (IBD)*

Introduction

Since the discovery of Lepenski Vir in 1960, there has been much disagreement over the nature of occupation at the Danube's Iron Gates site. The settlement of trapezoidal houses with red limestone floors has been described as 'Protoneolithic', 'Mesolithic', and even 'Neolithic' (*Jovanović 1969; 1972; Srejović 1969; 1972*). Indeed, aspects of the site's occupation, such as the pervasiveness of death in a domestic context and the use of plaster pyrotechnology to create red limestone floors, point to Southwest Asian Neolithic influences

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(*Nandris 1988; Hodder 1990*). House forms and burial customs, on the other hand, appear to be largely inspired by Iron Gates Mesolithic practices (*Bonsall 2008; Borić* et al. *2008*).

Disentangling what Borislav Jovanović (*1972.49*) called the "*autochthonous and the migrational components*" of the Lepenski Vir culture is far from straightforward. While the site is increasingly portrayed as a melting pot of local and imported traditions (*de Becdelièvre* et al. *2020; Hofmanová* et al. *2022*), the local forager culture is still widely described as 'dominant' during the Mesolithic-Neolithic transition phase, as though the migrants had merely integrated an established community (*Borić 2019.43*). The significance of the genetic evidence cannot be fully appreciated without a brief overview of the chronology of the site. Excavated by Dragoslav Srejović from 1965 to 1970 in advance of the construction of the hydroelectric Djerdap I dam, Lepenski Vir is a palimpsest of human activities ranging from the 10th to the 6th millennia BC (*Srejović 1972*). At least three main phases have been identified. The sequence of occupation broadly runs as follows (*Borić 2016*):

• Early/Middle Mesolithic or Proto-Lepenski Vir phase (*c.* 9500–7400 BC): this phase is characterized by rectangular stone-lined hearths and burials in extended supine and seated positions. Iron Gates hunter-gatherers may have visited the site periodically, using it as a camp, fishing and burial place. A thousand-year hiatus in occupation ensued (*Bonsall* et al. *2002; Borić 2019*).

• Mesolithic-Neolithic transition phase, or Transformational/Early Neolithic, or Lepenski Vir I-II (*c.* 6200–5900 BC): the village of trapezoidal houses belongs to this phase. Over 70 semi-subterranean houses with elaborate red limestone floors were built, almost all facing the river, distributed across at least six successive horizons of occupation (*Srejović 1972*). The site had a planned layout, with radial axes extending from a central building that was trapezoidal in shape and significantly larger than ordinary houses (*Srejović 1974; Radovanović 2000*). The stone statues, shaped like human heads with fish features, also belong to this phase. Some were found deposited on the last floor surfaces of the trapezoidal houses, which were renewed multiple times on the same location. Pottery was already in use (*Garašanin, Radovanović 2001*). Both intramural and extramural burials in extended supine position occur during this period. Some individuals were buried at the periphery of the village, in large multi-inhumation pits. Burials in flexed position on one side remain rare.

• Early-Middle Neolithic or Lepenski Vir III phase (*c.* 5900–5500 BC): after the trapezoidal houses were abandoned, a new settlement was established (*Srejović 1969*). Bayesian modelling of calibrated radiocarbon dates by Dušan Borić (*2019.28*) indicates that there was no break in occupation between this phase and the preceding one. Pit dwellings and, subsequently, quadrangular mud houses with domed ovens were constructed (*Srejović 1972*). The dead were now predominantly buried in a flexed position in the upslope area at the rear of the site. Some were buried within the fill of older trapezoidal houses, which may still have been visible as footprints on the surface of the site. The use of stone slabs to cap the burials, and in at least one case, the placing of an aniconic sandstone boulder near the skull of the deceased, recall earlier practices of the Mesolithic-Neolithic transition phase (*Borić 2016.315*). Bones of domesticated animals are recorded for the first time, but make up only a small percentage of the site's faunal assemblage (*Borić, Dimitrijević 2007*).

Lepenski Vir hardly conforms to Gordon Childe's notion of an imported Neolithic 'revolution' originating in the Near East (*Childe 1936; Brami 2019*). Although the village of trapezoidal houses is contemporaneous with Early Neolithic Starčevo settlements of the central Balkans (*Porčić 2024*), it has no close equivalent there. The site's location in the centre of the Iron Gates gorge, on the Danube River, near well-known fishing spots, speaks against an agricultural backdrop. Domesticates remain rare, even in the final phase of occupation at the site (*Borić, Dimitrijević 2007*). A detailed examination of organic residues in ceramic sherds from Lepenski Vir and other Iron Gates sites revealed that vessels were predominantly used for processing aquatic resources, which is unusual for European Neolithic sites (*Cramp* et al. *2019*).

Yet the biomolecular picture for human skeletons buried at Lepenski Vir is more contrasted. Archaeobotanical investigations of micro-plant remains trapped in the dental calculus of Transitional and Early/Middle Neolithic Phase individuals suggest the consumption of cereals (*Cristiani* et al. *2016; Filipović* et al. *2017; de Becdelièvre* et al. *2021*). Stable isotope analyses indicate an abrupt transition to a terrestrial diet *c.* 6200 BC, consistent with farming (or the con-

sumption of terrestrial resources in childhood, before individuals moved to the site). Isotopically, a shift in $\delta^{15}N$ signatures can be observed at the outset of the Mesolithic-Neolithic transition phase (*Bonsall* et al. *1997; 2004*). While Iron Gates Mesolithic skeletons have high $\delta^{15}N$ values, ranging from 13–16‰, compatible with fishing activities, those from the transitional period at Lepenski Vir can be as low as 10‰, suggesting consumption of lower trophic-level food, such as plant resources and primary herbivores (for an overview of the stable isotope values, see Maxime Brami *et al.* (*2022*), supplementary file 1). Interestingly, human isotopic signatures throughout this period fall on a continuum, with some individuals looking more like farmers isotopically and others more like fishers, or any shade in-between (*de Becdelièvre* et al. *2020*).

Ancient DNA adds further dimensions to the Lepenski Vir conundrum. Individuals buried at the site derive their ancestry from two distinct gene pools (*Hofmanová 2017; Mathieson* et al. *2018; Brami* et al. *2022; Hofmanová* et al. *2022; Marchi* et al. *2022*). Older genomes from Danubian or 'Iron Gates Hunter-Gatherers' (abbreviated as 'Iron Gates HG'), such as those from the Early/Middle Mesolithic phase, are homogeneous in their ancestry. By contrast, genomes associated with individuals from later phases, including those from the Early-Middle Neolithic phase, have an ancestry profile highly similar to Early Neolithic farmers of Anatolia and the Aegean Basin (abbreviated as 'Aegean'; see Brami (*2023*) for a discussion of the terminology). For a short period of time, at the start of the Mesolithic-Neolithic transition phase, both 'Iron Gates HG' and 'Aegean' ancestries are observed at the site. Some individuals buried then are entirely of 'Iron Gates HG' ancestry, while others are entirely of 'Aegean' ancestry. A third group is admixed in various proportions.

Aleksandra Žegarac *et al.* (*2025*) have now released four additional human genomes from Lepenski Vir, produced in the Palaeogenetics Laboratory of Johannes Gutenberg University Mainz. Three out of four genomes belong to neonates or very young infants, who were potentially born at the site. This article explores the implications of the new genomes for the overall interpretation of Lepenski Vir. A model in which Neolithic women joined a Mesolithic settlement is hardly compatible with the evidence presented here. Despite two populations mating at the site, there was no fusion of ancestry during the last phase of occupation, which reflects instead the arrival of migrant families from the Aegean basin. The finding of admixed neonates under trapezoidal house floors raises important questions about the function of these structures and the practice of subfloor burial.

Results

Evidence for migrant families at Lepenski Vir

In 2013, the publication by Dušan Borić and Douglas T. Price of strontium isotope results from Lepenski Vir and other Iron Gates sites served as a backdrop for the elaboration of a new interpretive model that remains dominant to this day (*Borić, Price 2013; Borić* et al. *2018*). Borić and Price (*2013.3302*) suggested that Lepenski Vir represented an established Mesolithic community that was joined by a few Neolithic women. The latter presumably came from Early Neolithic Starčevo sites outside the Iron Gates gorge, "*as part of an ongoing social exchange*" between Mesolithic and Neolithic communities. As will become clear, this model does not align well with the evidence obtained with aDNA. Furthermore, the underlying sexing information, based on anthropological markers, has since been found to be largely unreliable, with five out of 12 individuals (41.7%) sexed differently using molecular sex estimation methods (*Hofmanová* et al. *2022*). For instance, one of the 'females' used to argue for an influx of 'non-local' females to Lepenski Vir, Lepe32 in Burial 66, has since been found to be genetically male (*Hofmanová 2017.41*).

In our 2022 article for *Journal of World Prehistory*, we showed how the presence of Aegean men, women and children at Lepenski Vir – both during the Mesolithic-Neolithic transition and the Early/Middle Neolithic phases (Fig. 1) – challenged the model of an established Mesolithic community joined by a few Neolithic women (*Brami* et al. *2022*). The question remained whether newcomers had integrated an existing gene pool, or if entire families had instead relocated there, founding new lineages and households (*Brami, Diekmann 2023*). Newborns with Aegean ancestry would suggest mating interactions amongst migrants at the site, supporting the latter hypothesis. Now, a critical piece of thezpuzzle has been discovered, showing that some of the Aegean newcomers present at the site were born there, presumably to immigrant parents or their descendants. Indeed, Žegarac *et al.* (*2025*) report the genome of an infant boy whose ancestry profile reveals no signs of admixture whatsoever with Iron Gates HGs.

The genome in question belongs to Burial 83b, described as a 'neonate' in earlier publications, with an

age given as 48–50 weeks old (*Stefanović, Borić 2008; Borić 2016*). The age of this individual, calculated on the basis of the size of the humerus (82mm), has been previously given in gestational weeks, which is odd for a child that was already born. At 38–40 weeks, the humerus of a human foetus measures only 60–65mm (*Chitty, Altman 2002*). Burial 83b thus belonged to a neonate or a young infant, likely only a few weeks old, when he died. Our own analyses confirm that this child was directly descended from Aegean ancestors, clustering in PCA space with Early Neolithic individuals from Northwest Anatolia, for instance from the site of Barcın Höyük (Fig. 2.a). Naturally, we cannot exclude that the child was conceived outside of marriage and/or before his mother became a member of the Lepenski Vir society.

Infant 83b is associated with the latest phase of occupation at Lepenski Vir, dated to the Early/Middle Neolithic (5900–5500 BC). By that time, the trapezoidal houses were no longer in use and burial activities shifted to the northwestern edge of the settlement. The infant was found beside an adult, Burial 83a, and the remains of a neonate, in an unbuilt space near a large rock (*Borić 2016*). Radiocarbon dating suggests that the child (5762–5567 cal BC, 95% CI) was buried in this location several hundred years after the adult (6068–5914 cal BC, 95% *CI*), who was neither a biological parent nor a more distant relative (*Žegarac* et al. *2025*). We have now further confirmed this by additionally estimating biological relatedness using KIN for all published genomes at Lepenski Vir (see Supplementary Material, available online at https://doi.org/10.4312/dp.52.15). Although the adult and child are biologically 'unrelated', they share a common ancestry profile and likely originated from the same Aegean metapopulation (Fig. 2). In sum, there is conclusive evidence for the arrival of migrant families at Lepenski Vir and for the birth of children with entirely Aegean ancestry.

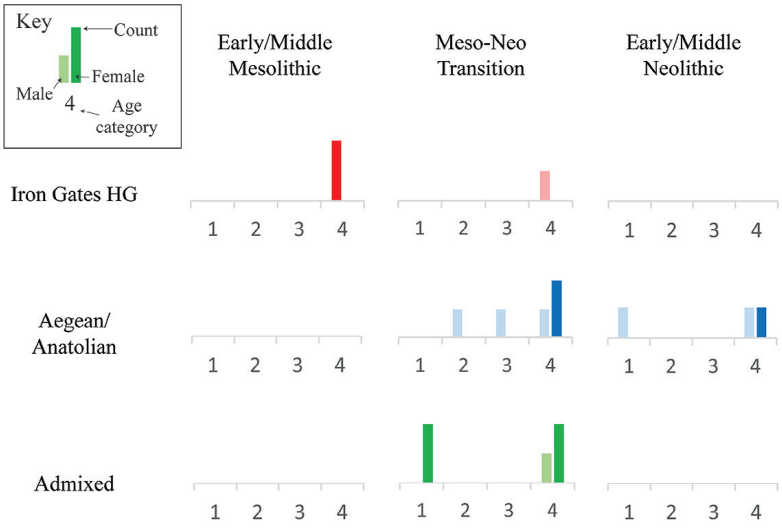

Fig. 1. Sex, age and ancestry background of the Lepenski Vir individuals that have produced genomic information. For a detailed overview of ancestry profiles (determined using a two-population qpAdm model) in each phase, see Table 1. Age categories:* 1 *Neonate/Infant (0–1 yrs);* 2 *Child (2–12 yrs);* 3 *Adolescent (13–17 yrs);* 4 *Adult (≥18 yrs).

Farmer-forager interactions were intensive but had no lasting impact on the Lepenski Vir gene pool

In their chapter for the book *Farmers at the Frontier*, Camille de Becdelièvre *et al.* (*2020.47*) argue that Lepenski Vir represented the harmonious fusion of two ancestries and cultural traditions, which they call the 'Mesolithic-Neolithic culture'. The underlying assumption is that farmer-forager interactions were finely balanced, at least during the Mesolithic-Neolithic transition phase, with Neolithic farmers raising their children as fishers ('Mesolithized farmers'), and Mesolithic foragers becoming farmers ('Neolithized foragers') (*O.c. 66*). Lepenski Vir, in other words, would serve as a paradigm for peaceful coexistence between farmers and foragers, living side by side and jointly adopting the Neolithic way of life. Farming frontier models, which entail the slow 'fusion' between incomers and indigenous people, have become less prominent since the aDNA revolution (*Zvelebil 1986; Bánffy, Whittle 2024*). Indeed, recent genetic studies reveal that Mesolithic ancestry made up less than 10% of the overall Danubian Neolithic gene pool (*Marchi* et al. *2022*). The patterns of recent admixture observed at Lepenski Vir, which happened at most two generations in the past, remain exceptional (*Brami* et al. *2022*).

Are fusion models nonetheless relevant to interpret the aDNA evidence from Lepenski Vir? A Mesolithic-Neolithic fusion model would imply panmixia and random distribution of ancestries at Lepenski Vir. We have previously argued that such a scenario is unlikely in light of the genetic evidence (*Brami* et al. *2022*). The fact that Aegean ancestry is so persistent at Lepenski Vir – and indeed becomes dominant during the final phase of occupation (Fig. 3) – is a strong argu-

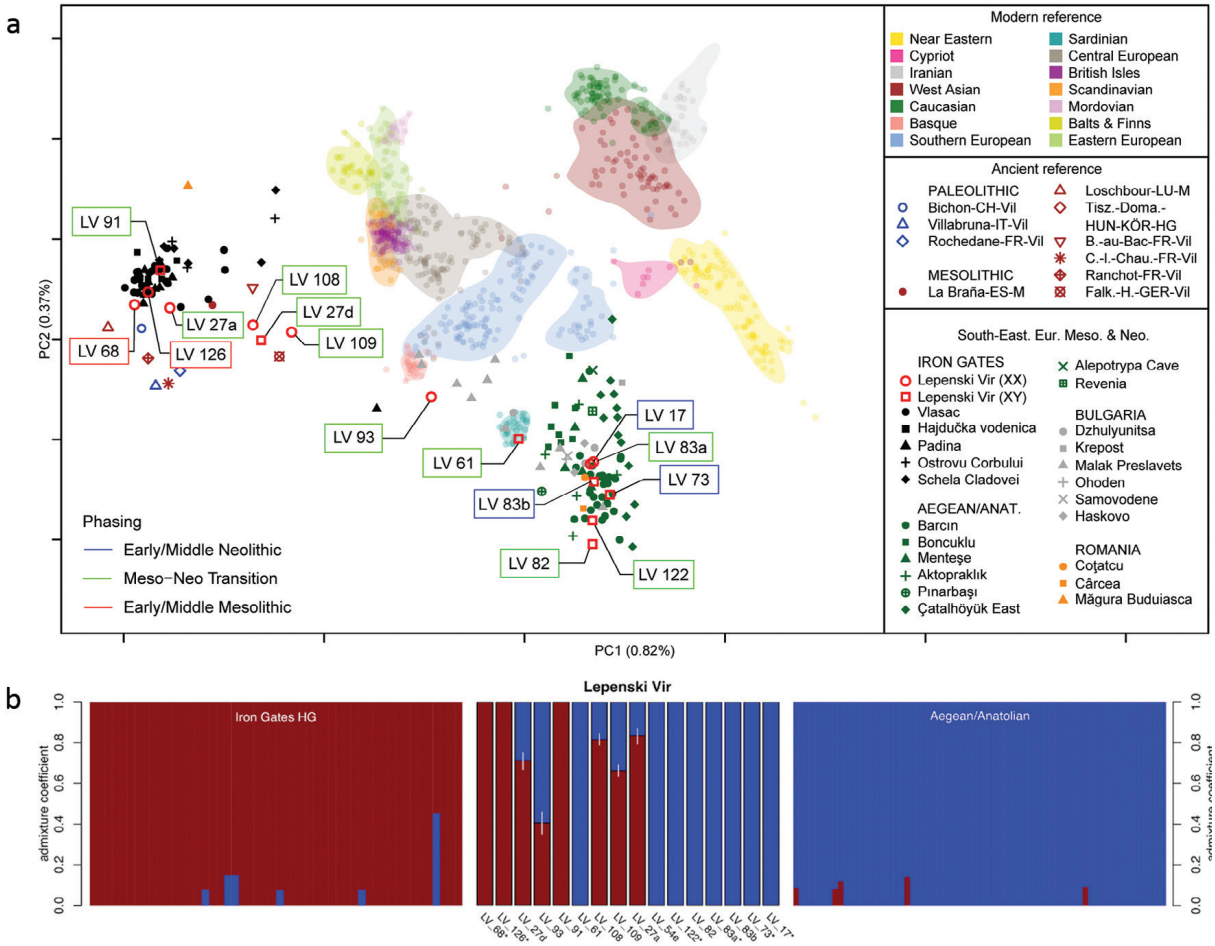

Fig. 2. **a** ***PCA of modern and projected ancient West Eurasians and Southwest Asians highlighting the Lepenski Vir (LV) individuals of the different phases;*** **b** ***Lepenski Vir individuals modelled as mixtures of Iron Gates HG and Aegean–Anatolian ancestry components with qpAdm. Updated after Brami*** **et al.** ***(2022). Each panel is ordered chronologically from oldest to youngest. Lepenski Vir burial No. abbreviated as LV.***

ment against the 'autochthonou' view of the site as a Mesolithic village that became Neolithic. For instance, Borić (*2016.347*) has suggested "*that the population of Lepenski Vir during [the Early/Middle Neolithic] phase III was a mixture of foreign women, and men and women who were descendants of the indigenous population but had by this time fully adopted Neolithic life- and death-ways*". Such a view is no longer tenable in light of the aDNA evidence.

If two stable populations of equal size had freely admixed at the site, we would expect their descendants to display *c.* 50:50 admixture ratios in the final phase of occupation, which is not what we observe at genomic level. Later individuals show as 100% Aegean in a two-population qpAdm model (Fig. 2.b). The ancestry profile of infant 83b suggests that a new wave of Aegean migrants arrived at the site, eventually supplanting or fully assimilating the pre-existing population. Alternatively, the fertility of Aegean farmers would have needed to be so high that any initial contribution of Iron Gates HG genes was ultimately lost. Mating would need to be tightly controlled for this model to be viable.

In sum, the Mesolithic-Neolithic transition phase (6200–5900 BC) is so far the only period when admixture between Aegean and Iron Gates HG populations is observed. A small community like Lepenski Vir might be expected to include both close biological relatives and more distant ones. However, so far, kinship analyses have only yielded negative results, with all individuals sampled appearing as 'unrelated', that is, within the first- to third-degree (*Brami* et al. *2022; Žegarac* et al. *2025*). The lack of close biological relatives at Lepenski Vir raises questions about sample size – 16 whole or partial genomes (Tab. 1) – and the nature of inhumations at Lepenski Vir, which may have attracted burials beyond the immediate community.

Despite Lepenski Vir's proximity to Padina and Vlasac, which are located on the same bank of the Danube, no identity-by-descent (IBD) sharing patterns have been detected between these sites (Fig. 4). The sole connections are with sites further downstream in the Iron Gates, namely Hajdučka Vodenica and Schela Cladovei (*Žegarac* et al. *2025*). For now, only individuals from the Mesolithic-Neolithic transition phase share long IBD segments (≥16 cM) at Lepenski Vir. Segments of DNA that are identical by descent are inherited from a common ancestor and are shortened over time by recombination. The number and length of shared segments can therefore be informative of the degree of genetic relatedness. While close relatives share higher

Burial No.	Genetic ID	Sex	Age	Body position	Cal BC (OxCal μ)	qpAdm	mtDNA	Y	References
Mesolithic (*c.* 9500-7400 BC)									
20	Lepe12	f	adult	FL	9006	..	U5	..	(1), (2)
68	Lepe51	XX	adult	ES	7764	Iron Gates HG	U4	-	(1), (2)
74	Lepe34	XX	adult	FL	8017	..	U5	..	(1), (2)
105	Lepe47	XX	adult	D	7674	..	U5	-	(1), (2)
126	I5407/Lepe49	XX	adult	D	..	Iron Gates HG	H	-.	(1), (2), (3)
Mesolithic-Neolithic Transition (*c.* 6200-5900 BC)									
11	Lepe7	XX	subadult	ES	6153	..	K	-	(1), (2)
21	Lepe13	XY	adult	D	5921	..	X	-	(1), (2)
26	Lepe15	m	adult	ES	5930	..	H	..	(1), (2)
27a	Lepe53	XX	adult	ES	6051	admixed	U5	-	(1), (2)
27b	Lepe17	XY	adult	ES	..	..	N1a	..	(1), (2)
27d	Lepe18	XY	adult	ES	6099	admixed	U5	I2	(1), (2)
39	Lepe22	XX	adult	D	5921	..	J	-	(1), (2)
43	Lepe23	..	subadult	D	..	..	K	..	(1), (2)
54d	Lepe28	XX	adult	ES	6151	..	K	-	(1), (2)
54e	I4665/Lepe27	XX	adult	ES	6047	Aegean	J	-	(1), (2), (3)
57	Lepe29	XX	subadult	D	5904	..	U5	-	(1), (2)
61	I4666	XY	child	ES	6056	Aegean	H	R1b	(3)
79b	Lepe37	XY	adult	D	..	..	U5	..	(1), (2)
79c	Lepe38	m?	adult	D	..	..	U5	..	(1), (2)
82	Lepe39	XY	adult	D	..	Aegean	T2	C2	(1), (2)
83a	Lepe40	XX	adult	FL	6068–5914*	Aegean	K1	-	(5)
87(1)	Lepe42	XY	child	D	..	..	U5	..	(1), (2)
89a	Lepe44	XY	adult	ES	5920	..	U5	..	(1), (2)
91	Lepe45	XY	adult	ES	6065	Iron Gates HG	U5	I2	(1), (2)
93	Lepe46	XX	adult	ES	6091	admixed	H	-	(1), (2)
108	Lepe54	XX	neonate	FL	6066–5847*	admixed	U5	-	(5)
109	Lepe55	XX	neonate	FL	6372–6073*	admixed	H	-	(5)
122	Lepe48	XY	subadult	D	5995	Aegean	K	C1	(1), (2), (4)
Early/Middle Neolithic (*c.* 5900-5500 BC)									
6	Lepe3	..	subadult	FL	..	..	N1a	-	(1), (2)
8	Lepe6	XX	adult	FL	5888	..	T1	-	(1), (2)
17	I5405	XX	adult	FL	5731	Aegean	HV	-	(3)
19	Lepe11	f	adult	FL	..	..	K	-	(1), (2)
32a	Lepe20	XX	adult	FL	5912	..	HV	-	(1), (2)
35	Lepe1	XX	adult	D	5640	..	H	-	(1), (2)
66	Lepe32	XY	adult	FL	5559	..	N1a	..	(1), (2)
73	Lepe52	XY	adult	FL	5819	Aegean	H	G	(1), (2), (4)
83b	Lepe58	XY	infant		5762–5567*	Aegean	T2	G	(5)
86	Lepe41	XY	..	D	..	..	J	..	(1), (2)

Tab. 1. List of previously-reported Lepenski Vir genomes used for this study (updated after Brami* et al. *(2022)). Genetic sex reported as XX/XY (where available). Anthropological sex reported as m/f. Key:* D *disarticulated;* ES *extended supine;* FL *flexed. References: (1) Hofmanová 2017; (2) Hofmanová* et al. *2022; (3) Mathieson* et al. *2018; (4) Marchi* et al. *2022; (5) Žegarac* et al. *2025. Dating: *as reported.

numbers of larger segments, numbers bers and sizes decrease with increasing numbers of generations to the common ancestor. Previous studies suggest that shared segments larger than 10 centimorgans (cM) indicate a common ancestor within the last 500 years (*Speed, Balding 2015*). Such relationships are known in the genetic literature as 'cryptic relatedness' (*Sul* et al. *2018*). Demography is an important factor when interpreting IBD sharing patterns. The lack of IBD sharing among Aegean individuals may reflect, for instance, the larger effective size of this population compared to Iron Gates HGs.

While the two neonates analysed by Žegarac *et al*. (*2025*), Burial 108 and Burial 109, are beyond third-degree related, according to current kinship estimation methods, they share one IBD segment longer than 20cM, indicative of distant relatedness (Fig. 4). Both show significant Iron Gates HG ancestry proportions in a two-population qpAdm test, ~82% for Burial 108 and ~66% for Burial 109, consistent with three grand-parents from the local gene pool. The neonates also share respectively one segment of IBD longer than 16 cM (Burial 108) and two segments of IBD longer than 20 cM (Burial 109) with an adult male, buried at the periphery of the village in a large pit, Burial 91. The latter was previously identified as deriving all of his ancestry from the Iron Gates HG gene pool (*Brami* et al. *2022*).

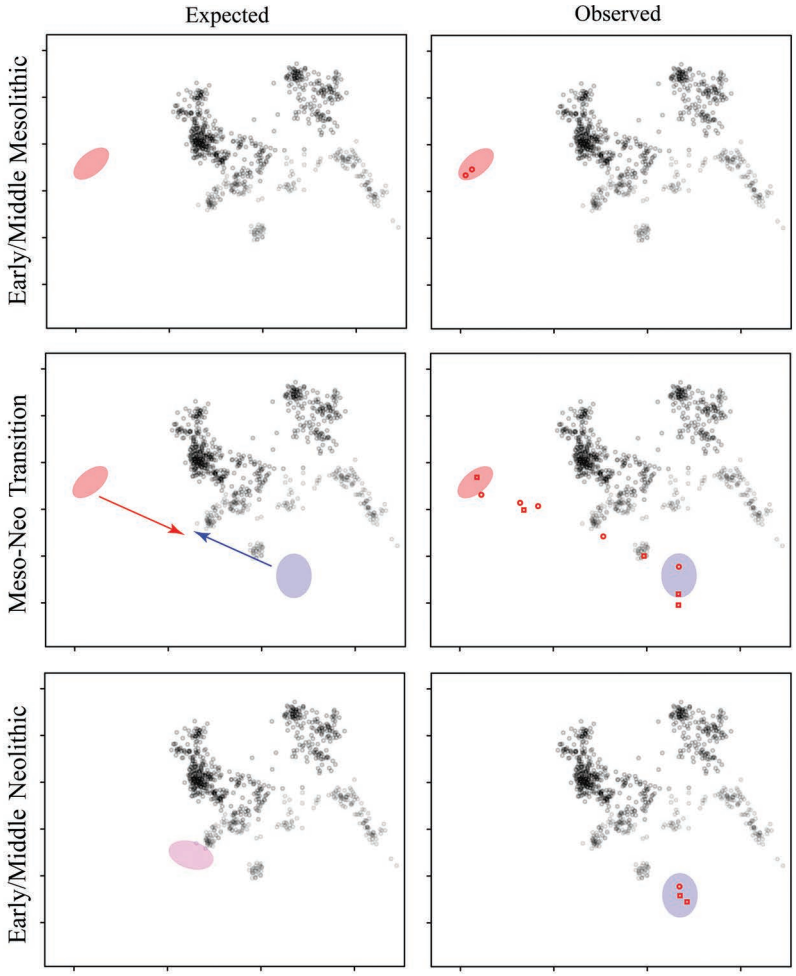

Fig. 3. Schematic view of the PCA showing expected patterns under a model of Mesolithic-Neolithic ancestry fusion, as opposed to observed patterns for Lepenski Vir (see figure 2 for details). Modern reference genomes are indicated in grey for orientation. If two populations of roughly equal sizes (red: Iron Gates HGs; blue: Aegean early farmers) had freely admixed at Lepenski Vir, one would expect their ancestries to fuse over time, resulting in a new population of admixed ancestry (purple). However, patterns of observed variations show that admixture processes between the two populations were short-lived. Indeed, Lepenski Vir individuals of the Early-Middle Neolithic phase fall close to Aegean early farmers on PCA.

New IBD results (Fig. 4) raise the possibility that several generations of Iron Gates HGs and/or their admixed descendants lived at the site of Lepenski Vir, possibly alongside Aegean farmers with whom they repeatedly mated. No clear direction of gene flow between the populations is evident, suggesting that males and females of both groups were involved equally. For instance, the percentage of Iron Gates HG ancestry is higher on the autosomes than on the X chromosome for neonate 108, which suggests that the excess of HG ancestry came from the father's side (Fig. 5).

The opposite is true for adult male 27d, who primarily derived his HG ancestry from his mother and likely had an admixed father. While patterns of farmer-forager interactions were short-lived and had no long-term impact on the Lepenski Vir gene pool, they represent a unique experiment in later European prehistory that deserves further investigation.

Population structure and burial distribution: the case of the neonates buried under trapezoidal house floors

The distribution of burials can hardly be described as random during the Mesolithic-Neolithic transition

phase. We have previously highlighted the presence of structure based on ancestry (*Brami* et al*. 2022; Brami, Diekmann 2023*). Individuals of Aegean ancestry appear to be preferentially buried within the village, inside or in-between trapezoidal houses, whereas Iron Gates HGs are primarily buried outside in pits (Fig. 6). The latter exhibit a more restricted range of isotopic signatures, consistent with a fish-based diet (*Brami* et al. *2022*). We can now refine this model, taking into consideration the two admixed neonates, found under trapezoidal house floors 4/4' at the centre of the village, Burials 108 and 109, both female (*Žegarac* et al*. 2025*).

These results do not fundamentally change the picture outlined in Brami *et al*. (*2022*), but raise new questions about the function of the trapezoidal houses and the practice of neonate burial under floors. Even considering the new genomes reported by Žegarac *et al.* (*2025*), the association between U mitochondrial lineages (typical for European hunter-gatherers) and burials outside in pits remains statistically significant (Fisher's exact test, p=0.00077). This association holds at the nuclear genomic level. Indeed, the three whole-genomes from the external pits (Burials 27a, 27d and 91) have more Iron Gates HG ancestry on average than other individuals from the transitional phase, including the neonates (permutation test, one-sided p= 0.0354). So far no Iron Gates HGs have been found buried inside the village of trapezoidal houses. All those buried intramurally are either of Aegean ancestry or admixed.

Our overall conclusion that Lepenski Vir was a first-generation pioneer site, founded by Aegean farmers, who occasionally admixed with the indigenous population of the Iron Gates, remains consistent with the evidence (Brami *et al*. 2022). Other scenarios are plausible, but do not fully account for spatial variations in genetic ancestry between areas inside and outside the village of trapezoidal houses. For instance, the site could have been settled by an already admixed population, who welcomed additional Aegean farmers, hence the gradual shift to Aegean ancestry observed during the Mesolithic-Neolithic transition phase (Fig. 2.b). Some of the intramural burials in the transitional phase could have been intrusive (*Perić, Nikolić 2016*), though Borić (*2019*) has offered a systematic refutation of this hypothesis in his article for *Starinar.*

Given that nearly all newborn infants (N=41) were found buried beneath trapezoidal house floors, we

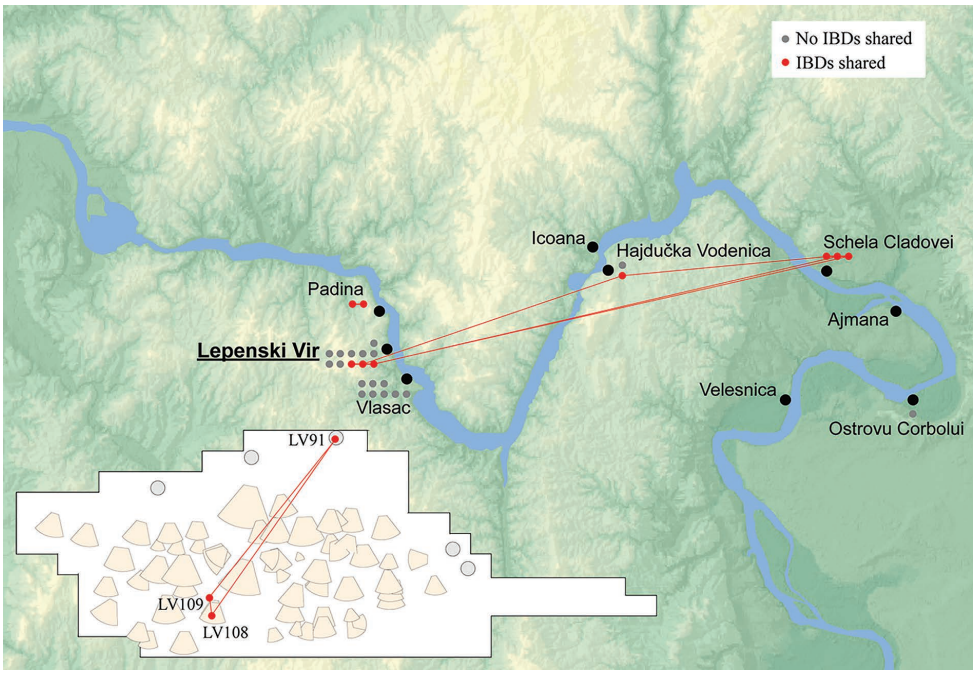

Fig. 4. Map showing pairs of individuals from the Iron Gates who share long genomic segments identical by descent (IBD). Sites where individuals are sharing at least one segment of 16cM are linked by a red line. IBD sharing patterns for the Mesolithic-Neolithic Transition phase at Lepenski Vir are indicated (see Figure 6 for reference). All IBDs are shared between individuals with an Iron Gates HG ancestry profile. IBD sharing patterns as reported by Žegarac* et al. *(2025). Notice that only genomes from the Iron Gates sites were included in this analysis.

previously postulated that non-kinship criteria, such as relative age, trumped ancestry in the relevant context at Lepenski Vir. As stated in our 2022 article:

"*We expect neonate burials to show different ancestry profiles compared to other community members buried within the houses, who may not have been co-residents*" (*Brami* et al. *2022. 121*).

The burial of neonates under house floors has chilling echoes in the Anatolian Neolithic, where neonates appear to be frequently buried intramurally, close to children and adults who were not biological relatives (*Yaka* et al. *2021; Yüncü* et al. *2025*). For instance, this practice has been documented at the 7th millennium BC sites of Barcın in Northwest Anatolia and Çatalhöyük East on the Central Anatolian Plateau. Both sites are plausible sources for the Aegean ancestry observed at Lepenski Vir. Preindustrial societies experienced high infant mortality. Infanticide, which is often described as an adaptive strategy for regulating birth rates (*Langer 1974; Hausfater, Hrdy 1984*), may also have contributed to the high number of buried neonates at small-scale farming sites.

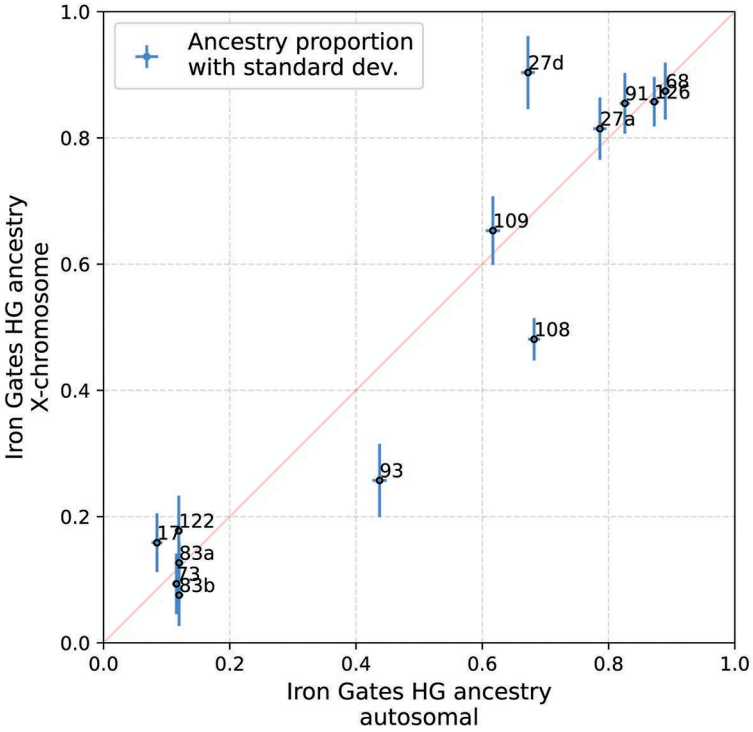

Fig. 5. Proportion of Iron Gates HG ancestry on the X chromosome and the autosomes with standard obtained from 5cM jack-knifing. Ancestry proportions were estimated as f3(Test, Iron Gates HG, Aegean)/f2(Iron Gates HG, Aegean); only individuals with at least 2000 SNPs on the X-chromosome were used. Any value significantly below the diagonal line would indicate an additional Iron Gates HG ancestry contribution on the father's side. Conversely, any value significantly above the diagonal line would indicate an additional Iron Gates HG ancestry contribution on the mother's side. At present, no sign of a systematic sex-biased admixture in one or the other direction can be observed.

Given the increase in fertility observed at Lepenski Vir and other Iron Gates sites from *c.* 6200 BC onward, a corresponding increase in infant mortality is expected (*Porčić, Nikolić 2016; de Becdelièvre* et al. *2021*). Over 70% of infants buried at Lepenski Vir died around the time of birth, at *c.* 38–40 gestational weeks, which reflects higher risk factors for ill health in the first weeks of life (*Stefanović, Borić 2008.6*). This timeframe is also consistent with infanticide. Sofija Stefanović and Dušan Borić (*2008*) have previously argued against infanticide at Lepenski Vir based on the balanced ratio of male to female infants. However, the supporting sexing information, based on PCR amplification of the amelogenin locus (*Čuljković* et al. *2008*), is highly dependent on DNA preservation. Newer sexing methods rely on the ratio of reads aligned to the X/Y chromosomes, without targeting specific regions. Therefore they are much more robust and usually reliable even at lower read numbers.

Female infanticide, the selective killing of newborn female children, would result in an overrepresentation of female infants (*Roberts, Manchester 1995*). This practice is still prevalent in several countries around the world. Intriguingly, five out of six of the newborn infants reported by Žegarac *et al.* (*2025*), all from the Mesolithic-Neolithic transition phase, have now been identified as genetically female (not all have produced sufficient genetic information for ancestry modelling). While sample size remains very small, no conclusion can be ruled out at this stage on the cause of death of the neonates. Historically, newborns have been killed for a variety of reasons, including lack of food, sickness and illegitimacy (*Langer 1974*).

Žegarac *et al.* (*2025*) claim that the trapezoidal houses at Lepenski Vir served as communal places to give birth or as nurseries to shelter babies from cold weather. Even if such interpretations were to be accepted, it is unlikely that all such buildings served this purpose.

Attempting to determine the function of spaces based on their burial content is difficult, not least because the trapezoidal buildings were abandoned in a structured manner after several phases of use (*Borić 2003*). Burial 108 was found deposited beneath the floor of Building 4 and Burial 109 just outside the SW corner of Building 4', an earlier house of roughly the same trapezoidal footprint (*Borić 2016*). Six neonates were detected within this building sequence; only two of them have produced genomic data (*Stefanović, Borić 2008*). For now, it is still unclear if the burials were placed before or after the reddish limestone floor was laid, or if the houses were in use at the time of deposition, although capping of burials by later floors would make this likely. If the neonates were systematically buried in foundation deposits rather than subfloor burials, deliberate killing would not only be plausible, but also likely. Only a detailed re-examination of the stratigraphy of the site, combined with denser sampling of the neonates, can help to address this issue.

Discussion: ancestry and culture at Lepenski Vir

The biomolecular data from Lepenski Vir continue to resist simple classification. During the so-called 'Mesolithic-Neolithic transition' phase, Lepenski Vir

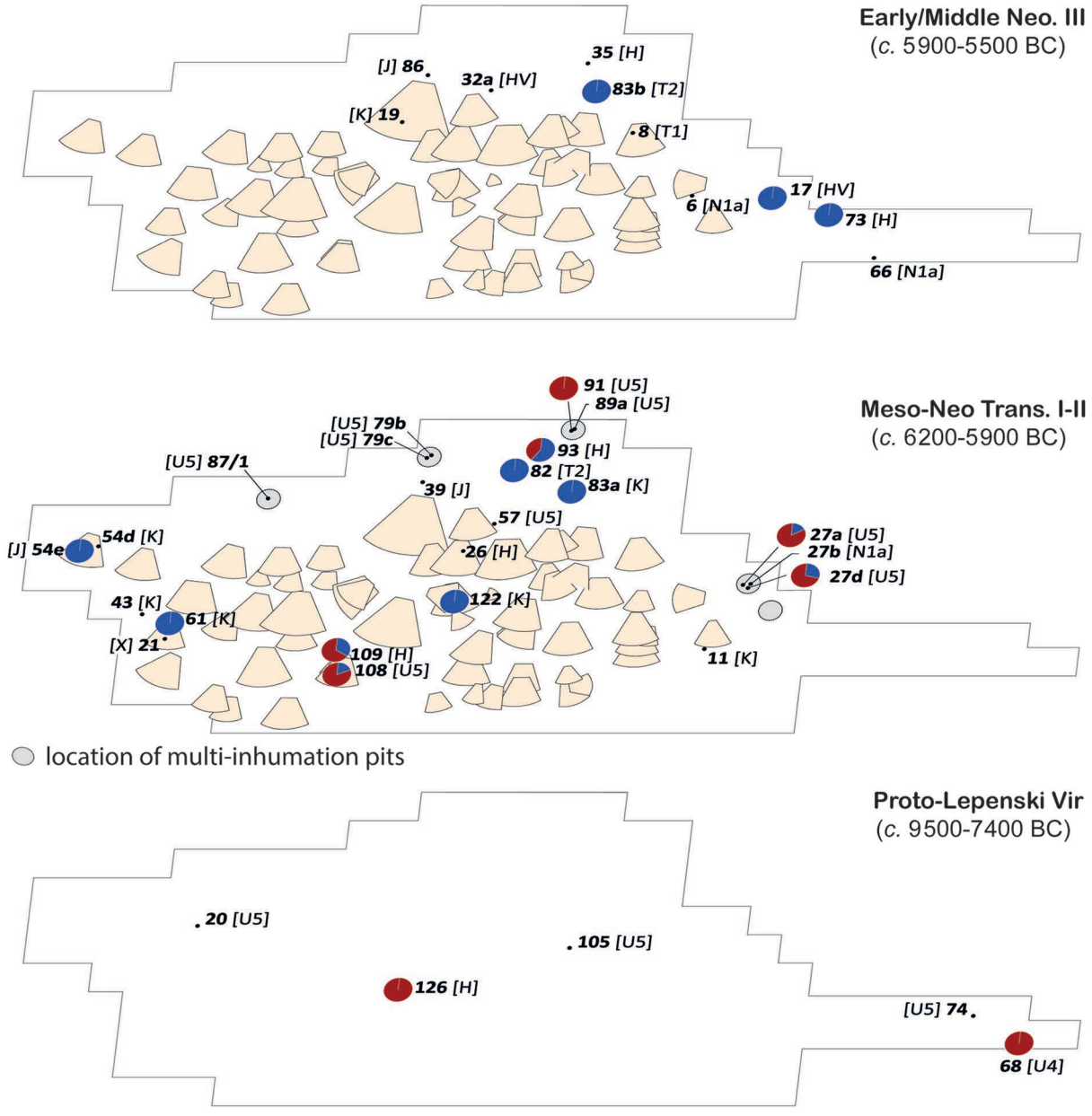

Fig. 6. Distribution of ancestry proportions (see Figure 2; pie charts: red: Iron Gates HG; blue: Aegean–Anatolian) and mitochondrial haplogroups (square brackets) for selected individuals during the three main phases of occupation at Lepenski Vir. Updated after Brami* et al. *(2022).

I-II, the site was a gathering point for two populations, Iron Gates hunter-gatherers and Aegean farmers, who appear to have raised their children together while burying their dead largely separately. Given the importance of the 'migrational component' to the Lepenski Vir culture, the site can hardly be described as a Mesolithic village (*Jovanović 1972*). Lepenski Vir might instead be thought of as a pioneer village or a gateway community that welcomed people from different horizons. The Iron Gates gorge was neither secluded nor unpopulated at the outset of the Early Neolithic, serving as one of the key stepping stones for farming expansion on the Danube river (*Marchi* et al. *2022*).

At the same time as early farmers settled in the central Balkans (*c.* 6200 BC), men, women and children of Aegean ancestry arrived at Lepenski Vir. They were preferentially buried inside or in-between trapezoidal houses, which may have been their homes. Some of their admixed descendants, like the two neonates buried in house 4/4', were also buried intramurally. A range of scenarios can explain the admixture patterns observed at the site, from random mating to sexual violence. The latter scenario cannot be ruled out, although it looks unlikely in view of the fact that men and women from both populations participated in this interaction process (Fig. 5). Conversely, the idea of a completely free and unregulated mating system between Aegean farmers and Iron Gates hunter-gatherers is only plausible for a short period of time, at the start of the Lepenski Vir I-II phase, and fails to account for the gradual shift to Aegean ancestry during this period. Later individuals of the Lepenski Vir I-II phase, dated to 6071–5914 cal BC at 1σ (68% probability) after correction for freshwater reservoir effect (Burials 54e, 82, 83a and 122), can be described as having 100% Aegean ancestry in a two-population qpAdm model (Fig. 2.b).

Further cultural changes were observed during the final phase of occupation, Lepenski Vir III. Trapezoidal houses ceased to be used and material culture changed abruptly to reflect Early Neolithic Starčevo influences (*Srejović 1969*). The changes at the site were not simply due to the introduction of agriculture, as suggested by Srejović (*1969.35*). Nor can the changes in the Early/Middle Neolithic phase be explained by the admixture of Mesolithic inhabitants with a few Neolithic farmers (*Borić 2016.347; de Becdelièvre* et al. *2020.57*). The contribution of the Iron Gates hunter-gatherers to the Lepenski Vir gene pool was entirely lost during this period – suggesting that the site had been abandoned and re-occupied by a new population of farmers from outside the Iron Gates gorge. An important piece of evidence has been presented in this article: an infant boy was born at the site to immigrant parents in phase III, Lepe58 in Burial 83b (*Žegarac* et al. *2025*). None of his ancestors came from the Iron Gates HG population. It is a strong indication that entire migrant families settled there, as opposed to individuals continuously joining an existing gene pool.

But even during the preceding Mesolithic-Neolithic transition phase, children and adolescents of Aegean ancestry were buried at Lepenski Vir, *e.g.*, Burials 61 and 122 (*Mathieson* et al. *2018; Marchi* et al. *2022*). Systematic sampling of neonates for aDNA would no doubt reveal further examples of children born at the site to immigrant parents. Interactions between farmers and foragers were thus short-lived and unbalanced, resulting in the genetic variation associated with Iron Gates HGs gradually being lost. At present, it looks as though farmer-forager interactions were restricted to the beginning of the transitional phase, when Lepenski Vir was still at the forefront of the Neolithic wave of advance.

Essential categories such as 'Mesolithic' and 'Neolithic' do not fully capture the syncretic process that took place during this period, which is often misrepresented as cultural hybridization. Syncretic practices can indicate competition rather than harmonious interactions between two groups sharing the same resources and symbolic sites (*Hayden 2002*). As highlighted here and in our 2022 article, ancestry differences played a subtle role in the spatial and temporal distribution of activities such as habitation and burial at Lepenski Vir. Those activities were also structured spatially in the Iron Gates. IBD sharing patterns (Fig. 4) deserve further consideration. Lepenski Vir individuals do not appear to share recent common ancestors with Iron Gates HGs buried at the nearby sites of Padina and Vlasac, supporting notions of communities existing side by side for hundreds of years without regular mating interactions (*Brami* et al. *2022*). The closest IBD connections are with individuals buried further downstream, at Hajdučka Vodenica and Schela Cladovei (*Žegarac* et al. *2025*).

In the light of the Lepenski Vir evidence, previous attempts to predict the ethnic identity or place of origin of people based on criteria as vague as burial practices (*e.g.,* extended supine position versus flexed on one

side), appear to be seriously flawed. Fine-grained, less essentialist archaeological research is needed to make sense of changes in genetic ancestry (*Shennan 2024*). If there is one lesson to be learned from the pattern observed here, it is the following: ancestry and culture often go hand in hand, but human ingenuity knows no limitations.

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Infectious diseases and the First Epidemiological Transition in Central and Western Eurasian prehistory: a review in light of the aDNA revolution

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ABSTRACT – *The hypothesis of a First Epidemiological Transition postulates that, with the advent of the Neolithic, the proximity to domesticated animals would have increased exposure to zoonotic pathogens, whereas the population growth and concentration that often follows the introduction of agriculture would have led to a high rate of transmission of infectious diseases. In this paper, we will synthesize the history of research on this issue. We will then use recently published data, coming mostly from aDNA studies in Central and Western Eurasia, to test the hypothesis. We find out that the hypothesis is mostly supported by the new evidence.*

KEY WORDS – *First Epidemiological Transition; evolutionary mismatch; bioarchaeology; palaeogenomics*

Nalezljive bolezni in 'prvi epidemiološki prehod' v prazgodovini srednje in zahodne Evrazije: pregled v luči revolucije stare DNK

IZVLEČEK – *Hipoteza o prvem epidemiološkem prehodu predpostavlja, da je na začetku neolitika bližina udomačenih živali povečala izpostavljenost zoonotskim patogenom, rast prebivalstva in zgoščenost poselitve, ki pogosto spremljata začetke kmetovanja, pa naj bi povzročila visoko stopnjo prenosa nalezljivih bolezni. V prispevku smo najprej povzeli zgodovino raziskav, zatem pa s pomočjo nedavno objavljenih podatkov, ki večinoma izhajajo iz študij stare DNK v srednji in zahodni Evraziji to hipotezo preverili. Ugotovili smo, da jo novi podatki večinoma podpirajo.*

KLJUČNE BESEDE – *prvi epidemiološki prehod; evolucijsko neskladje; bioarheologija; paleogenomika*

Introduction

When the Spanish first arrived in Mexico in 1520, a slave from Cuba who accompanied them inadvertently caused the death of between 30% and 50% of the Aztec population, including the sovereign Cuitlahuac. That slave was infected with smallpox. This and subsequent epidemics triggered an unprecedented population decline in Mexico: from an estimated 20 million inhabitants, the number dropped to 1.6 million a hundred years after first contact, representing a decrease of over 90% (*Diamond 1997.174; Koch* et al. *2019.21*). The rest of the Americas, and many other regions of the world colonized by European expeditions, experienced similar catastrophes. This phenomenon has been described in many ways. Today, the most appropriate term would likely be 'Accelerated Epidemiological Transition'.

The concept of 'Epidemiological Transition' refers to a change in the epidemiological patterns of a population due to transformations in its environment and/or

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lifestyle. The term first appeared in the scientific literature in the early 1970s (*Omran 1971*). Initially, it was used to describe what is now often called the 'Second Epidemiological Transition': a shift in the general health status of 19th-century Western populations as a result of industrialization and the development of public health policies. In this second transition, the elevated prevalence of infectious diseases and high overall mortality gave way to a predominance of chronic and degenerative diseases, with mortality increasingly concentrated in old age. The rapid pace of change that characterized this process in countries such as Japan warranted the addition of 'accelerated' to the name of this transition (*Omran 1971.531–532*).

Around the same time, scholars also began to propose the existence of a 'First Epidemiological Transition', although this terminology was not initially used (*Armelagos, Dewey 1970; Cohen, Armelagos 1984; Armelagos* et al. *1991*). According to its proponents, this process supposedly took place in prehistory, more specifically as a consequence of the so-called Neolithic Transition.

In broad terms, the most common outcome of Neolithisation was the emergence of agriculture and animal husbandry, as well as the adoption of a sedentary lifestyle typical of farming communities. In this new environment, the proximity to domesticated animals inherent in the management of livestock would have increased exposure to zoonotic pathogens (*Barnes 2005. ch. 8*). This, combined with poor nutrition, unsanitary conditions, and population growth and concentration – first in villages and later in cities – led to a high rate of transmission of infectious diseases and, perhaps, the first epidemics (*Diamond 1997.ch. 11*).

Over the past half-century, the hypothesis of the First Epidemiological Transition has been widely regarded as a plausible and coherent idea, but its empirical testing has faced significant challenges due to limitations in the methodologies used, namely, the palaeopathological analysis of human remains (*Larsen 1997; Roberts, Manchester 2010; Aufderheide, Rodríguez-Martín 2011; Grauer 2012*). Unlike congenital diseases, metabolic disorders, or trauma, infectious diseases are much harder to detect in human skeletal remains.

However, the systematic application of new methodological tools since 2015 has begun to shed light – especially in Eurasia – on what previously seemed a dead end. There are two main innovations, both related to the current ancient DNA revolution. First, the analysis of ancient pathogen DNA recovered from human remains, particularly from the oral cavity. Second, the analysis of ancient human DNA, which, when compared to modern human genomic data, seeks traces of diseases in the human genome, *i.e.* genetic changes related to the immune system that reflect adaptation through natural selection to new diseases. As a result, an entirely new range of possibilities has opened up.

In this paper, we will synthesize the history of research on this issue. We will then relate the new data, recently published and coming mostly from Central and Western Eurasia, to the longstanding questions, assessing the extent to which the new evidence aligns with the hypothesis of the First Epidemiological Transition. In the process, we will discuss the potential and limitations of these new methodologies.

Origins of the concept of First Epidemiological Transition

In the Western intellectual tradition, the earliest stage of human history – what we would now call the Palaeolithic – was seen as a period of miserable existence. Human populations were imagined as living under constant threat of extinction, suffering from food scarcity, insufficient resources and a lack of leisure time, and subjected to the whims of nature. The 'invention' of agriculture was thus conceived as a highly positive change, driving enormous progress in all areas (*Meek 1976*).

In line with this thinking, anthropology for a long time explained the slow demographic growth of contemporary hunter-gatherer groups as the result of supposedly high mortality, believed to be caused by the harshness of their lifestyle and by disease, while fertility was assumed to be high as well. In contrast, it was thought that farming populations experienced exponential growth due to improved health conditions that reduced mortality (*Armelagos* et al*. 1991.10*).

However, during the 1960s and 1970s, a profound shift occurred in anthropology's conception of the life and health of hunter-gatherers, most notably marked by the ethnographic studies presented at the 'Man the Hunter' conference (*Lee, DeVore 1968*). Among other findings, it was highlighted that their diet was exceptionally rich and varied, and that their workload, under normal conditions, was considerably lighter and more manageable than previously thought. While

some of it was later criticized (*e.g., Kaplan 2000*), the contributions of this conference are still regarded today as revolutionary. Roughly at the same time, Ester Boserup questioned the idea that technological changes have always been 'progressive'. Some were just necessary adjustments to increasing population, often with diminishing returns (*Boserup 1965*).

This paradigm shift in hunter-gatherer anthropology found its projection into the prehistoric past in various archaeological works, among which Mark N. Cohen's *The Food Crisis in prehistory* (*1977*) stands out. In this work, Cohen argued that the adoption of an agricultural way of life was not a long-awaited technological breakthrough but rather one in a long sequence of ecological adaptations humans had to make in response to ever-increasing demographic pressure. Specifically, Late Palaeolithic human groups were forced to artificially increase the availability of resources that provided the greatest number of calories per unit of land, something only possible through agriculture.

Thus, a new vision of the Neolithic Transition began to emerge, one that recognized clear drawbacks to the new way of life compared to pre-agricultural lifeways. Particularly relevant to our purposes is Cohen and colleagues' prediction that the transition to farming was accompanied by diminishing health. This was a counterintuitive idea, as it suggested that two seemingly contradictory processes occurred during the Neolithic: on the one hand, demographic growth; on the other, a decline in health (*Armelagos* et al. *1991*). It represented a radical break in conceptions of human evolution and history, as it separated the notion of reproductive success from other concepts such as well-being or happiness, which until then had been bound together in the generic idea of 'progress' (*Cohen 1989. 14*).

Although the concept had already begun to take shape, it was not until the turn of the century that the term 'First Epidemiological Transition' became widely used to refer to the increase in both nutritional and infectious diseases during the transition from the Palaeolithic to the Neolithic (*Barrett* et al. *1998; Armelagos, Harper 2005; Armelagos 2009; Lieberman 2013*). In the following decades, a collective effort was made to test this emerging hypothesis (*e.g., Cohen, Armelagos 1984; Cohen 1989; Steckel, Rose 2002; Cohen, Crane-Kramer 2007; Pinhasi, Stock 2011; Roberts 2015*).

In parallel, a similar evolution took place in the field of palaeodemography, with the introduction of the hypothesis of the Neolithic Demographic Transition (*Bocquet-Appel, Dubouloz 2004; Bocquet-Appel, Bar-Yosef 2008; Bocquet-Appel 2011*). Based on studies of cemeteries dated around the time of the Neolithic Transition, Jean-Pierre Bocquet-Appel and colleagues argued that the main driver of Neolithic population growth was an increase in fertility. After a certain period, this was followed by a rise in mortality, associated with greater susceptibility to and prevalence of infectious diseases in the Neolithic phase. Thus, the original argument about the demographic evolution of prehistoric communities was effectively reversed.

Health in prehistory according to the First Epidemiological Transition hypothesis

The development of the First Epidemiological Transition hypothesis would not have been possible without recourse to ethnographic analogy and the extrapolation of present-day epidemiological patterns into the past (*Cohen 1989.4–5*). In particular, ethnographic studies have provided a plausible – though always controversial (*e.g., Kelly 2013*) – model, from which archaeologists have imagined how Palaeolithic peoples might have lived, and how their way of life may have differed from that of Neolithic populations.

With regard to the First Epidemiological Transition hypothesis, the baseline assumption has always been (*e.g., Cohen 1989.17–20; Lieberman 2013.ch. 8; Suzman 2020.ch. 6*) that during the Palaeolithic, human groups engaged in hunting, gathering, and fishing were predominantly small, nomadic and scattered. Their diet was limited in quantity but extraordinarily diverse. Subsistence needs required them to maintain high levels of physical activity and mobility, moving seasonally in response to resource availability or cultural factors. All this had several consequences for their health.

Firstly, the combination of intense physical activity and relatively low caloric intake would have led to delayed sexual maturation in women and a relatively late age at first childbirth. Moreover, breastfeeding periods were likely prolonged – between two and four years – due to the scarcity of suitable weaning foods. The later onset of reproduction and the greater spacing between pregnancies meant that women had fewer children. Together with deliberate birth control influenced by social or cultural factors, this would have resulted in

relatively low birth rates and small groups with low population density. Secondly, their diverse diet meant that nutritional deficiencies were rare, and essential nutrients (carbohydrates, proteins, fats, vitamins, fibre, minerals) were likely well covered. Nomadism allowed populations to range over large geographic areas, limiting the risk of deficiencies tied to specific soils, such as those of iodine, fluoride, or selenium. Thirdly, their workload would have been relatively light, even though it may have been somewhat greater in Pleistocene Eurasia than among contemporary hunter-gatherers in warmer climates, who reportedly spend at least 75% of their time on leisure and rest (*Suzman 2020.ch. 6*).

Finally, the low population density would have limited the extent of epidemic outbreaks in both space and time (*Cohen 1989.33–35; Armelagos* et al. *1991.14–15; Barrett* et al. *1998.250–252; Barnes 2005. ch. 3*). The reasoning is as follows: for pathogens to reproduce, they must complete their life cycles repeatedly, either by cycling between the environment and humans or through direct person-to-person transmission. When potential hosts live in small, mobile, and relatively isolated populations, infectious agents may struggle to maintain transmission chains. If present in the environment (soil, vegetation, water, animals), pathogens may cease to be a threat when the group moves away. If transmitted person-to-person, opportunities for spread are limited by the scarcity of potential hosts.

Under these circumstances, only two types of infectious agents could have persisted long-term in Palaeolithic human populations. First, those not specialized in humans, capable of surviving in non-human reservoir species. These would have been transmitted to humans incidentally, through water, insect bites, animal bites, consumption of undercooked meat, or exposure to animal faeces (zoonoses). Second, pathogens with very long-life cycles, typically causing mild or chronic symptoms, which would have increased the chance of person-to-person transmission by not killing the infected host rapidly, or at all.

In such conditions, a pathogen might spread through all members of a group, triggering an epidemic outbreak that could sometimes be highly lethal. However, any such outbreak would have been short-lived and local in scope, given the difficulties for the pathogen to jump to other human groups and maintain its life cycle among them. These are commonly known as 'dead-end spillover' events (*Ellwanger, Chies 2021.3–4*) (Fig. 1).

In a review of this issue, Nathan D. Wolfe *et al.* (*2007*) observed that nearly all the diseases that have had major impacts on human history and evolution – especially in temperate climates – are transmitted from person to person: hepatitis B, syphilis, tuberculosis, and so on. Plague is a special case, inasmuch as it can be transmitted both human-to-human and via multiple ectoparasitic vectors, leading to different outcomes. Interpersonal transmission implies that, all else being equal, prevalence increases with the availability of potential human hosts.

Moreover, for a large proportion of these murderous diseases, humans who survive infection develop long-term immunity to potential future reinfections. When this combination of factors is present – direct human-to-human transmission and long-lasting immunity

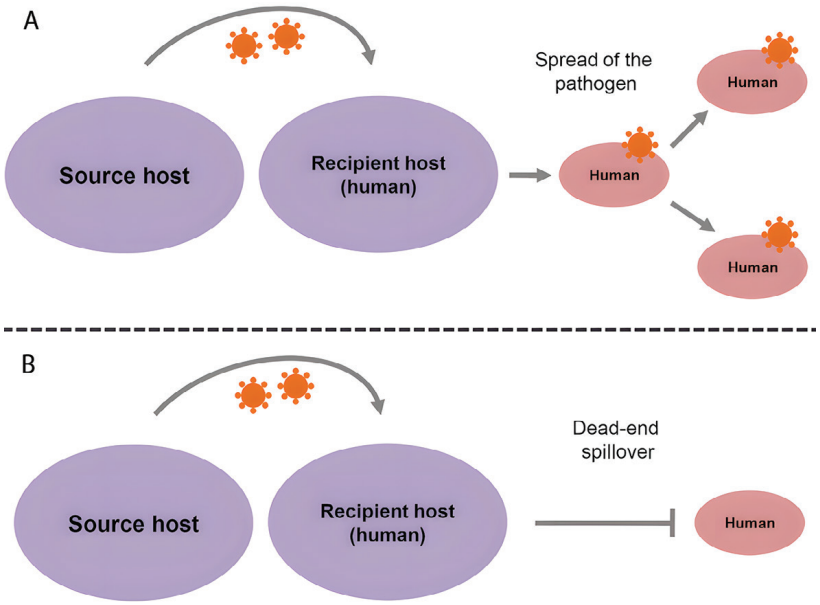

Fig. 1. A spillover event can have two basic outcomes.* A *the pathogen that crossed the barriers between species can spread among the population (through human-to-human transmission or a highly competent vector).* B *the pathogen is transmitted to a human, but without spreading among the human population due to the absence of social, biological, or environmental conditions favourable to the adaptation of the pathogen to the human population or its dissemination. This condition is called dead-end spillover (*Ellwanger, Chies 2021.Fig. 4*).

– the result is typically a 'crowd disease', *i.e.* an infectious disease that requires a large, dense, and interconnected human population to persist and cause sustained epidemics. Examples of crowd diseases include diphtheria, influenza A, measles, mumps, pertussis (whooping cough), plague, rubella, smallpox, typhoid, and typhus (*Wolfe* et al. *2007.Tab. S1*).

The minimum size of a human population within which a purely person-to-person pathogen can persist indefinitely is referred to as the critical community size (CCS). Estimating the CCS for ancient diseases is difficult, but it is known that contemporary measles, rubella, and pertussis require at least several hundred thousand individuals (*Wolfe* et al. *2007.280*) – far beyond what would have been typical of a Palaeolithic human group.

In short, zoonotic spillover and infectious diseases in general would have existed during the Palaeolithic. However, most of the deadliest diseases in human history, such as plague or smallpox, would have quickly burned out, making them unsustainable beyond sporadic and brief outbreaks, no matter how lethal.

To summarize, according to the hypothesis, Palaeolithic people would have enjoyed a generally good state of health, marred only by high infant mortality. Consistent with this, in contemporary hunter-gatherer societies the most common age at death among adults lies between 68 and 78 years (*Gurven, Kaplan 2007.349*).

The Neolithic – a major shift that first occurred in the Near East around 12 000 years ago – would have completely transformed the lifestyle and, consequently, the health of prehistoric populations. The most significant ruptures came with the transition from nomadism to sedentism, increasing population concentrations, and the shift in subsistence strategies from hunting-gathering to farming and livestock breeding.

On the positive side, the greater overall availability of food, combined with sedentism, would have supported increased fertility and demographic growth (*Bocquet-Appel 2011*). As a result of higher body fat levels inherent in the new diet, menarche would have occurred at an earlier age, extending women's reproductive lives. Likewise, the weaning age would have decreased due to the availability of highly caloric, soft, and digestible foods (based on cereal starches), which could replace breast milk more quickly than the fibrous foods (vegetables and tubers) commonly consumed in the Palaeolithic (*Cohen 1989.70–71*). This reduction in breastfeeding periods would have enabled shorter intervals between pregnancies.

The negative consequences, however, would have been considerable. To begin with, the new lifestyle entailed greater uncertainty and vulnerability (*Cohen 1989.64–69*). Of particular relevance to this discussion, changes in subsistence strategies had negative effects on dietary quality (*Cohen 1989.58–64; Lieberman 2013.205–212*). Diets became much less varied and largely dependent on cereals (carbohydrates), leading to nutritional deficiencies exacerbated by nutrient loss during food storage. Malnutrition weakens the immune system, making individuals more susceptible to disease, while illness in turn reduces nutrient absorption capacity (*Ulijaszek 1990*). Studies further indicate that infants and young children would have been especially at risk: after weaning, deprived of the protective properties of breast milk and given a nutritionally poor diet, their immune systems would have been compromised (*Goodman, Armelagos 1989.225–227*).

A longer reproductive life and shorter intervals between pregnancies not only increased fertility rates but also put the health of mothers and their children at risk. Among the inherent maternal risks were higher chances of mortality for both mother and newborn due to obstetric complications, hypertension and anaemia, infections, haemorrhages, eclampsia, ectopic pregnancies, and complications arising from miscarriages and treatments during pregnancy and postpartum.

In addition, the workload was likely heavier in prehistoric farming societies (*Lieberman 2013.212–214; Suzman 2020.ch. 9*). Preindustrial farmers spent nearly four times as many hours on subsistence activities as hunter-gatherers during critical phases of the agricultural cycle. Some tasks, such as grinding grain, were tedious and repetitive, causing particular stress on certain parts of the musculoskeletal system.

But above all, the most significant drawback was likely the proliferation and spread of infectious agents (*Cohen 1989.ch. 4; Barnes 2005.ch. 4; Lieberman 2013.214–219*). The first major contributing factor was the practice of animal husbandry. From the Neolithic onwards, domestic animals were milked, ridden, hitched to ploughs, and sometimes even cuddled or kept indoors, with humans routinely exposed to animal excrement. All of these increased opportunities for

zoonotic pathogens to spill over into human populations. These diseases originated not only from domesticated species but also from wild animals that came into contact with them (*Pearce-Duvet 2006.11; Ellwanger, Chies 2021.4–5*).

Permanent settlements – especially densely populated ones – also created ideal conditions for disease transmission. This occurred through multiple pathways. Food and water supplies were often contaminated due to the absence of proper sewage, waste, and faecal management systems. Stored food attracted rodents and insects, which served as vectors for numerous diseases. Accumulated refuse and poor hygiene promoted the proliferation of worms, protozoa, and bacteria. Stagnant indoor air circulation in these settlements facilitated the transmission of respiratory illnesses like influenza. Lastly, landscape modifications from agriculture – such as clearing forests for crops – further encouraged the spread of flies and mosquitoes, carriers of diseases such as malaria (*Pearce-Duvet 2006*).

Nevertheless, the most frequently highlighted consequence of demographic growth and population concentration was the increased number of potential hosts for all these pathogens. Once a certain population threshold was reached – only achievable after the Neolithic Transition – the large-scale spread of numerous human-to-human transmissible diseases, including crowd diseases, became possible. In a large, well-connected community, a crowd disease can persist more or less indefinitely. The pathogen survives by infecting individuals in nearby regions and returning years later, when births in the intervening period have produced a new generation of potential hosts no longer protected by previously acquired immunity. It is therefore common for such massive epidemics to unfold in successive 'waves' that ebb and flow, leaving trails of victims in their wake (*Wolfe* et al. *2007.280*).

In sum, drawing on ethnographic analogy and projecting known epidemiological patterns into the past, the First Epidemiological Transition hypothesis proposes that the adoption of agricultural and pastoral lifeways brought increased fertility rates, population growth, larger and denser settlements, more intensive and monotonous labour, a decline in sanitation, a less varied diet, greater vulnerability to famine, and a rise in infectious diseases and their spread across space and time. All these changes would have led to a marked decline in overall health.

Traditional methodological tools for studying the First Epidemiological Transition

On paper, the narrative of the First Epidemiological Transition appears, with certain qualifications, coherent and plausible. As we shall see, the traditional problem has been the difficulty of gathering data robust enough to test this hypothesis. In what follows, we will examine the possibilities and limitations of the methodological tools available prior to 2010 for addressing the questions posed.

Paleodemography

One way to test the hypothesis of the First Epidemiological Transition is by observing the demographic patterns of cemeteries from the Neolithic Transition. Studies have shown that this period of population growth, lasting approximately 500–700 years, was followed by a demographic equilibrium where births only slightly outnumbered deaths. It has been postulated that this was caused by a rise in mortality rates – particularly infant mortality – which would have offset the high birth rates (*Bocquet-Appel 2008a*).

The methodology employed to test this has relied on the analysis of the age-at-death profiles of individuals buried in Neolithic necropolises. In particular, researchers have focused on the proportion of juvenile individuals – defined as those aged 5 to 19 years – relative to the total population. Individuals aged 0 to 5 years are excluded from this calculation because their remains are more prone to decomposition, making their representation in the burial record highly susceptible to bias.

If the proportion of juveniles relative to the total population is high, the most logical inference is that more children were being born, implying an increase in fertility rates. With higher fertility, one would expect overall population growth. However, if such growth is only marginally recorded in the archaeological record, it suggests that some limiting factor must have been at play. In other words, although many children were born, a high rate of juvenile mortality likely prevented the population from expanding at the expected pace.

The Neolithic Demographic Transition, as described above, has been observed in dozens of cemeteries across the globe – including Europe, North America, North Africa, and the Levant (*Bocquet-Appel, Dubouloz 2004; Bocquet-Appel, Naji 2006; Bocquet-Appel*

2008b; 2011; Bocquet-Appel, Bar-Yosef 2008; Kohler et al*. 2008*).

Why did the Neolithic Demographic Transition occur? According to its proponents, it was the result of the overall deterioration in health status characteristic of the First Epidemiological Transition, particularly the high prevalence of infectious diseases (*Bocquet-Appel, Dubouloz 2004.30; Bocquet-Appel 2008a.48–49*). Although this explanation is entirely plausible, in itself it does not constitute definitive evidence that a decline in health occurred, nor does it demonstrate that the inferred increase in mortality was specifically due to a rise in infectious disease prevalence from the Neolithic onward.

Stress indicators in the musculoskeletal system

The most commonly adopted approach to testing the First Epidemiological Transition has, however, been bioarchaeological – that is, the study of human bones and teeth from archaeological sites in search of signs of health, lifestyle and disease. The methodology consists primarily of macroscopic analysis, complemented by microscopic, histological, radiographic, and biomolecular techniques (*Larsen 1997; Lewis 2007; Roberts, Manchester 2010; Aufderheide, Rodríguez-Martín 2011; Grauer 2012*). Among the data obtainable in this way are the types of pathologies present, whether diseases healed during the individual's lifetime, and whether they were active at the time of death.

The main analytical tool in this field is the study of stress indicators – that is, marks on bones formed during an individual's lifetime as a response to stressful events such as illness or periods of famine (*Buikstra, Cook 1980; Huss-Ashmore* et al*. 1982; Goodman, Armelagos 1989; Larsen 1997; Ortner 2012*). The most widely used and longest-standing indicators for assessing health status include subadult growth and adult stature, but other frequently studied markers are Harris lines, osteoporosis, osteoarthritis, osteomyelitis, periostitis, porotic hyperostosis, cribra orbitalia, enamel hypoplasia and caries.

Among the diseases that can be identified through the study of human remains are certain infectious conditions such as tuberculosis, leprosy, yaws, endemic syphilis, venereal syphilis, and brucellosis. It is also possible to detect nutritional disorders that may have affected past populations, including scurvy, rickets, and anaemia – the latter identified through porotic hyperostosis. In the realm of oral health, commonly identified conditions in teeth include caries, enamel hypoplasia, dental abscesses, premortem tooth loss, dental asymmetry, dental wear, and periodontitis.

Stress indicators have been presented as evidence of the diminishing health that, according to the hypothesis of the First Epidemiological Transition, accompanied Neolithisation. Data have been analysed from numerous sites in both the Old and New Worlds (see *e.g., Cohen, Armelagos 1984; Steckel, Rose 2002; Cohen, Crane-Kramer 2007; Bocquet-Appel* et al*. 2008; Hershkovitz, Gopher 2008; Wittwer-Backofen, Tomo 2008; Larsen* et al. *2019*). While some cases show evidence of stability or even improvement, the overall trend points to a decline in health following the transition to the Neolithic: increased incidence of caries and periodontitis, greater prevalence of detectable infections, higher rates of enamel hypoplasia, cribra orbitalia, and porotic hyperostosis, as well as reduced stature – indicating nutritional deficiencies and disease burden (*Larsen 2006; 2018; Roberts 2015*). Conversely, there is evidence for a slight decrease in physical activity, likely resulting from reduced mobility and workload, although this parameter varies significantly across contexts (*Larsen 2006.16–17*).

However, despite the ability to detect certain conditions through palaeopathology, the study of ancient diseases via skeletal indicators suffers from significant limitations.

The first problem concerns the visibility of diseases in osteological remains. Many of the stress indicators listed may disappear due to bone remodelling during healing or as a result of post-mortem decomposition. For stressors to leave marks on bone, the individual must have survived the episode and resumed normal growth. If the disease was acute, the person may have died before the illness could leave any trace in the skeleton. Conditions such as cholera, influenza, measles, plague, or typhoid fever often kill too quickly to produce identifiable skeletal lesions.

Even infectious diseases that are recognizable in the skeleton leave evidence in only a small proportion of cases. For instance, tuberculosis and leprosy affect the skeleton in only 3–5% of untreated individuals. When such lesions are observed, they are, as noted, a sign of recovery – or at least of resistance to the disease – because the individual survived long enough for the illness to manifest in the bones. This suggests that they were likely relatively healthy and possessed a robust

immune system. This phenomenon is known as the osteological paradox (*Wood* et al. *1992*). While measures have been proposed to mitigate such biases (*Milner, Boldsen 2017*), significant issues remain (*DeWitte, Stojanowski 2015*).

Additionally, infant remains are rarely as well preserved as those of adults in archaeological contexts. Recovery of these bones may also be hampered by the inexperience of excavators, as infant bones are smaller, harder to recognize, and more easily overlooked or misidentified as non-human. More importantly, they are far more susceptible to taphonomic processes such as decomposition and degradation. Infant remains are particularly valuable for understanding episodes of stress, and their absence can significantly affect research outcomes.

Finally, there are pseudopathological features – that is, changes to bones that resemble lesions caused by disease or nutritional crises during life but are actually the result of post-depositional processes. These may include: post-excavation handling; damage by scavengers and insects (*e.g.*, rodents can cause defects in supraorbital ridges that mimic trauma or osteitis); botanical activity (roots fracturing bone); climatic effects (freeze-thaw cycles causing fractures); chemical erosion (acidic, moist soils leaching bone minerals and mimicking osteoporosis); microbiological activity (producing periostitis-like patterns); and pressure effects (resulting in what appears to be intentional cranial deformation, scaphocephaly, or genuine fractures).

The second major problem is the ambiguity of the data derived from skeletal analysis. Many stress indicators are highly non-specific, particularly those linked to infectious episodes. This means they often do not allow the recognition of the specific stressor, nor its intensity or duration.

A particularly notable example of ambiguity is adult stature, which has been widely used as a general indicator of prehistoric population health in studies addressing the First Epidemiological Transition (*e.g., Cohen, Armelagos 1984; Mummert* et al. *2011*). It is true that stature is influenced by factors such as disease burden and nutrition. However, there has been increasing recognition in recent years that stature is a highly complex trait shaped by numerous variables that are not easily disentangled (*Rosenstock* et al. *2019; Marciniak* et al. *2022; Stock* et al. *2023; Cox* et al. *2024*). The most important of these is genetic: stature is a polygenic trait, influenced by dozens of genes that account for approximately 90% of an individual's potential maximum height. Relevant genetic variants are not evenly distributed among human populations. This is especially important in the context of recent European prehistory, given the 'cul-de-sac' nature of the subcontinent and the successive episodes of genetic turnover and gene flow resulting from migration events documented in recent studies (*e.g., Lazaridis 2018*). Furthermore, individual stature may also be shaped by epigenetic, cultural, social, and even population-level genetic processes (such as heterosis; see *Rosenstock* et al. *2019.5657–5658*).

Thus, while palaeopathology allows us to approach the study of the general health status of past populations and its changes over time, there are significant limitations that prevent us from determining with certainty the real impact that diseases – particularly infectious diseases – had in prehistory. This left the hypothesis of the First Epidemiological Transition in a state of partial underdetermination.

Applications of palaeogenomics to the study of the First Epidemiological Transition

However, the situation has changed dramatically over the past decade. The sequencing of Neanderthal DNA, published in 2010, marked the beginning of an empirical revolution fuelled by major methodological advances in genetics: the neutralization of ancient DNA contamination, the isolation of human genetic sequences, and the focus on single nucleotide polymorphisms (SNPs), along with next-generation sequencing and computational classification (see *e.g., Reich 2018; Spyrou* et al. *2019*). Regarding the study of the First Epidemiological Transition, since 2015 palaeogenomics has transformed the field by introducing two major methodological innovations: on the one hand, it has made it possible to detect infectious diseases in the skeletal remains of individuals who died before such infections could leave any trace on their bones; on the other, it has enabled the recognition of recent changes in the human genome, many of them linked to disease resistance.

If the microorganisms causing a disease were present in the bloodstream at the time of death, residual genetic material may remain in the bones and especially in the teeth. Thus, it is now possible to identify diseases that leave no osteological trace. Likewise, the new methodologies allow general assessments of an indivi-

dual's health based on their oral microbiome (*Warinner* et al. *2015*). Gut microbiomes can be studied using coprolite material – palaeofaeces – although they are rarely preserved in the archaeological record (*Schnorr* et al. *2016*). Most of the new evidence provided by palaeogenomics so far pertains to Central and Western Eurasia.

Despite the reasons for optimism, it is likely that we are still underestimating the true prevalence of infectious diseases in Central and Western Eurasian prehistory (*Sikora* et al. *2025.5,8*). Even today, detecting pathogens with low bloodstream loads remains challenging, as in the case of tuberculosis in most infected individuals. Moreover, pathogens that can currently be detected, like the agent of plague, often result in many false negatives (*Schuenemann* et al*. 2011*). It is also probable that some microbes are better preserved in human tissues that are not typically sampled systematically. Moreover, identifying eukaryotic pathogens – responsible for conditions such as amoebic dysentery, toxoplasmosis, giardiasis, leishmaniasis, or malaria – remains problematic due to the high levels of contamination in their DNA sequences. Additionally, no evidence of RNA viruses has yet been found in prehistoric human remains, including those responsible for illnesses such as influenza, hepatitis C, measles, dengue, rabies, polio, mumps, and many others. While this absence might suggest that prehistoric Eurasian populations did not suffer from any of these diseases, it is more likely a reflection of the current inability to accurately identify RNA viruses, given the lower probability of RNA preservation.

In sum, the detected infection rates almost certainly underestimate the actual prevalence of infections, owing to the low likelihood of ancient pathogen DNA surviving and being correctly identified. A further complication is that differential preservation may result in the underrepresentation of Palaeolithic diseases in current datasets compared to those of post-Neolithic times.

Some important pathogens have not yet been directly recorded in prehistoric contexts, but their presence in Eurasian prehistory can be inferred from ancient DNA studies of cases from historical periods. These historical microorganisms help calibrate microbial mutation rates and estimate the timing – through molecular dating – of key events in their evolution, such as zoonotic transfers to humans or the divergence of significant variants.

In addition to direct pathogen identification, human adaptation to pathogens has also been studied. Due to natural selection, it is common for pathogens and their hosts to coevolve. Hosts with genetic immunity or resistance to a disease have greater chances of survival and reproduction, thereby passing this advantage to their offspring and increasing its prevalence in the population. Pathogens, in turn, can counteract such immunity with new mutations that enhance their transmission or reproduction, or make them more efficient, and so the cycle continues (*Alizon* et al. *2009*).

The evolution of the host – in this case, humans – in response to pathogen threats can help determine whether the available data on pathogen proliferation during different periods of Eurasian prehistory are truly representative.

In the past decade, the sequencing of thousands of complete genomes from individuals across historical timeframes, and their comparison with contemporary genetic databases, has made such studies possible. Since it is not easy to ascertain which phenotypic traits are influenced by specific genes, nor what effects different genetic variants may have, genome-wide association studies (GWAS) have been particularly valuable. These studies examine correlations between certain genetic mutations and specific conditions or phenotypic traits in present-day populations. On the negative side, while GWAS data have allowed the identification of genetic variants that enhance immune function, they often do not resolve the question of which particular diseases these polymorphisms protect against, since modern samples come from individuals who have generally not been exposed to these pathogens, thanks largely to vaccination programmes.

In what follows, we summarize the main discoveries of the last decade. Our literature review is not exhaustive, but includes all the new evidence known to us, and should provide a broad picture of the state of knowledge at the time of this writing.

New evidence on infectious diseases in hunter-gatherer communities of Central and Western Eurasia

The data for the earliest periods are indirect and derive from studies of the human genome (Fig. 2). Viruses appear to have played an important role in human evolution. David Enard and Dmitri A. Petrov (*2020*) analysed the evolution of certain genes related to vir-

us-interacting proteins (VIPs), which help defend against viral infections. From this, they deduced that RNA viruses have had a greater impact on human evolution than DNA-based viruses, as they tend to be more pathogenic and more prone to zoonotic transmission. Notably, they suggest that Neanderthals developed defences against such viruses, and that these genetic correlates were passed to our species through hybridization. In another study, strong selection was observed in dozens of genes related to VIPs that act against coronaviruses in East Asian populations around 25 000 years ago, in the Pleistocene. If confirmed, this would constitute the oldest evidence of a possible epidemic (*Souilmi* et al. *2021*).

The HLA region of chromosome 6 (human leukocyte antigen system) in humans' functions similarly to the major histocompatibility complex (MHC) found in many animals: the genes of the HLA system code for cell surface proteins that are a fundamental part of the human immune response. Significantly, at least some groups of Central European hunter-gatherers carried in their genomes a configuration of the HLA system different from that observed in later human populations. This configuration made them more resistant to certain viruses and less resistant to bacteria than present-day Europeans, suggesting that viral exposure was an ancestral condition (*Immel* et al. *2021.6*).

Conversely, there is genetic evidence that Palaeolithic humans were less exposed to certain viruses, such as retroviruses, than their evolutionary relatives, the non-human primates, possibly because they took measures to avoid infections. Supporting this is the lack of acquisition of new endogenous viral elements (EVEs) over the past 60 000 years (*Guzmán-Solís* et al. *2023.50*).

Hepatitis B was present in Eurasia prior to the advent of agriculture and animal husbandry (*Kocher* et al. *2021; Sikora* et al. *2025.5*). According to Artur Kocher *et al.* (*2021.186*), at that time it was likely a chronic but not epidemic infectious agent. However, Charlotte J. Houldcroft and Simon Underdown (*2023.519*) argue that even as a chronic condition, Pleistocene hepatitis B could have caused significant morbidity and potentially death by exacerbating other illnesses. They fur-

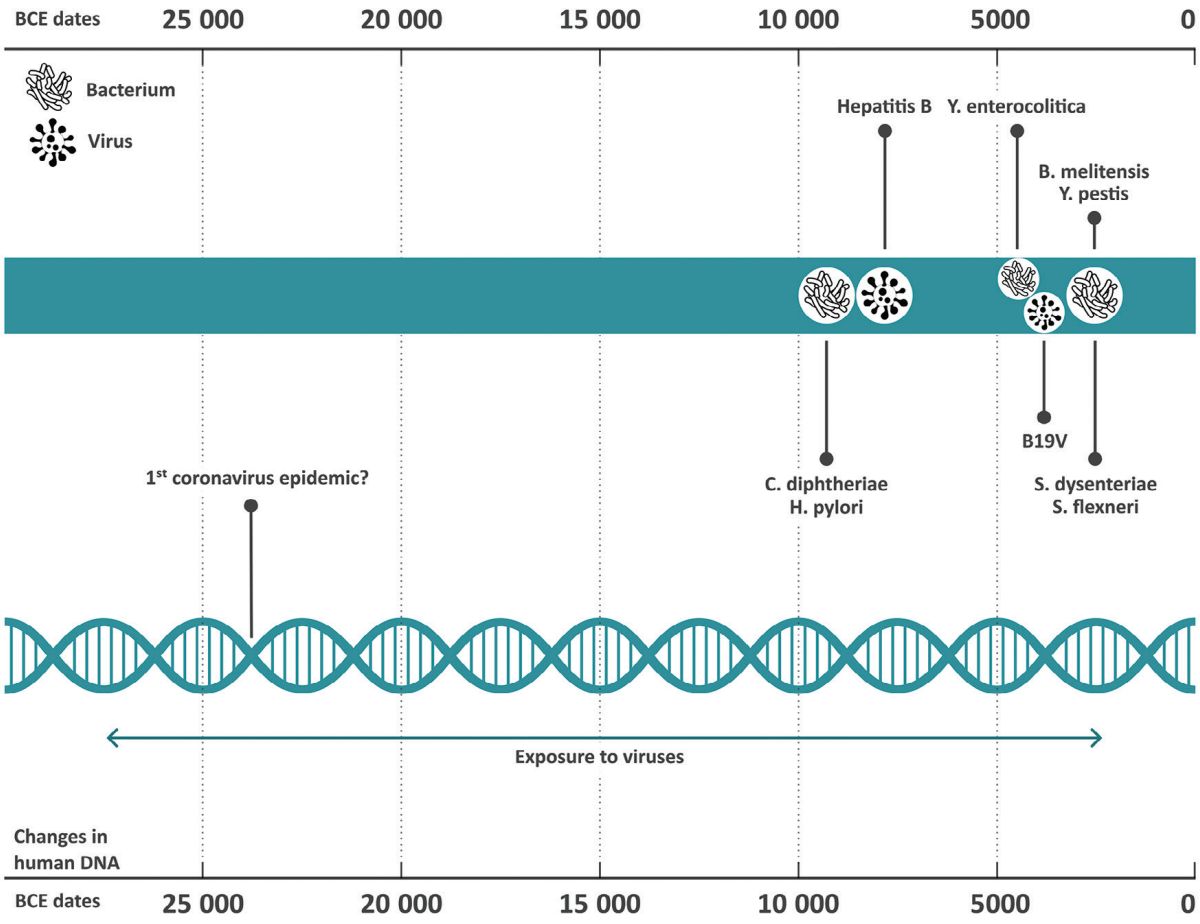

Fig. 2. Timeline of pathogens recovered, and of changes in the human DNA, for prehistoric hunter-gatherer populations of Central and Western Eurasia.

ther suggest that under certain circumstances the virus could have reached epidemic levels, particularly during its emergence as a human pathogen.

Another DNA virus identified in prehistoric remains is Parvovirus B19, recovered from skeletal remains associated with a Holocene hunter-gatherer cultural context near Lake Baikal in Central Eurasia (*Mühlemann* et al. *2018*). The health effects of B19V infection range from asymptomatic cases to fifth disease in children, arthritis in adults, and miscarriages in pregnant women.

Additionally, evidence has been reported of *Corynebacterium diphtheriae*, the infectious agent which cases diphtheria, in Russia during the last quarter of the 10th millennium BCE, in a Mesolithic context. The same individual was also infected with *Helicobacter pylori;* a pathogen associated with gastric infections (*Sikora* et al. *2025.5*). Similarly, *Yersinia enterocolitica*, the causative agent of yersiniosis, has been found in the teeth of an individual from the third quarter of the 5th millennium BCE (*Sikora* et al. *2025.5*). This individual, apparently a Mesolithic hunter-gatherer, likely contracted the disease after consuming raw or undercooked meat from a wild animal, possibly a suid, cervid, equid, bovid, or caprid.

A case of brucellosis, a zoonotic disease caused by the bacterium *Brucella melitensis*, has also been documented in a child from the third quarter of the 4th millennium BCE in Central Eurasia (*Macleod* et al. *2024. 3*). This population of hunter-gatherers is notable, however, for providing the earliest evidence of plague, caused by the bacterium *Yersinia pestis*.

The Cis-Baikal region near Lake Baikal has historically been a hotspot for zoonotic transmission events involving *Yersinia pestis*, as the area is home to numerous marmots, a key animal reservoir for plague. Two epidemic outbreaks of plague have been recorded in four cemeteries in the region: the first, and most significant, occurred in two cemeteries around the mid-4th millennium BCE, while a second event affected the other two cemeteries several centuries later, in the late 4th millennium BCE. The first and most important outbreak was particularly evident at the Ust-Ida I cemetery, where *Yersinia pestis* was detected in 12 of 31 sampled individuals (39%), although strong evidence suggests the actual infection rate was much higher among those buried at the necropolis. Analysis of radiocarbon dates, the age profile of the deceased, and the genetic study of kinship ties among them all point in the same direction: these were two independent zoonotic transmission events, which caused, especially in the first instance, high-mortality epidemic outbreaks, particularly among children. The disease spread from person to person, probably via respiratory transmission. The study also emphasizes that these epidemics were short-lived, and there is no evidence that they extended beyond the local human groups (*Macleod* et al. *2024*).

Traces of *Yersinia pestis* have also been found in Latvia, in a context associated with pre-agricultural populations of the late 4th millennium BCE (*Susat* et al. *2021*).

Finally, a recent ancient DNA study by Martin Sikora *et al*. (*2025*) identified 209 infections after analysing 1313 individuals across various regions of Eurasia. In the database underpinning this study, we have separated samples coming from hunting-gathering communities from those coming from agricultural/livestock keeping ones. In the hunter-gatherer category we have included Palaeolithic and Mesolithic samples, as usual, but also other Holocene hunter-gatherer groups, mainly from present-day Russia, even though they are labelled 'Neolithic' in the dataset. We have excluded samples from 'Eneolithic cultures' such as Srednestogovskaya, as they are often transitional to pastoralism. Among the resulting subset of 174 individuals, the authors have found 18 cases of infection by anthroponotic pathogens (*Shigella flexneri*, *Shigella dysenteriae*, *Corynebacterium diphtheriae*, *Helicobacter pylori*, hepatitis B, herpesviruses, and other mild infectious agents) and two zoonotic infections (*Yersinia enterocolitica* and *Yersinia pestis*). Taking into account co-infections, this equates to 14 individuals infected overall (8%), 13 of them (7.5%) of anthroponotic pathogens, and two of them of zoonotic diseases (1.1%) – as there is one individual co-infected both with an anthroponotic and a zoonotic microbe. Viruses account for 14 infections (70% of the overall infections and 5.7% of individuals), while bacteria for only six (30% of all infections and 2.3% of individuals) (*Sikora* et al. *2025.supplementary table 2*).

To find out whether there is any time-dependent preservation bias in this dataset, *i.e.* whether the older samples are poorly preserved compared to the younger ones, we have made a distinction between Palaeolithic and Mesolithic samples, on one side, and mid-Holocene Eurasian hunter-gatherers – from European

Russia and Siberia– on the other. The latter group were roughly contemporary with most Neolithic and Bronze Age populations in Western Eurasia, and there are indications that sometimes pathogens passed from hunter-gatherers to farmers and vice versa (*Kocher* et al. *2021.187*). Among the Palaeolithic and Mesolithic subset, comprising 86 individuals, 11 infections are known: 10 anthroponotic and one zoonotic. Taking into account co-infections, this equates to six individuals infected overall (7%), five of them (5.8%) of anthroponotic pathogens, and one of them of a zoonotic disease (1.2%). Likewise, among the mid-Holocene Russian/Siberian hunter-gatherers' subset, comprising 88 individuals, nine infections are known: eight anthroponotic and one zoonotic. Taking into account co-infections, this equates to eight individuals infected overall (9.1%), eight of them (9.1%) of anthroponotic pathogens, and one of them of a zoonotic disease (1.1%) – because there is one individual co-infected both with an anthroponotic and a zoonotic microorganism. As these results are very similar, we can rule out significant time-dependent preservation biases, although the sample size is relatively small (*Sikora* et al. *2025.supplementary table 2*).

To sum up, in the Sikora *et al.* (*2025*) dataset, zoonotic diseases are very rare among Central and Western Eurasian hunter-gatherers, at around 1%, and viruses are more frequent than bacteria. In general, the rate of detected infection is relatively low, in just 8% of all sampled individuals.

New evidence on infectious diseases among farming and herding communities of prehistoric Central and Western Eurasia

A study of the oral microbiota from south-central Italy, spanning from the Upper Palaeolithic to the Chalcolithic, revealed the emergence and increase of pathogenic species in the more recent periods. These pathogens, in addition to being agents of periodontal disease, can damage connective tissue and interfere with the individual's immune response. This suggests a worsening state of health during this time, consistent with the anthropological analysis of the teeth from which the samples were obtained (*Quagliariello* et al. *2022*).

Hepatitis B continued to be present after the Neolithic transition, now represented by a distinct lineage (*Kocher* et al. *2021*). Infection by *Plasmodium vivax*, one of the parasites responsible for malaria, has been recorded in three Eurasian individuals separated by more than 5000km and dated to the 4th and 3rd millennia BCE: two were undoubtedly members of agricultural communities, while the third may have been a hunter-gatherer transitioning to a pastoral economy (*Michel* et al. *2024*). This pathogen has also been found in Central Europe during the Bronze Age (*Sikora* et al. *2025.5*) (Fig. 3).

The presence of *Salmonella enterica* in Eurasia dates back at least 6500 years, and its specific adaptation to humans has been linked to the Neolithisation process (*Key* et al. *2020; Sikora* et al. *2025.5*). Other pathogens transmitted via the faecal-oral route include *Shigella boydii*, which can cause dysentery and was found in a Bronze Age burial in Siberia, and *Escherichia coli*, capable of producing intestinal infections (*Sikora* et al. *2025.5, supplementary table 2*).

Regarding brucellosis, a study successfully sequenced the DNA of *Brucella melitensis* from a sheep recovered at a Neolithic site in Anatolia (Menteşe Höyük). Phylogenetic analysis revealed that its speciation and adaptation to humans likely occurred between the 9th and 7th millennia BCE, within a socioeconomic context marked by the development of livestock economies. Notably, the human remains associated with this site showed a high frequency of osteoarthritis and anaemia, indicative of infection (*L'Hôte* et al. *2024*). Similarly, one of the pathogens causing leptospirosis, *Leptospira borgpetersenii*, has been identified in Neolithic Sweden from the mid-4th millennium BCE. Today, this bacterium is mainly found in cattle, suggesting a zoonotic process (*Sikora* et al. *2025.5*).

Louse-borne relapsing fever (LBRF), caused by *Borrelia recurrentis*, is a disease historically associated with crowded and unsanitary living conditions. It is little known today, but if untreated can be fatal in up to 40% of cases and has considerable epidemic potential. This disease was first detected around the mid-4th millennium BCE and soon became widespread (*Sikora* et al. *2025.5–6; Swali* et al. *2025*). Woollen clothing may have created more favourable conditions for the proliferation of lice that transmit the bacterium compared to plant-based textiles, as lice prefer the rougher texture of wool for egg-laying (*Swali* et al. *2025.8*).

However, the most outstanding pathogen is undoubtedly *Yersinia pestis*, the infectious agent causing plague, which also has immunosuppressive effects that can exacerbate other conditions. It has been found in Eurasian farming and/or herding populations from the

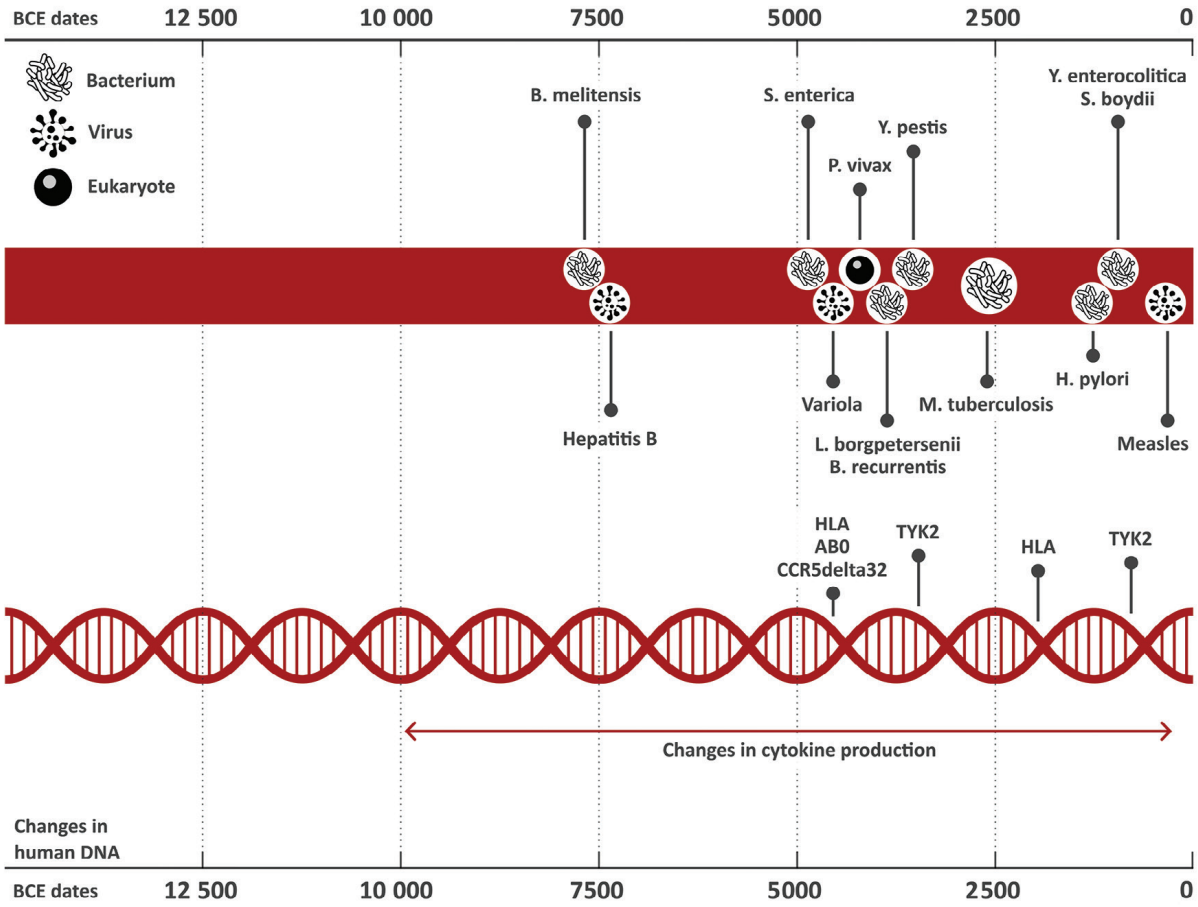

Fig. 3. Timeline of pathogens recovered, and of changes in the human DNA, for prehistoric farming and herding populations of Central and Western Eurasia.

third quarter of the 4th millennium BCE to the early 1st millennium BCE, across a vast area from Britain to Armenia, and from the Iberian Peninsula to the Altai Mountains (*Rasmussen* et al. *2015; Andrades Valtueña* et al. *2017; 2022; Spyrou* et al. *2018; 2019; Rascovan* et al. *2019; Swali* et al. *2023; Sikora* et al. *2025*). Its prevalence appears to have gradually increased, peaking at the end of the 4th millennium BCE in western Eurasia and the Eurasian steppe, and experiencing several additional peaks over the following 3000 years (*Sikora* et al. *2025.6*).

An intense debate surrounds the transmission routes and virulence of prehistoric plague. Three main plague lineages have been identified based on chronology and characteristics. The oldest lineage, known as preLNBA, lacks the ymt gene (murine toxin), which enables *Yersinia pestis* to survive in the flea's midgut and be transmitted by this insect. It also lacks certain virulence genes found in later lineages. Nevertheless, the recurring presence of the bacterium in the remains of multiple individuals buried together suggests that person-to-person transmission was possible (*Macleod* et al. *2024; Seersholm* et al. *2024; Sikora* et al. *2025.4–5*). Moreover, some strains of the preLNBA- lineage may have carried the gene encoding the *Yersinia pseudotuberculosis*-derived mitogen (ypm), which would have made them potentially more dangerous (*Macleod* et al. *2024.10–12; Seersholm 2024.119–120*).

This early plague was a widespread disease in Late Neolithic Europe. A study of 108 individuals from Scandinavia, dated to the transitional centuries between the 4th and 3rd millennia BCE and sometimes separated by hundreds of kilometres, detected *Yersinia pestis* in one out of every six individuals. At Frälsegården, 13 of 47 individuals (28% of the total) were infected, with the bacterium detected over six generations, spanning 150–180 years. The analysis also revealed the existence of at least three strains of preLNBA- A, B and C (*Seersholm* et al. *2024*). Plague was detected in the first generation, strain A, and in generations three to five – strains B and C. These reinfections may have resulted from successive, independent zoonotic events. Alternatively, such patterns are also consistent with what would be expected in a crowd disease transmitted from person to person in a large, well-connected population, with successive waves infecting those who,

being younger, had not yet been exposed to the pathogen.

By the end of the 4th millennium BCE, the LNBA- lineage emerged. Initially believed to be incapable of flea-borne transmission, it is now thought that such transmission was possible, though less efficient than in the strains causative of the Black Death (*Slavin, Sebbane 2022*). Furthermore, these lineages appear to have been capable of causing the bubonic form of plague, albeit in a less severe form (*Andrades Valtueña* et al. *2017.3688*). Finally, the LNBA+ lineage did possess the ymt gene. This lineage appeared for the first time in Russia in the first half of the 2nd millennium BCE, and it is believed that both lineages coexisted for at least 2500 years, until LNBA- eventually became extinct due to being less competitive (*Andrades Valtueña* et al. *2022.7–8; Spyrou* et al. *2018.2*).

A recent global phylogenomic analysis of ancient and modern *Yersinia Pestis* strains (*Dutta* et al. *2025*) provides further empirical support for much of what has been suggested in the previous paragraphs. According to this study, plague has persisted in long-standing, widespread, diverse Eurasian reservoirs since prehistory. For the majority of this time, the pathogen evolved slowly in a range of hosts, namely rodents, fleas and soil. However, at key junctures in human history – increased long-distance trade, intensified population concentration and mobility – reoccurring spillover events, followed by massive human-to-human transmission, caused bursts of accelerated genomic evolution and the quick succession and replacement of genetically distinct *Yersinia pestis* strains in relatively brief chronological intervals. The authors identify two such moments in Eurasian prehistory: the first in the Neolithic/Bronze Age – more precisely between the late 4th millennium and the early 2nd millennium BCE; and the second later in the Bronze Age – roughly from the mid-2nd to the mid-1st millennium BCE (*Dutta* et al. *2025.Fig. 3A*).

Smallpox (variola virus) has not yet been detected in prehistoric samples, but it may have been an important zoonotic pathogen during this period. A study estimated its age using calibrated viral mutation rates as a reference and determined that the jump to the human species occurred sometime between 6000 and 2000 BCE, in line with historical written sources (*Forni* et al. *2023.5*). Slightly later is the chronology attributed to the origin of tuberculosis, approximately 2600–200 BCE (*Sabin* et al. *2020*). As previously mentioned, the detection of RNA viruses is extremely challenging. We do know that measles (*Measles morbillivirus*), an RNA virus, may have emerged in the 6th century BCE (*Düx* et al. *2020*), consistent with a zoonotic pathogen with a high critical community size.

The study by Sikora *et al.* (*2025*), mentioned earlier, has provided significant insights into the evolution of infectious diseases in post-Neolithic Central and Western Eurasian prehistory. Most notably, the category of 'zoonotic' pathogens – almost absent in hunter-gatherer groups – shows a marked increase in prevalence within the dataset starting in the late 5th millennium BCE among agro-pastoral communities (Fig. 4).

To better understand this phenomenon, we have divided the records from the article's database corresponding to post-Neolithic Eurasian prehistory into three periods:

(1) For the Early Neolithic, prior to the 4th millennium BCE, the sample is small: 46 individuals, with only one identification of a pathogen in the anthroponotic category – Torque teno virus 27 – representing 2.2% of individuals.

(2) For the Late Neolithic and Chalcolithic (4th–3rd millennia BCE), 120 individuals were analysed, yielding five positives (4.2%) for anthroponotic pathogens – Hepatitis B and *Borrelia recurrentis* – and 11 (9.2%) for zoonotic pathogens – *Yersinia enterocolitica*, *L. borgpetersenii*, *Salmonella enterica*, and *Yersinia pestis*. Four of the overall 16 infections were viruses (25% of the overall infections and 3.3% of individuals), while 12 were bacteria (75% of all infections and 10% of individuals). The overall rate of infection rises up to 13.3%.

(3) Finally, for the Bronze Age, 223 individuals were examined, resulting in 19 positives for anthroponotic agents – *Shigella boydii*, *Helicobacter pylori*, hepatitis B, *Borrelia recurrentis*, *Plasmodium vivax*, herpesvirus – and 22 for zoonotic agents – *Yersinia enterocolitica*, *Salmonella enterica*, and *Yersinia pestis*. Taking into account co-infections, there are 36 individuals infected overall (16.1% of the sample), with 17 infected from anthroponotic agents (7.6%) and 21 from zoonotic pathogens (9.4%). Of the 41 infections, 32 are bacteria (78% of all infections), eight are viruses (19.5% of all infections), and one – *Plasmodium vivax* – is an eukaryote (2.4%). After accounting for co-infections, there are eight individuals infected from

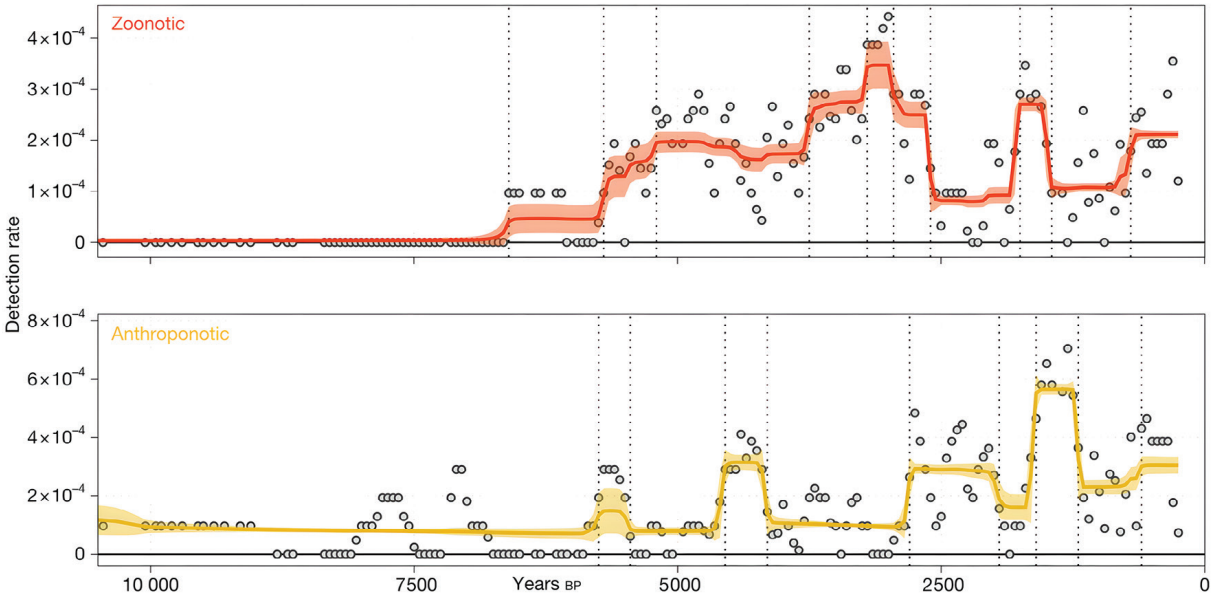

Fig. 4. Trendlines for detection rates inferred using Bayesian change-point detection and time series decomposition for ancient microbial species in the zoonotic (top) and anthroponotic (bottom) reservoir class (*Sikora *et al.* 2025.Fig. 5b*).

viruses (3.6% of the sample), and 29 from bacteria (13%).

In short, infection rates went up throughout the post-Neolithic prehistory of Western and Central Eurasia, from 8% in hunter-gatherers to 16.1% in the Bronze Age. Interestingly, DNA viruses are not driving this surge in infections, as they tend to be slightly less frequent in the dataset as time moves forward. The big culprit are bacteria, which go from a 2.3% infection rate in hunter-gatherers to 13% in the Bronze Age (Fig. 5).

As for the evolution of human DNA, the studies conducted so far have employed various methods, often refined as research progressed, sometimes leading to slightly different results (*Mathieson* et al. *2015; Domínguez-Andrés* et al. *2021; Kerner* et al. *2021; 2023; Childebayeva* et al. *2022; Akbari* et al. *2024; Barrie* et al. *2024; Irving-Pease* et al. *2024; Pandey* et al. *2024; Ravn* et al. *2025*). Nevertheless, they all broadly converge on the same conclusions. The emerging picture from this collective effort is one of numerous genetic changes associated with the strengthening of the immune system – *i.e.* increased resistance to disease – chronologically aligned with the Late Neolithic and Bronze Age in Europe. Indeed, nothing appears to have exerted greater selective pressure on Europeans in the last few millennia than the frequent and intense exposure to pathogens from the 4th millennium BCE onward, especially during the 3rd and 2nd millennia BCE (*Kerner* et al. *2023.5*).

While not exclusively, selection is concentrated around the HLA region on chromosome 6, closely linked to human immune response, as noted earlier. Probably also related to protection against new infectious agents are the progressive rise in the frequency of blood group B at the expense of group A (*Kerner* et al. *2023.3; Akbari* et al. *2024.6*); evidence of selection acting on the CCR5delta32 haplotype (*Akbari* et al. *2024.7; Ravn* et al. *2025*); and the abrupt change in inflammatory response – cytokine production – in the final millennia of European prehistory, which reduced immunity to tuberculosis in favour of resistance to other pathogens (*Domínguez-Andrés* et al. *2021.3,6*), to cite only a few of the selection signals that have been identified.

A particularly striking case is the P1104A variant of the TYK2 gene, inversely related to the immune response to tuberculosis: individuals carrying two copies of this variant have a much higher risk of developing severe tuberculosis. If, as described above, tuberculosis has accompanied humanity since at least the 3rd millennium BCE, one might expect the frequency of P1104A to have declined steadily since then. However, its presence in the European population is estimated to have increased between the mid-4th and late 2nd millennium BCE. Later, the frequency of this polymorphism decreased, as expected (*Kerner* et al. *2021; Akbari* et al. *2024.6*). Other genotypes associated with reduced resistance to tuberculosis appear to have evolved in parallel (*Immel* et al. *2021.7*).

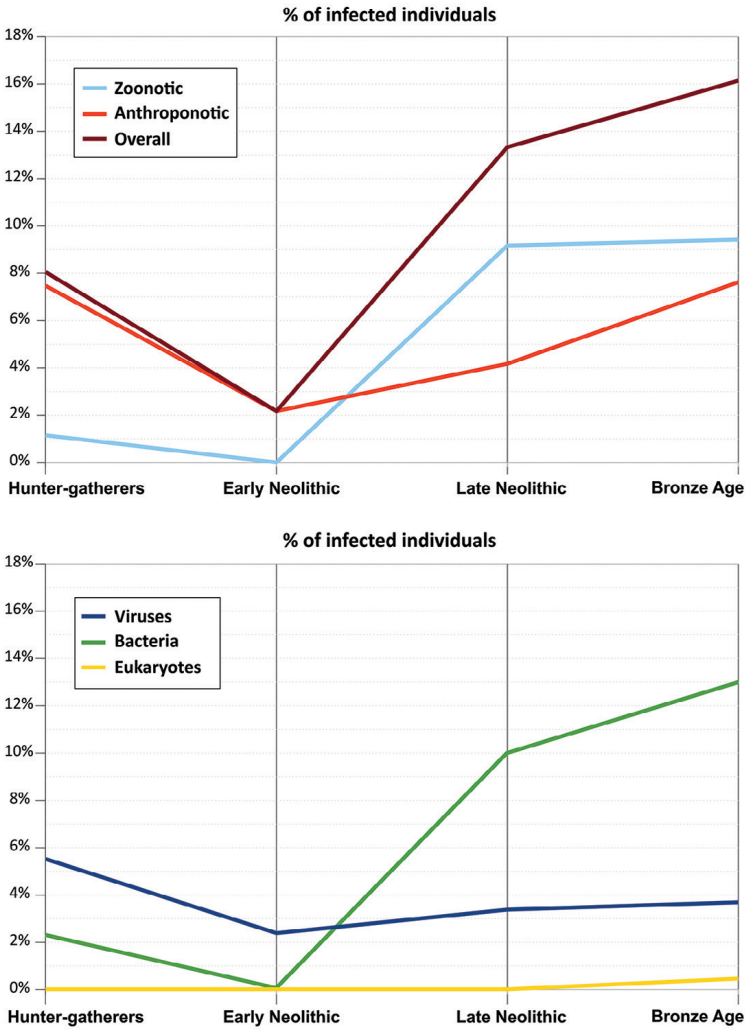

Fig. 5. Evolution of the rate of infection in the Prehistory of Central and Western Eurasia, in terms of percent of individuals infected (created by the authors from data in* Sikora *et al.* 2025.supplementary table 2*).

Discussion

The evidence reviewed here largely supports the hypothesis of a First Epidemiological Transition, albeit with some important qualifications.

The first point to consider is that, when discussing epidemiological patterns, it is not justified to draw a strict dichotomy between prehistoric societies of hunter-gatherers, on the one hand, and those of farmers or herders on the other. More meaningful distinctions emerge when we consider factors such as dietary diversity and abundance, the intensity of animal husbandry practices, demographic density, the existence of agglomerated settlements, and cultural practices surrounding individual and collective hygiene.

In this sense – and only in this sense – it is reasonable to highlight the Neolithic as a pivotal moment in human history. While not universal, the particularities of agrarian lifeways meant that these parameters were more commonly found in Neolithic societies than in those preceding them (*Barker 2006*). We know, for example, that European Neolithic societies experienced a demographic boom (*e.g., Shennan* et al. *2013*) (Fig. 6). The evolutionary history of human parasites also points to significant population growth during the Neolithic Transition (*Miles* et al. *2025*). Furthermore, it is clear that the environmental impact of human societies in the last few millennia of prehistory was far more profound than during the Palaeolithic, even though the latter's impact was not negligible (*Boivin* et al. *2016*).

Finally, a recurring theme in these studies is the existence of evolutionary trade-offs in the adaptation of ancient Europeans to the epidemiological conditions of post-Neolithic prehistory, in line with the so-called antagonistic pleiotropy hypothesis (*Kerner 2023.11*). As is well known, traits advantageous for survival and reproduction in one context may become detrimental when circumstances change. In this case, the enhancement of immune responses to the new infectious agents emerging during the final millennia of prehistory has come at a cost in the present day, in a context where improved hygiene and vaccination programmes have dramatically reduced pathogen exposure. Now, most of these genetic variants predispose us to a higher risk of developing autoimmune diseases, particularly inflammatory gastrointestinal disorders such as coeliac disease or Crohn's disease, multiple sclerosis, or hereditary hemochromatosis, among others.

All this is consistent with the fact that in the Late Neolithic and Bronze Age of Central and Western Eurasia infection rates went up considerably, from 8% to 16.1%, according to the dataset in Sikora *et al.* (*2025*). The existence of a First Epidemiological Transition in prehistoric Central and Western Eurasia is further supported by the greater diversity of potential pathogens in the immediate environment of human communities. In the same study, the rate of infection of zoonotic pathogens went up from 1.1% for hunting and gathering communities to 9.2% and 9.4% for the Late Neolithic and Bronze Age, respectively.

The observed behaviours of certain diseases also point in this direction. For instance, plague in the small hunter-gatherer communities around Lake Baikal appears to have manifested as brief, lethal dead-end spillover events, consistent with predictions from the hypothesis. In contrast, in Late Neolithic Scandinavia – where a significant population gathered and organized itself around the construction of large funerary monuments – plague seems to have recurred across generations, a pattern compatible a priori with that of a crowd disease, though alternative explanations for this phenomenon cannot be ruled out. Again, this would align with expectations derived from the hypothesis at the heart of this study.

In the Sikora *et al.* (*2025*) dataset, the infection rate for viruses remains low throughout. By contrast, the infection rate for bacteria significantly increases as we get closer to the Bronze Age. There is a growing consensus that RNA viruses must have posed a constant threat during this era, given their considerable capacity for interspecies transmission and person-to-person spread, and their usually higher virulence (*Ellwanger, Chies 2021.7; Sikora* et al*. 2025.8*). Therefore, it is likely that the low rates of infection for viruses correspond to DNA viruses but not RNA viruses, which are much harder to detect with the current methodologies.

Human DNA evolved after the Neolithic as though under significant pressure from the rising threat of infectious diseases. Some of the observed changes in immune system responses warrant particular attention.

As noted earlier, Palaeolithic populations seem to have been in relatively frequent contact with certain types of viruses, as reflected in their genomes through adaptations in regions such as the VIPs coding genes and the HLA loci. However, comparable adaptations to pathogenic bacteria are not apparent – at least not to the same extent. In contrast, the last millennia of prehistoric Europe saw strong selection for genetic variants associated with cytokine production: a muted inflammatory response to certain viruses, paired with a more robust response to a range of bacteria. In other words, the immune strategy appears to have inverted after the Neolithic Transition.

In an environment saturated with pathogens and rich in opportunities for transmission, bolstering defences against highly dangerous bacteria such as *Yersinia pestis* or *Borrelia recurrentis* makes clear evolutionary sense. But why would a dampened response to viruses also be favoured? Jorge Domínguez-Andrés *et al.* (*2021.3–4*) suggest an explanation: it may have been evolutionarily advantageous to avoid hyperactive immune responses to the numerous viruses circulating in post-Neolithic communities, given the human immune system's tendency toward hyperinflammation in the form of 'cytokine storms'. In such a pathogen-rich environment, some degree of tolerance to viral infections might have constituted an effective defensive strategy.

A similar dynamic can be observed in the immune response to tuberculosis. As multiple lines of evidence (see above) suggest, tolerance to *Mycobacterium tuberculosis* infections increased during recent European prehistory. While seemingly counterintuitive, this pattern might be explained by the fact that latent tuberculosis infection – the most common form among contemporary humans – can help the immune system defend against other infections (*Domínguez-Andrés* et al*. 2021.6*). In a highly pathogenic environment such as that of the 4th–2nd millennia BCE in Europe, this protective effect may have outweighed the relatively small risk of developing severe tuberculosis. This evolutionary strategy appears to have persisted until around 1000 BCE, when the increasing threat posed by tuberculosis likely reversed the trend.

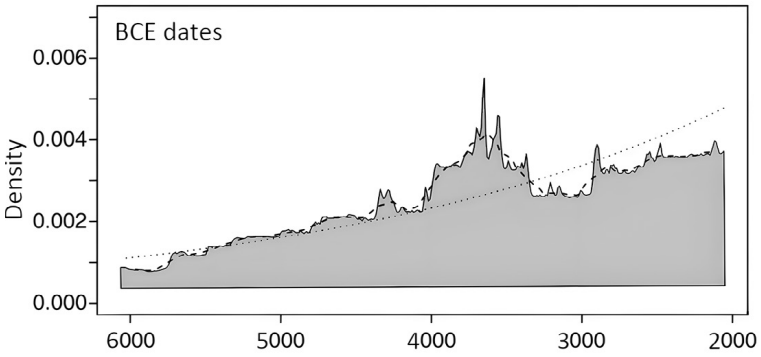

Fig. 6. Population density change inferred from summed calibrated date probability distributions (SCDPD) for 7944 radiocarbon dates in 12 regions across Western Europe. An exponential generalized linear model is indicated in dotted lines for reference (modified from Stephen Shennan* et al. *(2013.Fig. 4).

Taken together, aDNA analyses of pathogens and humans reveal the emergence of novel and virulent diseases after the Neolithic, thereby providing empirical support for the First Epidemiological Transition hypothesis in Eurasia.

However, recent studies point to an intriguing nuance: in Central and Western Eurasia, the highest infection rates and the most significant changes in immune responses occurred during the later Neolithic and Bronze Age, rather than at the onset of the Neolithic. This requires further investigation. With the current evidence, the most plausible explanation would be that it took some time and certain technological innovations for agriculture to generate the conditions conducive to a significant population growth (*Shennan* et al. *2013; Müller 2017*). Additionally, certain social and political mechanisms needed to be in place for substantial agglomerations of people to occur. Perhaps it is no coincidence that, between the 5th and 3rd millennia BCE, people in Europe may have begun to gather in massive numbers in places to live together, or temporarily to build monumental structures (*Gaydarska, Chapman 2022*); or that people in the Eurasian steppes began to depend to a much greater extent on keeping livestock (*Anthony 2023*).

Conclusions

The hypothesis of the First Epidemiological Transition was originally proposed as a bold and provocative idea that ran counter to the prevailing narrative in Western thought about the Neolithic, a narrative that had persisted from the Enlightenment through to the 1960s and 1970s. Its arguments derived largely from ethnographic analogy, which made them theoretically compelling but difficult to test against the archaeological record.

For decades, one of the main pieces of evidence cited in favour of the hypothesis was the widespread deterioration of health during the Neolithic, inferred from stress indicators in the musculoskeletal system of ancient human remains (bioarchaeology). Among these markers, stature became regarded as the key indicator of a population's general health status. Macroscopic analyses of human skeletal remains even identified cases of infectious diseases such as tuberculosis and leprosy. Studies of the so-called Neolithic Demographic Transition (palaeodemography) pointed in the same direction, suggesting an increase in juvenile mortality in post-Neolithic prehistory.

However, significant challenges remained in empirically testing the hypothesis. Stress indicators were not always recognizable, and when they were, their causes often proved ambiguous, and they were nonspecific. Height, in turn, was shown to result from a complex interplay of genetic and environmental variables. A similar problem arose with the mortality increases suggested by palaeodemographic studies: although infectious diseases were suspected to have played an important role in the Neolithic Demographic Transition, disentangling their specific contribution from other factors was far from straightforward. As such, until roughly a decade ago it was not possible to rigorously test the hypothesis due to a lack of crucial data.

Starting in 2015, the dramatic methodological advances taking place in the field of genetics began to be applied to prehistoric studies. This marked a radical shift, as it became possible for the first time to directly detect prehistoric pathogens in human remains. Beyond mere detection, these advances allow researchers to address questions about the zoonotic or other origins of diseases, the geographic and chronological contexts of their emergence, modes of transmission, the rise of new variants, virulence, the potential occurrence of epidemics, and the coevolution of pathogens and their hosts.

Studies conducted – so far concentrated in Central and Western Eurasia – have documented the presence of hepatitis B, salmonellosis, brucellosis, louse-borne relapsing fever (LBRF), plague, and many other infectious diseases in Neolithic and Bronze Age contexts across the continent. Temporal analysis of these pathogens reveals a marked increase in zoonotic diseases caused by bacteria beginning in the fourth millennium BCE.

In parallel, changes in the human genome suggest that human evolution accelerated during the final millennia of European prehistory, driven by the selection of genes enhancing immune system function at precisely the moments when numerous novel pathogens began circulating in Eurasia (4th–2nd millennia BCE). For such notable genetic transformations to have occurred, the impact of disease on Eurasian populations must have been substantial: many people likely died, leaving survivors who possessed some degree of genetic resistance. It therefore seems reasonable to conclude that these diseases had a major demographic impact on Neolithic and Bronze Age societies in Eurasia. Whether this large-scale phenomenon was sudden and catastrophic – in other words, whether it manifested as major epidemics – remains an open question.

All of these findings are consistent with predictions from the First Epidemiological Transition hypothesis, which posits that zoonoses linked to animal husbandry

and increased population density were key drivers of the rise in infectious disease prevalence. Yet the evidence suggests that this shift occurred predominantly during the later phases of the Neolithic and into the Bronze Age, rather than at the very onset of the Neolithic. Although infections certainly existed during the Palaeolithic – and may occasionally have manifested as epidemics – the variety, abundance, and nature of infectious agents in later European prehistory represent a qualitative change that justifies the designation of a First Epidemiological Transition.

Despite their undeniable novelty, these discoveries strengthen the validity of the traditional methods of prehistory, such as archaeology and ethnographic analogy. The evidence provided by palaeogenomics largely corroborates inferences held for decades. Even today, despite the critical contributions of palaeogenomics, bioarchaeology and palaeodemography remain invaluable for assessing the overall health status of prehistoric populations. In particular, bioarchaeology provides crucial contextual information for understanding palaeogenomic data, offering insights into key epidemiological variables such as age, sex, height, social and economic status, place of residence, and many others for both infected and uninfected individuals (*Lewis* et al. *2023.4*).

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Simulacra of the ancestors: the Neolithic Package as a reconfiguration of 'skull cults'

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ABSTRACT – *The 'skull cults' of the Neolithic Near East have long attracted scholarly attention but are often treated as an isolated regional phenomenon. This study explores their deeper origins and broader connections by examining material culture and symbolic practices from* c. *150 000 to 8000 BP across Europe and the Near East. Using multifactorial statistical analyses of 32 features covering demography, body treatment, burial contexts, and grave goods from 219 sites, we integrate archaeological, climatic, theoretical, and archaeogenetic data. Results suggest that some traits of the Neolithic Southwest Asian 'skull cults' originated in the Middle Palaeolithic, while their defining distinction – primary burials in domestic settings versus secondary burials in public areas – emerged during the Mid-Upper Palaeolithic, notably at Pavlov (Czechia). The diversification of 'skull cults' accelerated after the Last Glacial Maximum amid large-scale population movements. In the Early Holocene, as agricultural households developed, these rituals were gradually replaced by new symbolic media such as pottery, figurines, and stamps – the so-called Neolithic Package. These portable 'simulacra' redefined representations of the body, house, and community. Although 'skull cults' disappeared, their symbolic legacy persisted, transmitted through material proxies that carried shared ideological codes across post-LGM Europe and the Near East.*

KEY WORDS – *skull cult; Neolithic Package; Neolithic; Upper Palaeolithic*

Simulakri prednikov: neolitski paket kot preoblikovani 'kulti lobanj'

IZVLEČEK – *Preučevanje 'kultov lobanj' na neolitskem Bližnjem vzhodu predstavlja pomembno raziskovalno temo, čeprav se pogosto dojema kot prostorsko omejen pojav. V članku s pomočjo študija materialne kulture in simbolnih praks proučujemo njihov izvor in povezavo v času med c. 150 000 in 8000 leti pred sedanjostjo v Evropi in na Bližnjem Vzhodu. S pomočjo multivariatnih statističnih analiz smo analizirali 32 značilnosti, razvrščenih v 8 kategorij, povezanih z demografskimi podatki, obravnavo teles, pogrebnim kontekstom ter grobnimi pridatki na 219 arheoloških najdiščih. Rezultate smo povezali z arheološkimi, klimatskimi, teoretskimi in arheogenetskimi podatki. Ugotavljamo, da nekatere značilnosti neolitskih kultov lobanj v Jugozahodni Aziji izvirajo iz srednjega paleolitika, medtem ko se ključne razlike – primarni pokopi v bivalnem prostoru v nasprotju s sekundarnimi pokopi na javnem prostoru – pojavijo v sredini mlajšega paleolitika na najdišču Pavlov (Češka). Raznolikost 'kultov lobanj' se je po zadnjem glacialnem maksimumu močno povečala zaradi obsežnih selitev prebivalstva. V zgodnjem holocenu so te rituale z razvojem hišnih gospodinjstev postopoma nadomestili novi simbolni mediji, kot so keramika, figurice in pečatniki, t.i. neolitski paket. Ti prenosni 'simulakri' so na novo opredelili predstave o telesu, domu in skupnosti. Čeprav so 'kulti lobanj' izginili, se je njihova simbolna dediščina ohranila in prenašala s pomočjo nadomestkov, ki so imeli v obdobju po zadnjem glacialnem maksimumu skupni ideološki kod v Evropi in na Bližnjem vzhodu.*

KLJUČNE BESEDE – *kult lobanj; neolitski paket; neolitik; mlajši paleolitik*

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Introduction

In southwest Asia, 'skull cults' were a widely spread and relatively standardized symbolic activity during the Neolithic transformation (*c.* 12 000–9000 BP) (see Fig. 1 for chronology). The term 'skull cult' generally refers to a series of structured acts involving primary burials in residential buildings and secondary burials of skulls or other skeletal elements in public spaces (*Kenyon 1981; Özdoğan, Özdoğan 1989; Kuijt 2000b; 2001; 2008; Kuijt, Goring-Morris 2002; Akkermans, Schwartz 2003; Goring-Morris 2005; Akkermans 2008; Fletcher* et al. *2008; 2008; Kanjou 2009; Hodder, Pels 2010*). In this wider ritual context, the skulls received particular attention. For example, plaster was applied to recreate facial features (Fig. 2), shell or obsidian inlays were set in the eye area, and hair attachments were added on the scalp, all of which indicate an effort to 'resurrect' the dead who now symbolize the ancestors (*Arensburg, Hershkovitz 1988; Griffin* et al. *1998; Goren* et al. *2001; Kuijt 2008*). In the graves, various other symbolically significant objects like animal bones, antlers, shells, flint, and ground stones could also be used, and ochre could have been applied to various parts of the skeletal remains (*Goring-Morris* et al. *2009; Baird* et al. *2013*).

More significantly, the association of these complex post-mortem rituals with house destruction and renovation cycles indicates their significance in re-structuring the nascent agricultural communities around the new concepts of the house and the household (*Byrd 1994; Bar-Yosef 1998; 2001; Rollefson 2000; Kuijt 2001; 2008; Flannery 2002; Kuijt, Goring-Morris 2002; Verhoeven 2002; Banning 2003; Croucher* et al. *2006; Atakuman 2014*). During the house renovation cycles, domestic buildings were first cleaned and then partially demolished to create a foundation deposit for the new structure that was rebuilt on the same location and plan. This process arguably increased the prestige of the house by making its history visible in the höyük/tell formations (Fig. 3) (*Bailey 1999; Hodder, Cessford 2004; Düring 2005; Bogaard* et al. *2009; Russell* et al. *2009; Hodder, Pels 2010; Carter* et al. *2015*). Renovation cycles included plastering and decorating walls and floors with animal skull installations and paintings, displaying the house's lengthy ancestral history (*Matthews 2005; Farid 2007; Twiss* et al. *2008; Hager, Boz 2012*). These structured acts influenced many aspects of life, from daily routines of tending primary burials beneath house floors to seasonal cycles involving secondary burials in communal spaces. In this context, many researchers consider 'skull cult' rituals as part of a broader seasonal regeneration rituals, that negotiated private and communal spaces in response to the emerging concepts of household with the new economic conditions of the agricultural lifestyle (*Bar-Yosef, Belfer-Cohen 1991; Byrd 1994; Byrd Monahan 1995; 2000; Bar-Yosef 1996; Kuijt 1996; 2000a; 2000b; 2001; 2008; 2018; Boyd 2001; Goring-Morris, Belfer-Cohen 2002; 2008; Hodder, Cessford 2004; Goring-Morris 2005; Matthews 2005; Nakamura, Meskell 2009; Twiss, Russell 2009; Belfer-Cohen, Goring-Morris 2010*). In fact, the wider anthro-

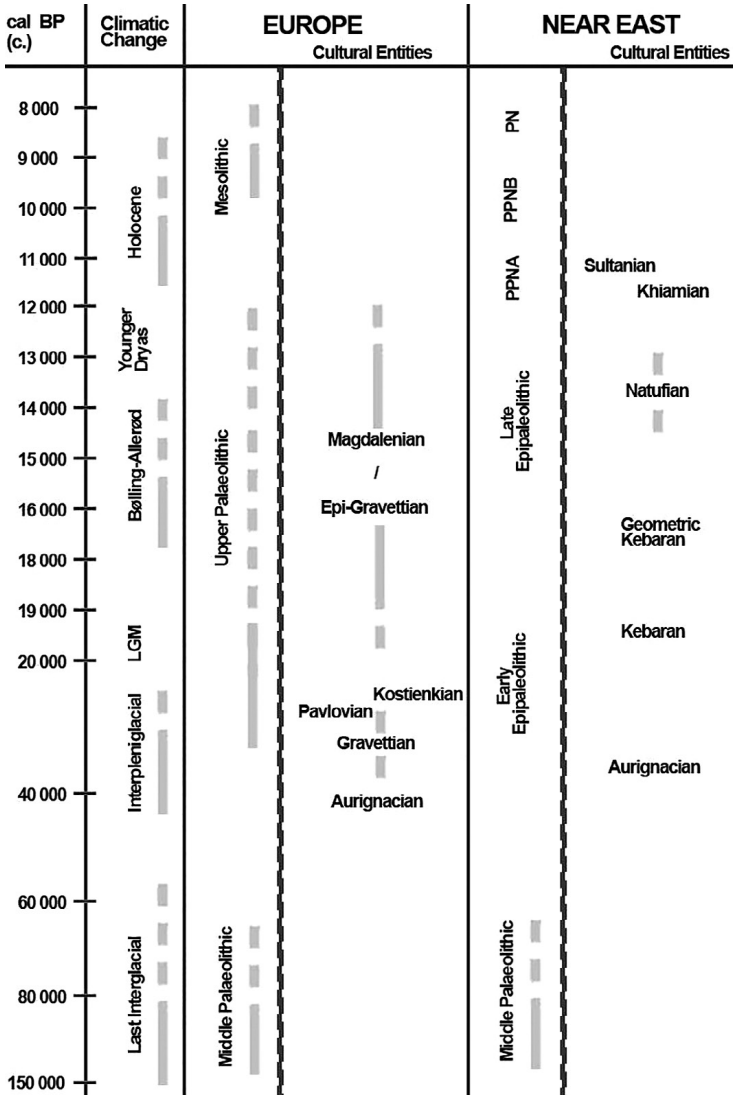

Fig. 1. Comparative chronology.

pological literature also posits that human mortuary ritual was one of the most powerful media for negotiating social identity and territorial claims at many scales, within variable contexts of climatic, ecological, and social pressures, during the evolution of human social and cognitive complexity (*Hertz 1960; Binford 1968; Saxe 1970; Renfrew 1976; Tainter 1978; Bloch, Parry 1982; Hodder 1982a; 1982b; Parker Pearson 1982; Thomas 1988, 2000; 2002; Barrett 1990; Metcalf, Huntington 1991; Carr 1995; Gillespie 2001; Van Dyke, Alcock 2003; Budja 2010; Bradley 2012; Robb 2013*).

Fig. 2. Aswad skulls (*Stordeur, Khawam 2007. Fig. 5.1*).

While the 'skull cults' of southwest Asia in the Neolithic period have often been studied in isolation, evidence suggests that skulls have been of particular interest since the earliest recorded human burials and mortuary activities. The first proper human burials in the prehistoric record, at the Skhul and Qafzeh Caves (approximately 130 000–100 000 BP), indicate a focus on the retrieval of skull pieces (*e.g.,* Skhul 9) (*Stringer 1998; Pettitt 2010*). Alternatively, the modified skull pieces found at Herto-Ethiopia (160 000–150 000 BP) (*Clark* et al. *2003*), or the skull and mandibular pieces found at the Klasies River Mouth or Border Cave in South Africa (100 000 BP) (*Rightmire 1979; Rightmire, Deacon 2001; Barnard 2010.42–43*), indicate a specific focus on skulls since the Middle Palaeolithic. Further literature indicates the presence of skull-focused mortuary activity in the more complex burials of Upper Palaeolithic and Mesolithic European societies (40 000–8000 BP) (*Klíma 1991; Svoboda 2006; 2007; 2008; Pettitt 2010; 2014; Orschiedt 2013; 2018*). For example, the Pavlov sites in Czechia exhibit remarkable parallels to the southwest Asian Neolithic 'skull-cult' rituals, as will be discussed further in the text. While skulls continue to be an important part of rituals in the New Guinean groups (*Van Baaren 1968; 2010; Soukup 2018*), Bornean Dayak people (*Darmadi 2017; Sada* et al. *2019*), and the Naga Tribe of northeast India (*Mills 1926; Hutton 1965*), they are otherwise rarely practiced in the post-agricultural and industrialized societies today.

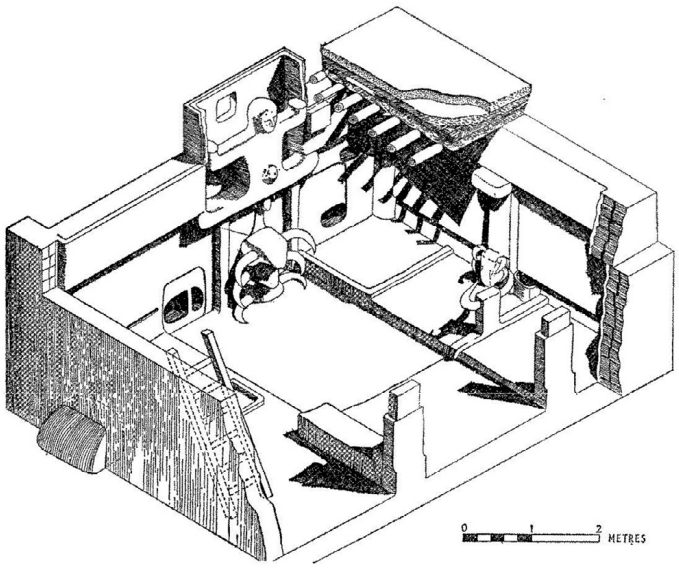

Fig. 3. Çatalhöyük 'History House' (*Mellaart 1963.Fig. 14*).

There are already a number of databases and wider qualitative syntheses on the prehistory of human mortuary practices in the literature (*Pettitt 2010; 2014; 2018; Riel-Salvatore, Gravel-Miguel 2013; Orschiedt 2018; Atakuman* et al. *2019*). While we utilize these, we aim for a quantitative approach focusing on the formation, spread, and dissolution of particular symbolic behaviours that offer an alternative perspective on understanding the formation of southwest Asian 'skull cults' and the spread of the Neolithic way of life to Europe. For the purposes of our research, we hypothesize that various sub-features of the southwest Asian Neolithic 'skull-cult complex' emerged during various stages of the Palaeolithic, as responses to varied climatic, ecological, and social stressors encountered by hunter-gatherers in different ecological niches. Our aim is thus to trace the historical development of key aspects of 'skull cult' practices over a broad temporal span (*c.* 150 000–8000 BP) and across a wide geographical area, with particular emphasis on Europe and the Near East. Our intention is not to offer an evolutionary synthesis, as proposed by Paul

Pettitt, nor to introduce new interpretative frameworks to account for changes in mortuary practices across time and space. Rather, we focus on identifying the features that culminate in the Southwest Asian 'skull-cult complex', and on proposing an interpretative approach to its dissolution in conjunction with the completion of the Neolithic process and the rise of new material and social regimes.

To achieve our goal, we gathered data from 219 sites (Fig. 4) in Europe and the Near East, spanning from the Middle Palaeolithic to the end of the 7th millennium BC, when agricultural lifestyles were well established across a wide region of the Near East and surrounding areas. For each site, the major primary and secondary literature were examined, with a table of references used for each site given in Site-based reference list (see Supplementary File at https://doi.org/10.4312/dp.52.21). By utilizing this literature, 32 features were recorded in eight categories for each site (see Main categories and features analyzed in the article), focusing on site type, disposal type, human remains, modifications of the human skull, animal remains, items related to burial context, burial makers, and figurines. This data was analysed across five distinct periods (summarized below) and eight regions (western Europe, eastern Europe, southwestern Europe, southeastern Europe and Aegean, Anatolia and northern Mesopotamia, Levant, Siberia, and Iran) (Figs. 1,4).

Our selection of time periods and regions is grounded in widely accepted chronological frameworks, informed by major climatic events, patterns of human dispersal, and socio-economic adaptations to specific ecological niches. These criteria ensure the internal coherence of data sets within defined temporal and spatial boundaries.

Period 1: Middle Palaeolithic* (c. *150 000–40 000 BP)

The available data for this period are limited and primarily pertain to Neanderthal sites. Due to the sparse nature of the evidence, this period encompasses a broad chronological range and marks the earliest emergence of human burial practices and skull-related activities.

Period 2: Early Upper Palaeolithic* (c. *40 000–25 000 BP)

This phase aligns with the dispersal of *Homo sapiens* from Africa to various regions across the globe and coincides with the environmental conditions of the Last Glacial Maximum (LGM). It is characterized by the development of relatively standardized mortuary practices and symbolic behaviours across Eurasia.

Period 3: Late Upper Palaeolithic* (c. *25 000–12 000 BP)

Defined by episodic retreats from severe glacial conditions, this period saw the establishment of long-term habitation sites and the proliferation of regionally distinct mortuary traditions focused on skull treatment in Europe and southwest Asia.

Period 4: Early Holocene* (c. *12 000–9000 BP)

Spanning the Early to Middle Holocene, this period reflects significant adaptive shifts culminating in the advent of agriculture. It is also marked by the rise of the 'skull-cult complex' in southwest Asia. Since our focus is on the southwest Asian 'skull-cult complex', we analyse this period in two subdivisions.

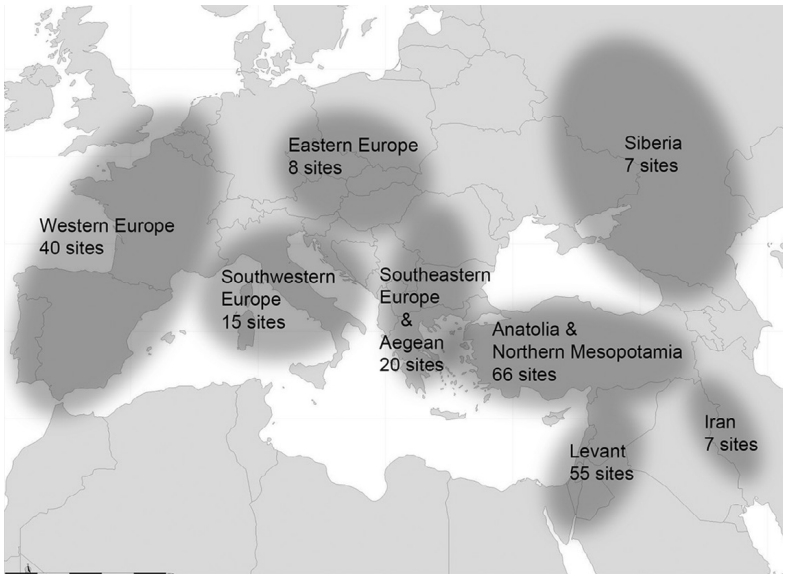

Fig. 4. A map indicating regions and the total number of sites studied in this article (Plus 1 site from Australia).

Period 4a (PPNA: 12 000–10 500 BP) and *Period 4b (PPNB: 10 500–9000 BP),* with PPN standing for the Pre-Pottery Neolithic.

Period 5: Post-Neolithic/Early Chalcolithic* (c. *9000-8000 BP)

This phase is characterized by the demise of many PPN settlements, the introduction of a new material culture centred on clay artefacts, the spread of Neolithic lifeways into Europe and the

Caucasus, and the gradual disappearance of 'skull-cult' practices.

Period 1: Middle Palaeolithic (c. 150 000–40 000 BP): interplay of human and animal skulls

While some would argue that the earliest responses to death in hominins start with *Australopithecus* and the *Homo habilis* at *c.* 3.5–3 million years BP (*e.g.,* AL-333 and Sterkfontein) (*Clarke 1998*), these cases are difficult to confirm since they mostly involve skeletal concentrations without burial or symbolic material culture. A more significant and probably more structured presence of ritualized responses to death may belong to *Homo antecessor* (*i.e.* Gran Dolina, *c.* 800 000 BP) (*Carbonell* et al. *1995*) and *Homo heidelbergensis* (*i.e.* Sima de los Huesos, *c.* 500 000 BP (*Arsuaga* et al. *1993*). Specifically, at Sima de los Huesos, adults in particular were selected for collection in a deep shaft inside the cave, from where a material culture resembling grave goods, such as ochre-covered hand-axes, has been recovered, indicating a much more advanced stage in mortuary behaviour and potentially territorial and social complexity (*Carbonell, Mosquera 2006*). Such behaviours continue to be present in different species, such as *Homo naledi* at Rising Star Cave (*Berger* et al. *2015*) and the Neanderthals at Pontenwydd (*Green* et al. *1981*), as well *Homo sapiens*.

In general, inhumations are quite rare in the archaeological record before the LGM (*c.* 25 000–18 000 BP); while various other methods, such as cremation, dismembering, fragmenting, scattering, open area disposals, and feeding to wild animals seem to have been commonly used by different cultural groups, thus leading to an absence in the archaeological record (*Smirnov 1989; Pettitt 2010; Hovers, Belfer-Cohen 2018; Atakuman* et al. *2019*). However, we begin to see an indisputable symbolic code in mortuary practices at Skhul and Qafzeh Caves by approximately 130 000 BP, which becomes the hallmark of *Homo sapiens* (Figs. 5,6) (*Schwarcz* et al. *1988; Stringer* et al. *1989; Gargett 1999; Hovers* et al. 2003*; Vandermeersch, Bar-Yosef 2019*). This symbolic code involves the use of grave markers to indicate the location of the burial, the incorporation of ochre, stone tools, shells, animal skulls, bones, tusks, and horns into the grave, as well as some focus on skull removal (Fig. 12). Along with *Homo sapiens*, the Neanderthals exhibit similar ritualized reactions to death, as known from the sites of Tabun, Amud, Kebara, Dederiyeh, Shanidar, Regourdou, La Ferrassie, and La Chapelle-aux-Saints (Fig. 8) (*Peyrony 1934; Vandermeersch, Trinkaus 1995; Rendu* et al. *2014; Dibble* et al. *2015*).

Fig. 5. Human burial at Qafzeh cave (*Vandermeersch 1970.Fig. 8*).

The emergence of these complex social behaviours and symbolic practices corresponds with the mild and stable climate of the Mikulino interglacial period, occurring approximately 130 000 to 115 000 years ago, when a warmer climate led to the expansion of forest and the retreat of ice sheets, allowing for the reoccupation and migration of fauna and human populations into previously glaciated areas. These environmental changes likely influenced human behaviours and settlement patterns, with *Homo sapiens* and Neanderthals adapting to new ecosystems and resources (*Finlayson 2004; Gamble* et al. *2004*). The presence of burial and other types of mortuary practices in both *Homo sapiens* and Neanderthals may indicate prior evolutionary emergence, in an ancestral species such as *Homo heidelbergensis* or *Homo naledi* (*Arsuaga* et al. *1993; Carbonell, Mosquera 2006*). However, considering the later appearance of mortuary practices in Neanderthals (*c.* post 70 000 BP), it is also plausible that there occurred some information exchange between the two species.

Thus, the first chronological group in our study covers approximately 150 000-40 000 BP and is represented by 16 sites in Europe, Siberia, southern Levant, northern Mesopotamia, Iran, and Australia (Figs. 7,8). Out of these 16 sites, only two are of *Homo sapiens,* while 14 are of the Neanderthals. The two *Homo sapiens* burial sites, *i.e.* the caves of Skhul and Qafzeh, are chronologically much earlier (*c.* 130 000–90 000 BP) than

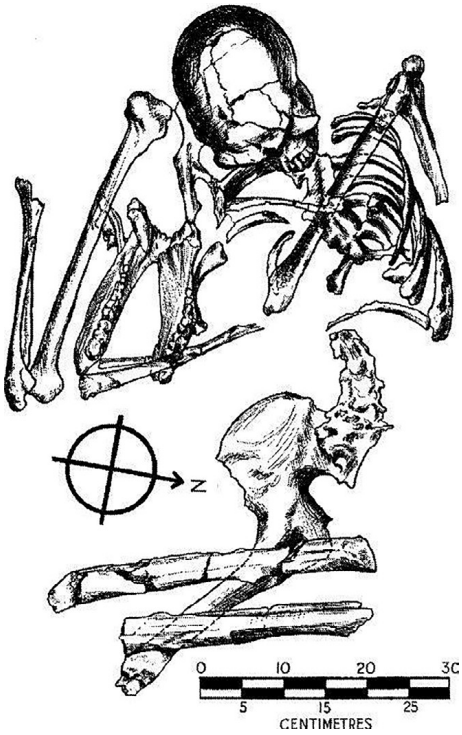

Fig. 6. Human burial at Skhul cave (*Garrod, Bate 1937.Pl. LII*).

the bulk of the Neanderthal sites (*c.* 70 000–50 000 BP), except the site of Tabun, which has an unreliable dating covering a wide range (*c.* 150 000–80 000 BP).

In a broader context, both the *Homo sapiens* and Neanderthal burials of this period were typically located in significant, repeatedly used landscape features such as caves (Fig. 11). While these caves were likely used as living quarters, distinctively designated areas were used for burial accumulations within them (*e.g.,* Skhul, Qafzeh, La Ferrasie, Regordou). Generally, individual interments dominated throughout both species (Fig. 12) (*Smirnov 1989*), although some sites featured multiple burials (*e.g.,* Qafzeh, Shanidar, La Ferrasie, Spy). In both Neanderthal and *Homo sapiens* groups, various positions were used for interment, but certain preferences are evident. For instance, at Skhul, *Homo sapiens* graves were laid in flexed or semi-flexed positions with various orientations, while in the Neanderthal burials at La Ferrassie, in particular, the adult skeletons, such as La Ferrassie 1 and La Ferrassie 2, were found laid out with their heads to the west and feet to the east. We should note that burials occur during this period, but they are not always of intact skeletons, especially with Neanderthals, and there is fragmentation of skeletal pieces and skulls, as well as a prevalence of cut marks, which are sometimes associated with nutritional cannibalism (*Bello* et al. *2011*).

There are some skull-related activities, such as focusing on the human mandible and skull fragments at Roc de Marsal, Tabun, La Ferrassie, and Spy. Creative variability in skull-related activity can also be observed at the Neanderthal human and cave bear burials at Régourdou Cave (*c.* 65 000–55 000 BP) (Fig. 9). Here, the bear skulls were carefully placed in a stone chamber in the cave while one Neanderthal burial was covered with bear skeletal pieces and stones, which seem to have acted like a place marker. Likewise, at Qafzeh Cave, animal horns were deliberately placed within graves, and large stones appear to have been positioned as markers associated with the burials (Figs. 8,10,12).

While all age and sex groups are present, children and infants are represented in relatively higher numbers, likely due to early mortality. At the same time, young adults are relatively scarce, and males are slightly more common than females. The treatment of typically adult males can also be differentiated by adding animal remains as grave goods, removing human skeleton pieces as body treatments, and using stone piles and/or standing stones as place markers, such as at Qafzeh, Kebara, La Ferrassie, Moustier, and Regourdou (Figs. 8, 10,12).

In terms of grave goods, the Neanderthal burials typically exhibit fewer artefacts (less than 5% of cases), including ochre, shells, deer bones (Amud), turtle remains (Dederiyeh), and, notably, bear bones and skulls (Régourdou), sometimes accompanied by stone tools. Neanderthals at times also practiced the use of grave

Fig. 9. The burial of cave bear skulls at Drachenloch (adapted from https://www.penn.museum/sites/expedition/the-cult-of-the-cave-bear/).

markers (Kebara), such as stone accumulations over the dead. *Homo sapiens* graves commonly contain red ochre, seashells, flint artefacts, and animal bones like deer (Qafzeh) and wild boar (Skhul), while grave markers, such as ground stones, are commonly used. Ochre seems to be more strongly associated with adults than other age groups in both Neanderthals and *Homo sapiens* groups (Figs. 8,10,12) (*Henshilwood, Dubreuil 2009*).

Ochre has been utilized in Africa for over 500 000 years (*Tylén* et al. *2020; Dapschauskas* et al. *2022*) as a crucial element of early burial rituals as well as body painting, which Christopher S. Henshilwood and Benoît Dubreuil (*2009*) argue may have contributed to cognitive development and early language. Francesco D'Errico and Marian Vanhaeren (*2009*) also note that the use of ochre in ceremonies could strengthen shared values and group identity. Clive Gamble (*1999*) also notes that ochre facilitated intergroup communication and collaboration, perhaps symbolizing age, gender, or social roles. Ochre use is often associated with blood as a symbolic element of life and death, and thus its ritual use may be metaphorically referring to life cycle rituals surrounding birth, initiation, marriage, or death (*Power 2010; Watts 2018*). This is supported by evidence from Middle Palaeolithic burials showing correlations between ochre use and age groups, and to a lesser extent, gender, as inferred from distinct grave goods.

Within this context, some researchers suggest these practices reflect territorial responses to population pressures (*Gamble, Roebroeks 1999*). Joao Zilhão (*2015*) and Mary C. Stiner (*2017*) argue that burials at frequently inhabited sites indicate strong social ties and continuity, while at the same time reflecting the new ways of symbolic communication and collaboration among groups with emergent differences in social status (*Gamble 1999*). Zilhão (*2015*) posits that Middle Palaeolithic burials frequently took place at regularly inhabited sites, indicating a structured territoriality that influenced burial customs. Similarly, Stiner (*2017*) highlights that intentional burials in familiar locations underscored the social significance of these sites, representing communal claims and continuity across generations. These burial practices suggest strong social bonds, shared ancestry, and increased collaboration among early human communities. Zilhão (*2015*) also notes that demographic patterns were not evenly distributed, with infants and older individuals comparatively underrepresented. Recent analyses further suggest that many of those interred were male, implying that mortuary practices were shaped by gendered patterns linked to hunting parties and mobility. Such biases indicate that burial was selectively applied, reflecting cultural choices about who was considered appropriate for funerary treatment and underscoring the role of age and gender in structuring social identity.

Period 2: Early Upper Palaeolithic (c. 40 000–25 000 BP): the first glimpses of the 'skull-cult complex'

The Early Upper Palaeolithic marks a pivotal period in human prehistory, coinciding with *Homo sapiens*' migration out of Africa into the broader Old World during challenging climatic conditions, culminating in the LGM. This era encompasses the Aurignacian (*c.* 50 000/45 000–30 000 BP) and Gravettian (*c.* 30 000–25 000/20 000 BP) phases in Europe. In the Near East, however, the Aurignacian label is generally used for the entire period. Although defining a 'typical' Upper Palaeolithic burial is difficult, the period saw a marked rise in burial practices – especially multiple interments. Julien Riel-Salvatore and Claudine Gravel-Miguel (*2013*) argue that this trend reflects shifting conceptions of individual identity and social relationships, particularly during the unstable climatic conditions of the LGM, which seem to have catalyzed increased social interaction and cooperation, during which burial and symbolic material culture perhaps became central expressions of individual and communal identity. More significantly, many features characteristic of the Early Holocene mortuary practices in the Near East – such as the symbolic use of space, figurines, and elaborate interment – appearto have originated in the central European steppes by at least 30 000 BP.

Our study focuses on 21 archaeological sites (Fig. 13 and Site-based reference list) distributed across Europe and the Near East, including sparse Aurignacian sites like Peştera cu Oase (Europe), Nazlet Khater (Egypt), and Ksar Akil (southern Levant), with the remainder belonging to the Gravettian tradition (Site-based reference list). Graves as clearly defined physical spaces were uncommon during the transition from the Middle to Upper Palaeolithic in both Europe and the Near East. Nonetheless, certain sites hint at the deliberate symbolic treatment of human skulls. Peştera cu Oase in the Carpathians offers one such example. The mandible of Oase 1 (*c.* 40 000 BP) was found on the cave surface, while the cranial remains of Oase 2 (*c.* 35 000 BP) include parietal and temporal fragments (*Rougier* et al. *2007*). Similarly, sites like Nazlet Khater and the cave of Ksar Akil (*Bergman, Stringer 1989*) demon-

strate skull burials, as well as other mortuary behaviours such as dismemberment and accumulation of skeletal parts – practices reminiscent of Middle Palaeolithic rituals (Fig. 19). Human skulls were also buried at the Gravettian site of Predmosti in Europe, whereas skeletons without skulls were noted at Cussac and Paviland (Fig. 14). In some cases, animal skulls – such as mammoth or bear – were venerated as ancestral symbols instead of human skulls (*Lascu* et al. *1996; Pettitt 2010; Cârciumaru* et al. *2015*). Practices involving stone markers, hearths, dismemberment, and the use of mammoth bones were often interlinked and most prominent in central and eastern Europe (Fig. 18).

During the Mid-Upper Palaeolithic (*c.* 35 000–20 000 BP), burials became more common and somewhat more standardized, though they remained relatively rare compared to other mortuary treatments like dismemberment or skeletal scattering. There is a notable increase in multiple interments and the formal incorporation of mortuary rituals into broader belief systems (*Formicola 2007; Pettitt 2010*). One of the most significant innovations of the Early Upper Palaeolithic was the inclusion of symbolically charged and portable items in burials (*Gamble 1982; Svoboda 2008*). These included human and animal teeth and bone pieces fashioned into personal ornaments. Another particularly striking development is the inclusion of anthropomorphic figurines and the integration of architectural elements into burial contexts (Figs. 14,20). According to Gamble (*1982; 2007*), these artefacts, particularly those referencing the human form or body parts, suggest an increasing emphasis on personal memory and social ties.

This symbolic elaboration was paralleled by the more intricate integration of burial practices with architectural and ritual spaces – such as open-air huts in eastern Europe and decorated caves in western Europe (Fig. 18). These symbolic landscapes brought people together and anchored group identities. Early examples include the bear skulls and wall paintings in Chauvet Cave, the equine skull placed next to a human head at Ostuni, and the therianthropic figurine from Stadel Cave (*Vacca, Coppola 1993; Conard 2003; Fosse, Philippe 2005*). Large open-air settlements like Dolní Věstonice featured complex spatial organization and mammoth bone structures used for both habitation and burial purposes (Fig. 17). Ritual features in these sites – such as fragmented bones, burning, exposure, and burial – point toward a broader ritualized context, often described as 'pit rituals' (*Trinkaus, Jelínek 1997; Oliva 2000; 2005; Svoboda 2008*). Disarticulated human remains from these pits have been interpreted as forerunners of 'ancestor cults' or 'skull cults' (*Klíma 1995; Pettitt 2010*). At Sungir, the association of mammoth bone architecture with burials also suggests that human and animal skulls and skeletal pieces could have been used interchangeably. These practices reflect a developing spatial and ritual concept involving death, caves, animal skulls, and figurative art (*Pettitt 2010*).

Indeed, figurines are often discovered in caves and pits alongside human and animal remains (*e.g.,* Barma Grande) (*Formicola 1989; Pettitt 2010*). The site of Avdeevo contains figurines within ritual pits, some marked with ochre, fire damage, and motifs of dangerous creatures (*Gvozdover 1989*). At Dolní Věstonice, the scattering of both human remains and clay figurines throughout the site underscores their symbolic association. Strikingly, at Sungir, two individuals (Fig. 16) were found buried head-to-head in a pose resembling a figurine from Gagarino (Fig. 15) (*White 2006*). Accordingly, the burials of the Upper Palaeolithic seem to be entangled in wider events of communal gatherings, hunting, food sharing, and other social exchanges. The dead in this context must have become central symbols in seasonal and social cycles, *i.e.* manifestations of complex beliefs about continuity and rebirth (*Yeshurun* et al. *2013*).

Pettitt (*2006; 2010*) posits that Palaeolithic burials, being rare events, were often associated with individuals who held a particular significance witin their communities. Indeed, there is a notable difference in the ratio of male to female burials (18:5) (*Riel-Salvatore, Gravel-Miguel 2013*). Beads, ochre, and stone markers are mostly associated with adult males, while females are more often interred in multiple burials that include fig-

Fig. 15. The ivory figurine called the 'double statuette' at Gagarino (*White 2006.Fig. 30*).

urines. The presence of richly furnished graves, including those of children, may indicate emerging social stratification (*Parker Pearson 1999*). Whereas common grave goods during this time included ochre, animal bones (bear, wolf, deer, mammoth), and shell beads, there was notable regional variation (*d'Errico, Vanhaeren 2015*). Ochre and animal bones are common across regions, while seashells, deer teeth, and bone awls are more typical of Italy. Eastern European burials more often include fox teeth, ivory items, and mammoth bones. Indeed, skull-focused mortuary practices – involving both human and animal skulls – are most common in southern Europe. Sites like Barma Grande and Dolní Věstonice highlight the close symbolic connection between mortuary rituals and representations of identity (*Gvozdover 1989*; *White 2006*). These differences are also reflected in recent genetic studies where a notable degree of regional differentiation among the individuals of western and southwestern Europe (Fournol cluster) and central and southern Europe (Vestonice cluster) (*Seguin-Orlando* et al. *2014; Posth* et al. *2023*).

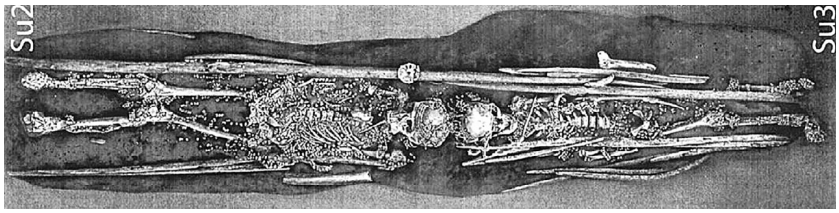

Fig. 16. Sungir burials (*Bader 1998.Pl. 9*).

*Period 3: Late Upper Palaeolithic (*c. *25 000–12 000 BP): dispersal and regional variations of 'skull cults'*

The Late Upper Palaeolithic (LUP), spanning approximately 25 000/20 000 to 11 600 BP, is broadly divided into two phases. The earlier phase (*c.* 25 000/20 000–15 000 BP) corresponds to Magdalenian (northern and western Europe), Epi-Gravettian (southern, central, and eastern Europe), and the Epipalaeolithic (Near East). The later phase (*c.* 15 000–11 600 BP) includes the post-LGM re-expansion and consolidation of these cultures. During the LUP, as Ice Age conditions waned, ecological niches across Europe and the Near East expanded. These changes enabled intensified interaction networks, reflected archaeologically in evolving mortuary practices, symbolic behaviours, and expressions of identity (*Gamble 1991; Barton* et al. *1994; Maier 2012; Pettitt 2014; Berto* et al. *2017*).

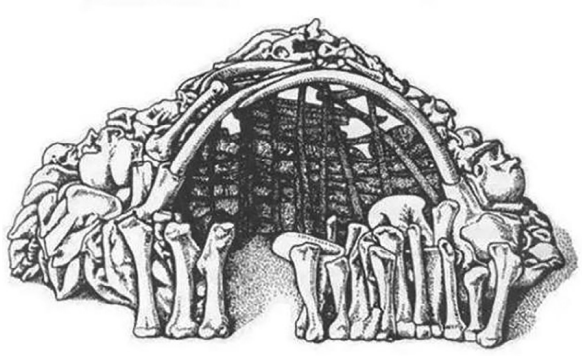

Fig. 17. Mammoth dwelling (*French 2021.Fig. 7.6*).

Palaeogenomic studies confirm major population shifts following the LGM, with transformations in genetic lineages indicating significant demographic movements and replacements (*Villalba-Mouco* et al. *2019; Posth* et al. *2023*). Genetic continuity across this period is evident in individuals associated with the Fournol cluster, bridging the Gravettian and Magdalenian phases (*Straus* et al. *2015*). In contrast, the Italian Peninsula experienced a marked turnover, with the Gravettian-linked Věstonice cluster giving way to the Villabruna cluster (*Bortolini* et al. *2021; Posth* et al. *2023*). This transition may have occurred as early as 17 000 BP, influenced by environmental stressors and demographic reconfigurations (*Peresani* et al. *2021*). In the Near East, particularly at Pınarbaşı in Anatolia, a genetic admixture of approximately 52% western European hunter-gatherer and 48% Natufian ancestry reflects long-distance population movements between southeastern Europe and the Levant (*Feldman* et al. *2019*).

Our data for this time period is comprised of 54 sites: 27 sites from Europe, 22 sites from the southern Levant, 2 sites from Anatolia, and 3 sites from Upper Mesopotamia and Iran (Fig. 21 and Site-based reference list). Approximately 50 individuals have been documented from Eurasia, primarily through fragmentary skeletal remains (*Pettitt 2010; Riel-Salvatore, Gravel-Miguel 2013*). In Europe, burials remain sparse until the Magdalenian, whereas in the Levant, burial practices appear to increase in frequency during the early LUP. Notable burial sites in the Levant during the Kebaran (*c.* 22/21 000–15 000 BP) include Ohalo II, 'Ayn Qasiyya, Kebara, Ein Gev I, Kharaneh IV, Wadi Mataha, Neve David, Uyun al-Hammam, and Moghr el-Ahwal. In the later Natufian period, large burial assemblages appear at Hayonim, El-Wad, Wadi Hammeh 27, Azraq 18, Ain Mallaha, Raqefet, and others. Outside the Levant, examples include two burials at Pınarbaşı (Anatolia)

and over 35 individuals from Shanidar Cave (Iran), likely dating to the Late Natufian (Fig. 22).

During this time, regions with the highest concentrations of burials may represent the earliest forms of cemeteries (*Orschiedt 2013*), which also emerged in the Natufian Levant, marking formal spaces for interment distinct from daily life (*Grosman 2003*; *Grosman* et al. *2008; Munro*, Grosman *2010*; *Nadel* et al. *2013*). In Europe, sites with complex parietal art – such as Altamira, Lascaux, Trois Frères, and Enlène – likely functioned as meeting places for wider social gatherings (*Gamble 1999*; *Pettitt 2010*), as an alternative strategy of social cohesion at regional levels.

There is a visible increase in the demarcation of communal and private spaces for secondary and primary burials, specifically the intensification of cemeteries and multiple burials, together with the use of abandoned places as burial locations. The Near East features elaborately constructed mortuary spaces, while Europe emphasizes cave ritualism. Interestingly, in the southern Levant, distant communities often share more burial similarities than neighbouring ones – suggesting expansive social networks. This contrasts with Europe, where proximity often correlates with cultural similarity. Note that the sites of Öküzini and Pınarbaşı in Anatolia cluster with Europe (Fig. 25), which may be a reflection of the shared cultural practices and shared palaeogenomic profiles during this time period (*Feldman* et al. *2019; Marchi* et al. *2020*).

Throughout the LUP, child and infant burials decreased in frequency compared to earlier periods, possibly due to improved survival rates or changing symbolic norms. Some treatments – like burial under floors or hearths – were more common among subadults. Gender analysis shows a near-parity (19 males, 13 females) (*Riel-Salvatore, Gravel-Miguel 2013*), with females more often associated with figurines, ochre use, and certain types of grave markers. A number of treatments appear to be more associated with subadults compared to adults, such as multiple burials, using beads, and figurines, and burial under the floor and hearth at sites such as Ain Mallaha, Abu Hureyra, and Hayonim. Figurines, ochre, multiple burials, and the use of grinding stones as grave markers are more related to females at sites such as Neuwied-Irlich, El Miron, and Erq el-Ahmar, while single interment and the use of a large stone have high similarity values with males at sites such as Los Azules, Kharaneh IV, and Wadi Mataha (Figs. 25,26).

The dismemberment of skeletons, skull-oriented practices, and the circulation of human bone fragments in the form of ornaments, *etc.*, indicate that symbolic communication through the dead was becoming increasingly common in the Late Magdalenian/Late Upper Palaeolithic (*Henry-Gambier 2002; Pettitt 2010; Orschiedt 2013; Schulting 2015*). Skull-focused practices – including removal, decoration, plastering, and transformation into ornaments or cups (Fig. 23) – are diverse and intense during this period across Europe and the Near East. Sites such as Placard, Mas d'Azil, Isturitz (Europe), and Azraq 18, Shubayqa 1, Wadi Mataha (Near East) exemplify such behaviours. In Europe, burials without skulls were widespread among the Epigravettian groups, whereas skull-focused customs (such as modified skulls and skull cups) were common in Magdalenian groups (*Bello* et al. *2011; Riel-Salvatore, Gravel-Miguel 2013*). Skull cups are human crania that were deliberately shaped post-mortem by removing the facial bones and cranial base. The edges were often retouched or smoothed, suggesting intentional craftsmanship. Their use is interpreted as ritualistic, possibly linked to ancestor veneration, symbolic consumption, or social display. These modified skulls were likely used as ritual drinking vessels or symbolic containers, reflecting complex mortuary and possibly cannibalistic practices. Symbolic integration of burial into architectural space, especially in southwest Asia, becomes a hallmark of the LUP (Figs. 24,26).

Repeated plastering of floors and the use of ground stones, and vessels as grave markers reflect growing sedentism and a new engagement with territorial identity. The plasters used could be of a variety of locally available materials, such as silt, sand, and clay (*e.g.,* Ohalo, Ain Mallaha, Abu Hureyra).

The intensification of skull-centric rituals and the establishment of cemeteries should be viewed as efforts to articulate both individual and collective identities,

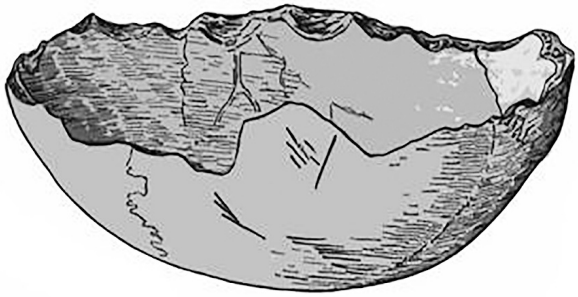

Fig. 23. Skull-cup from Le Placard in France (*Petru 2018.Fig. 3*).

especially in a context where long-distance interactions and geographical-ecological pressures were influential (*Bar-Yosef 1998; Belfer-Cohen, Goring-Morris 2013; Bello* et al. *2015*). In western Europe, skull cups were probably used as symbolic items of ritualized food consumption in ancestor rituals (*Orschiedt 2002; Bello* et al. *2011*). Practices like dismemberment, the circulation of human remains, and skull veneration mark a deepening relationship between the living and the dead. In this context, the repeatedly used burial sites and cemeteries represented not only forms of territorial behaviour that link communities to the land, but also emerging new types of in-group identities and structures, in this new form of engagement with space (*Littleton, Allen 2007*). These trends suggest the emergence of new symbolic systems, integrating architecture, burial, and social space – rooted in Gravettian innovations, but exceptionally enriched and diversified by the Magdalenian and Natufian periods.

In this context, cemeteries represent not only territorial claims but also mechanisms for social cohesion and the regulation of intra-group hierarchy. In the Near East, architectural elaboration, specifically the repeated plastering of floors, occurs in relation to burials in these spaces. The skull-oriented practices in the Near East became more prevalent during the last phases of the Natufian in the conditions of the Younger Dryas climatic degradation. Ian Kuijt (*1996*) emphasizes that Late Natufian burial practices were not primarily about individual identity, but rather about cultivating a sense of belonging to a broader community, which played a crucial role in regulating social dynamics during times of environmental and socioeconomic stress, and may have functioned to restrain the accumulation of power within communities. Ancestral practices – whether embedded in caves decorated with figurative art in Europe or situated in the cemeteries of the southern Levant – appear to respond to similar social needs. As primary and secondary burials became more widespread, and domestic and communal spaces became more clearly delineated, social ties within and between groups were reinforced and negotiated through ritual.

Period-4: Early Holocene/PPNA and PPNB (c. 12 000–9000 BP): the southwest Asian 'skull-cult complex'

Coinciding with the beginning of the Holocene climatic amelioration, Europe entered the Mesolithic period (*c.* 12 000–7500 BP, while the Near East transitioned to the Pre-Pottery Neolithic (*c.* 12 000–9000 BP). Our analysis divides this era into two phases: Period 4a (*c.* 12 000–10 500 BP) and Period 4b (PPNB: *c.* 10 500–9000 BP). In Phase A, the data set includes 22 sites (Fig. 27 and Site-based reference list): 8 from the Upper Tigris, 4 from the Upper Euphrates, eight from the Levant, and two each from Cyprus and the Greek Aegean. In Phase B, the dataset consists of 75 sites (Fig. 28 and Site-based reference list): three from the Upper Tigris, seven from the Upper Euphrates, six from central Anatolia and the Lake District, 27 from the Levant, eight from Iran-Caucasus, 17 from Europe, and seven from Cyprus and the Greek Aegean.

Skull-centred burial rites persisted in Mesolithic Europe, albeit to a lesser extent than before (*Grünberg, 2015; Orschiedt, 2005; 2018*). In contrast, the Near East saw the architectural elaboration of communal and private burial spaces, with monumental buildings integrated into burial symbolism. These transitions laid the groundwork for complex social structures, shifting ritual behaviour, and increasing reliance on domesticates.

During Phase A, adults are more frequently associated with treatments such as skull burials, skull perforation, masks, figurines, grooved stones, and architectural elaboration – especially in sites such as Jerf el-Ahmar, Tell Mureybet, and Göbekli Tepe. Gender-wise, many traits are shared, but certain symbolic items are skewed by gender: females are more often linked to skull burials, masks, figurines, and grooved stones (*e.g.,* Jerf el-Ahmar, Göbekli Tepe, Netiv Hagdud), whereas males are more often associated with animal skulls/horns, stone markers, and ochre (*e.g.,* Çayönü, Maroulas) (Figs. 29,32,33). In Phase B, adults and subadults both share mortuary features, though some distinctions exist: adults are more frequently associated with single burials and the use of ochre (*e.g.,* Bestansur, Boncuklu, Sheikh-e Abad, Vlasac [Serbia]), while subadults are more linked with beads, stone markers, and grooved stones (*e.g.,* Aşıklı, Kfar Hahoresh, Basta, Arene Candide [Italy]). Gender distinctions in this phase also persist: males are associated with single burials, animal remains, and stone vessel pieces (*e.g.,* Avelines Hole, Ais Giorkis, Kfar Hahoresh, Abu Hureyra). Females are associated with stone markers, masks, figurines, and grooved stones (*e.g.,* 'Ain Ghazal, Basta, Nevali Çori, Shillourokambos) (Figs. 30,35,36).

Although mortuary traits are shared across sites, regional variation is significant. In Phase A, there is a notable similarity between the southern Levant and Upper Tigris, even though the Upper Tigris and Upper Eu-

phrates – geographic neighbours – differ culturally (Fig. 31). Outliers in both regions often resemble each other, suggesting strong contact between these regions, likely supported by expansive obsidian exchange networks that reinforced complex social and symbolic interaction. In Phase B, the relational dynamic shifts. For example, the Upper Euphrates becomes less distinct from the Upper Tigris and southern Levant, suggesting increased interaction (Fig. 35; *Karamurat 2024.278, Tab. 6*). At the same time, central Anatolia's mortuary behaviours resemble Upper Mesopotamian groups more than the southern Levant, despite the known genetic flow between central Anatolia and the southern Levant (Figs. 31,34).

Skull-focused practices, including removal, burial, plastering, painting, perforation, and modification, are a continuation of earlier traditions and are evident at sites such as Göbekli Tepe, WF16, Körtik, and others during Phase A. In Phase B, such activities intensify; practices include colouring, plastering, modelling, and decorating skulls while sites like Kfar HaHoresh, 'Ain Ghazal, Jericho, Boncuklu, Shillourokambos, and Vlasac show varied forms of skull modification (Figs. 30, 31).

In Phase A, monumental and communal architecture – such as Göbekli Tepe's pillars and Jericho's tower – proliferated across the Levant and north Mesopotamia (Figs. 29,33). These served as communal forums for post-Younger Dryas hunter-gatherers to renegotiate cooperation. However, growing territoriality and competition emerged, a trend perhaps rooted in the Bølling–Allerød period. By Phase B, large communal monuments declined in favour of architectural elaboration within domestic and communal spaces. Examples include floor and wall plastering or painting at 'Ain Ghazal, Tell Mureybet, and Aşıklı (Fig. 36). Burials became more integrated into the architecture, with increasing complexity around spatial placement, especially at major sites (*e.g.,* Çayönü, Jericho). This shift reflects a heightened focus on social demarcation and symbolic identity. During both phases, anthropomorphic symbols flourished in the Near East, as seen in the pillars at Göbekli Tepe, masks at Nahal Hemar, and statues at 'Ain Ghazal. These elements are new representations within the symbolic complex of 'skull cults' and ancestor veneration, reflecting emerging concepts of individual and collective identity in ritual practice (Figs. 31,34).

For Europe, we have no data for Phase A; however, with Phase B, we see similar skull-focused behaviours with notable distinctions in western and southeastern Europe (Fig. 34). In formerly Magdalenian areas of western Europe, cave sites continue to be used for both single and multiple burials as well as cemeteries. Modified skulls and skull pieces were given burials, and figurines were observed as grave goods (*e.g.,* Olenij Ostrov). The site of Vlasac and Lepenski Vir at the Iron Gates region in Serbia stands out with its remarkable similarities to the Near Eastern and Anatolian practices. In these regions, human bones are regularly found in architectural contexts. Formerly detected in the Gravettian sites of Czechia, this particular tradition seems to have spread further to the Balkans and Anatolia during the Late Upper Palaeolithic movements, which continued into the early Holocene contexts of these regions. Indeed, these movements are detected in palaeogenomic research (*Feldman* et al. *2019; Koptekin* et al. *2025*), where the earliest Anatolian DNA from Pınarbaşı (*c.* 14 000 BC) is composed of equal proportions of Natufian and western Hunter-Gatherer (WHG) genetic composition. During the Early Holocene, the sites of Girmeler and Aktopraklık continue to demonstrate the presence of this gene pool in western Anatolia before and during the Neolithization process in these regions. Specifically, the WHG component observed in these Anatolian individuals is best modelled via the Iron Gates region, reflecting a path of mobility into Anatolia (*Koptekin* et al. *2025*).

Period 5: Post-Neolithic/Early Chalcolithic (9000–8000 BP)

Decline of the 'skull cult' symbolic complex and the spread of the Neolithic Package

The last phase of the Early Holocene examined in this study – spanning the 7th and 6th millennia BC – includes 56 archaeological sites: 42 sites in the Near East, 14 sites in Europe, including eight in the Balkans, and six sites in the Greek Aegean (Fig. 37 and Site-based reference list). The 7th millennium BC in the Near East is associated with the emergence of fully developed agricultural communities, alongside the gradual abandonment of many Pre-Pottery Neolithic B (PPNB) sites. During this time, a new form of household organization emerged, and with the emergence of a new material regime of portable clay objects, exemplified by pots, figurines, and stamps, the symbolic discourse began to shift away from the 'skull cult' rituals (*Atakuman 2015*). These artefacts were deeply influential in the dispersal of the Neolithic way of life into neighbouring regions, such as the Aegean, Europe, and Iran, through

both population movements and information exchange (*Brami* et al. *2022; Koptekin* et al. *2023*).

The above-mentioned portable objects with anthropomorphic symbolism proliferated with the accompanying major shifts in household composition and growing competitive interactions in the first agricultural societies (*Kuijt 2000a; 2000b; Bailey 2005*). Palaeogenomic studies demonstrate that formerly kin-based households of the Early Holocene sedentary hunter-gatherers were replaced by non-kin households during the 7th millennium BC (*Kuijt 2009; Larsen* et al. *2015; Yaka* et al. *2021; Altınışık* et al. *2022; Yüncü* et al. *2025*). Accordingly, we suggest that the concepts of house and community began to be negotiated via the new material *simulacra*, which allowed for the regulation of the body and food, among those who were not related via blood-kin genealogies (*Pearson* et al. *2013; Atakuman 2015; Larsen* et al. *2015; Pearson* et al. *2023*). Thus, while the 'skull cults' themselves may have faded, their symbolic legacy endured – transformed and transmitted through material proxies. These proxies were flexible and mobile, making them ideal carriers of ideology during a time of significant social reorganization and geographic expansion.

A striking pattern during this time is the diminishing presence of adult males in settlement burial contexts. In domestic contexts – beneath floors, ovens, and platforms – subadults and females are more frequently represented (Figs. 38,41). For example, at Çatalhöyük, the majority of burials are those of children (*Boz, Hager 2013*). At Tepecik-Çiftlik, communal buildings contain predominantly infant burials (*Büyükkarakaya* et al. *2019*). In contrast, adult males are increasingly buried in communal or extra-settlement spaces, such as courtyards in Bahçelievler and Durankulak (*Bačvarov 2002; Todorova 2002; Näslund 2009; Fidan 2020*). This trend suggests a gendered and age-based differentiation in burial spatiality, possibly linked to emerging social hierarchies or symbolic roles. Collective burials and skull-related activities persisted in communal areas at sites like Çatalhöyük and Tepecik-Çiftlik, although their frequency was reduced compared to earlier PPN phases (*Haddow* et al. *2020*). The use of communal burial areas continued to be a part of rituals during the 6th millennium, as seen at the Halaf Period Domuztepe in south-eastern Anatolia (*c.* 8200–7200 BP) or the site of Uğurlu in the north Aegean (*Atakuman, Erdem 2015; Karamurat* et al. *2021*).

Skull-centric mortuary practices, such as skull removal, plastering, colouring, and decoration, continued at sites like Köşk Höyük, Çatalhöyük, and Ofnet. These practices retained elements of the earlier PPN 'skull cult' traditions. However, by this time, such practices were absent in regions such as Greece, northwest Anatolia, and western Anatolia (Figs. 40,41). Instead, the symbolic focus shifted to anthropomorphic figurines, pottery, and stamps – often integrated with well-plastered domestic architecture and associated with female and subadult burials. In contrast, skull rituals persisted in the Balkans and parts of Europe, likely as remnants of Late Upper Palaeolithic hunter-gatherer traditions (Fig. 39). Sites such as Karanovo and Yabalkovo exhibit skull veneration alongside symbolically rich and diverse ceramic styles, including poly-pod box pots, anthropomorphic house models, figurines, and stamps (Fig. 42) (*Karamurat* et al. *2021*).

As autonomous agricultural communities emerged, symbolic emphasis transitioned from 'skull cults' to portable objects that encoded ancestral meanings through new visual forms. These materials, particularly figurines, stamps, and anthropomorphic ceramics, allowed social groups to articulate identity and affiliation without relying on physical ancestral remains. Çiğdem Atakuman (*2015*) argues that this transformation marked a deeper material and ideological shift: from place-bound architecture and skull rituals (dominant in the Early Neolithic, *c.* 12 000–9000 BP) to portable and symbolic artefacts in the Late Neolithic (*c.* 9000–7000 cal. BP) (Fig. 42). As Cédric Bodet (*2025*) argues, these objects functioned as ideograms of a broader Neolithic symbolic language, closely tied to the reproduction of social structures. Though new in form, these artefacts carried ancestral codes through anthropomorphic and zoomorphic imagery.

While the hunter-gatherer rituals focusing on human skulls and secondary burials were gradually replaced by the representative material culture, or *simulacra*, of agricultural communities, this does not mean that the symbolic references completely disappeared. Specifically in Anatolia, we observe the continuity in ancestral imagery use at the Late Neolithic site of Domuztepe's Death Pit (*Campbell, Healey 2011*) and at the Early Bronze Age site of Alacahöyük elite burials, where the animal and human skulls continued to be the centrepiece of ceremonies.

Conclusion

Our findings demonstrate that the core elements of skull-focused post-mortem activity began during the Middle Palaeolithic (Period 1), in both *Homo sapiens*

(*c.* 130 000 BP) and Neanderthal groups (post–70 000 BP) (Fig. 43). This early symbolic repertoire – marked by the systematic use of ochre, animal skulls and antlers, the deliberate removal of human skulls, and the marking of graves – was likely related to the negotiation of territorial claims and social identities through references to ancestry and the past. Such practices reflect a fundamentally human means of constructing social memory. In the early Upper Palaeolithic (Period 2), particularly during the Gravettian period, this symbolic system was elaborated through the incorporation of a new material culture, especially figurines, and the formalization of burials within architectural contexts such as huts, hearths, and ritual pits. These developments emerged in response to the harsh climatic conditions of the Last Glacial Maximum, especially in central and eastern Europe. We observe that the origins of the southwest Asian 'skull cults', *i.e.* the complex interplay of primary and secondary burials with respect to private and communal architecture, and skull-centred activity, likely emerged in eastern Europe during the Gravettian period.

As the climate intermittently improved (*e.g.,* Bølling–Allerød) during Period 3 (LUP), 'skull cults' became more widespread and regionally differentiated. This may be related to the development of stronger territorial identification with the long-term sedentary camp sites during the climatically favourable conditions. During this time period, Epigravettian groups in Europe often practiced skull removal, whereas Magdalenian groups are known for skull modification practices, such as the creation of skull cups. Practices such as skull modification, the circulation of human remains, and the emergence of burial grounds during this period should be interpreted as socially meaningful acts. The dismemberment of skeletons, the making of ornaments, and the practices centred on the skull suggest that extensive networks of relationships were established through the parts of the dead body, and at the same time, the concepts of individual, group, and community in a wider context began to be evaluated with different criteria. In such a context, the emergence of cemeteries may be related to both the formation of hierarchies of ritual control within the group, and the intensification of inter-group competition and territorial activity in the pioneering stages of the transition to sedentism and an agricultural economy.

In the southern Levant, the final synthesis of the 'skull cult' tradition occurred in Period 4, the Early Holocene (*c.* 11 700–8000 BP), marked by increasing architectural elaboration, the widespread use of anthropomorphic figurines, and the erection of stone pillars in fune-

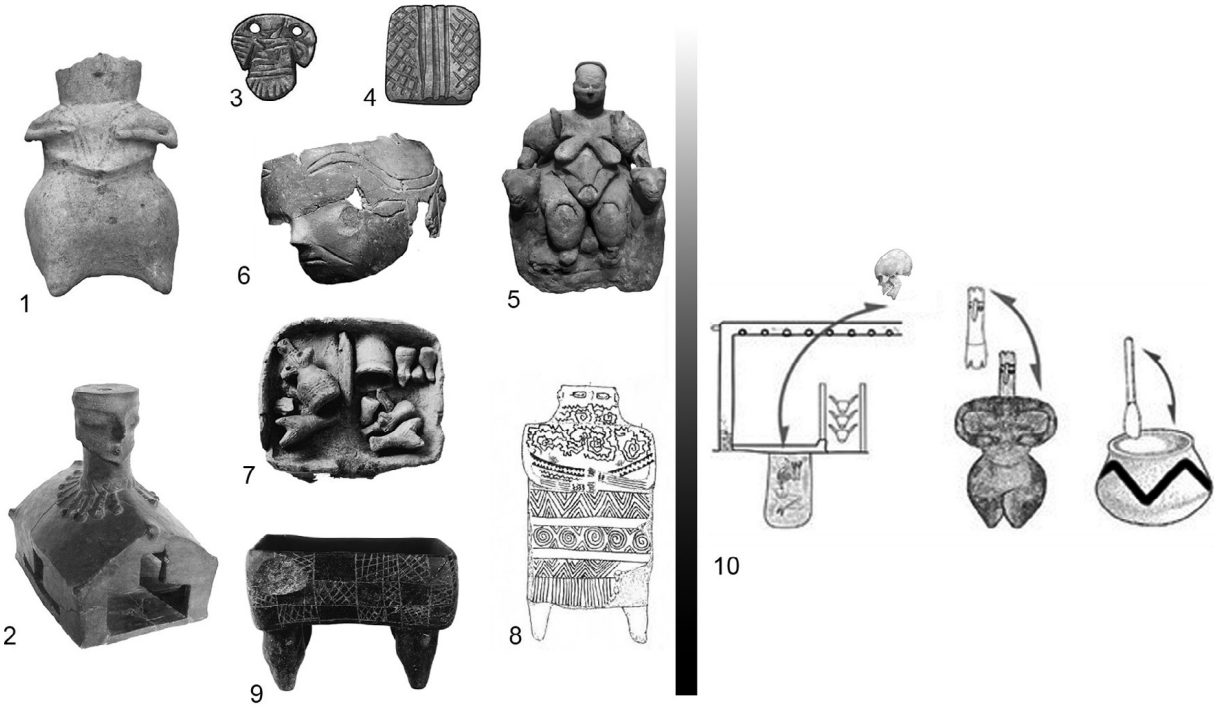

Fig. 42. New symbolic items emerging in the Pottery Neolithic and a representation of some items metaphorically referring to the 'skull cult' (*1 Çilingiroğlu 2022; 2 Koništrkoska Nasteva 2005; 3 Mallowan, Rose 1935; 4 Carter 2010; 5 *available at www.catalhoyuk.com/node/736;* 6 Hodder, Meskell 2011; 7 Alram-Stern *et al.* 2022; 8 Özdoğan, Dede 1998; 9 Özdoğan 2013; 10 Atakuman, Gemici 2024*).

rary contexts (Fig. 43; Fig. 44). During the PPNA (Phase 4a), post-Younger Dryas hunter-gatherers began to renegotiate the terms of cooperation, interaction, and territoriality through large-scale projects enacted at places such as Göbekli Tepe. However, by Phase B (PPNB), as the significance of domesticates in the economy increased, architectural elaboration and ancestral rites at smaller group sites such as Çayönü gained

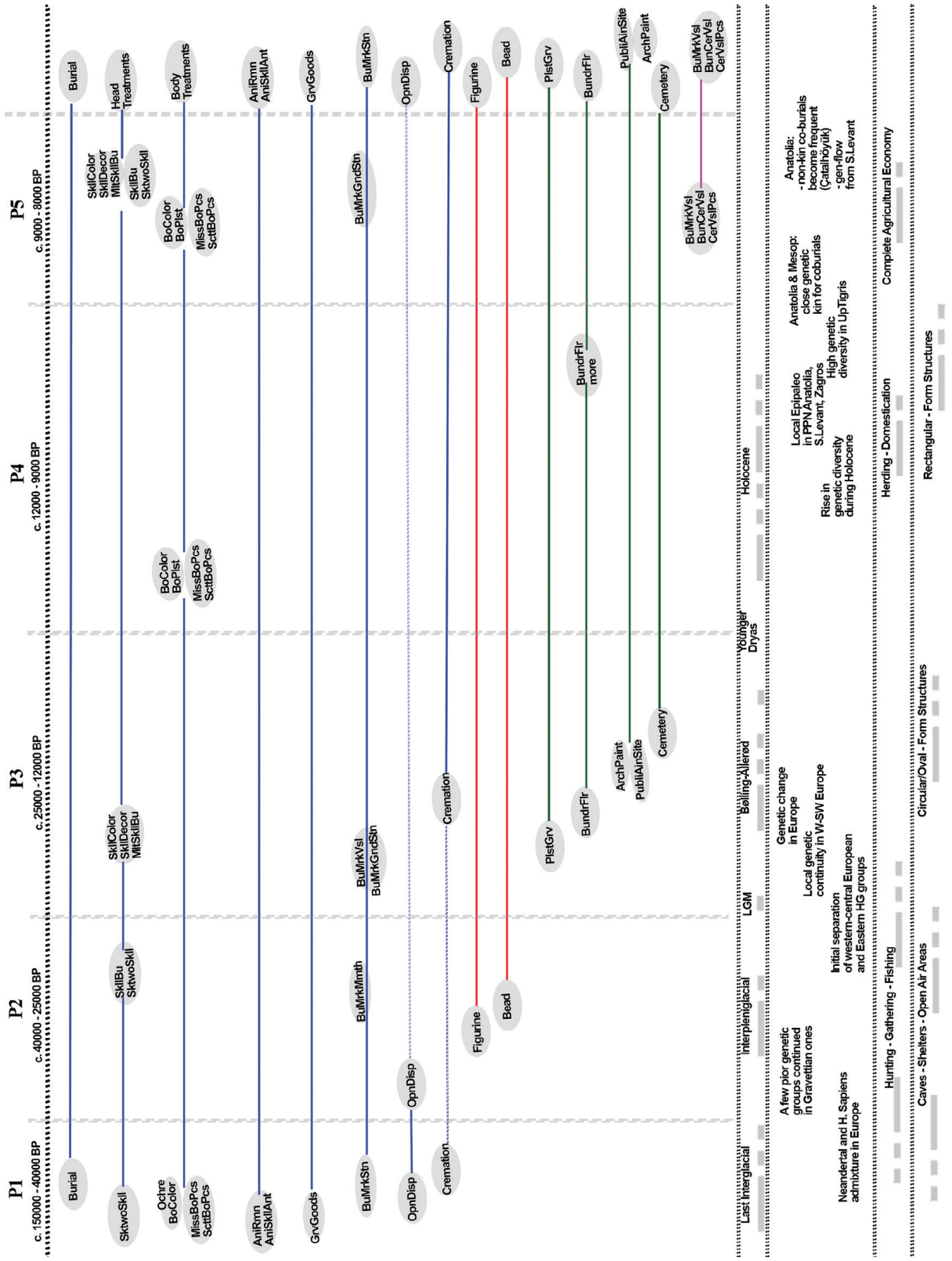

Fig. 43. The emergence of symbolic practices in human funerary rituals over time, in relation to climate, palaeogenomic insights, subsistence patterns, and broader societal dynamics.

emphasis (*Atakuman 2014; 2015*). Burials were more integrated into the architecture, with increasing complexity around spatial placement, especially at major sites. This shift reflects a heightened focus on social demarcation and identity construction in the midst of the dwindling hunter-gatherer economy and ideology. During both phases, anthropomorphic representations flourished in the Near East as new items within the symbolic complex of 'skull cults'.

During Period 5 (*c.* 9000–7000 BP), there was a significant shift from skull-focused burial rituals to the use of portable objects like anthropomorphic and zoomorphic vessels, figurines, and stamps (Fig. 42), which coincided with the advent of autonomous households and the shift toward an agricultural economy. Many studies indicate that household composition changed during this period, from kin-based families to non-kin families that cooperated around the necessities of food production and consumption, rather than blood ties and its symbolic representation in the form of 'skull cults' (*Kuijt 2009; Pearson* et al. *2013; Larsen* et al. *2015; Yaka* et al. *2021; Altınışık* et al. *2022; Pearson* et al. *2023; Koptekin* et al. *2025*). In such a context, portable clay items with anthropomorphic, zoomorphic, and architectural references to the ancestral past became instrumental in constructing the new and varied relationships with new communities in new geographies around the concepts of 'house', 'community', 'gender', and 'domestication'.

Ultimately, the relatively rapid and widespread adoption of these material culture items, the so-called Neolithic Package, in Europe during the spread of Neolithic lifestyles can be attributed to the broad recognition and acceptance of the symbolism and ideas underpinning the pots, figurines, and stamps. As such, the adoption of these symbolic forms in Neolithic Europe should not be seen as technological adaptations or innovations, but as material transformations of long-established symbolic codes rooted in the Upper Palaeolithic.

Alain Testart (*1985*) once argued that, ideologically, the emergence of agriculture and a society in tune with its necessities is the outcome of a long individualizing process in the relations of production, which started in the Later Palaeolithic. It is tempting to frame the development and dissolution of 'skull cults' in this perspective; *i.e.* the prehistoric 'skull cults' examined within the scope of this paper may have emerged to emphasize communality in the context of growing individuality in hunter-gatherer contexts. Yet, in our opinion, their demise is ultimately connected with their inability to incorporate increasingly individualizing agricultural societies.

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Counting and comparing: figurative representation density in Neolithic Central Europe and the Balkans

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ABSTRACT – *As Neolithic figurative finds – that is to say anthropomorphic and zoomorphic figurines, vessels, applications and impressions – were uncovered in Europe and the Near East, it was quickly apparent that they all shared common features over several millennia and thousands of kilometres: they were made of clay, usually depicted women, and were found in settlements. This led to cross-cultural comparisons and, in turn, wide-ranging interpretations regarding the use of figurative representations during the Neolithic. However, this cross-cultural approach eventually met its limits, as regional studies highlighted differences in features and distribution among various cultural groups. Figurative finds were, in fact, not spread evenly across Europe. While some areas yielded multitudes, others yielded none. This article addresses the challenges of making cross-cultural comparisons, and underlines the need for a quantitative and contextualized approach: introducing a new relational database containing more than 2500 figurative representations from Central Europe and the Balkans, we compare find densities across cultural groups and regional clusters in order to examine the development of clay figuration in Neolithic Europe.*

KEY WORDS – *Neolithic; figurines; Central Europe; Balkans; figurative representations*

Štetje in primerjanje: pogostost figurativnega upodabljanja v neolitiku Srednje Evrope in Balkana

IZVLEČEK – *Ko so bile v Evropi in na Bližnjem vzhodu odkrite neolitske figurativne najdbe – torej antropomorfne in zoomorfne figurice, posode, aplike in odtisi – je hitro postalo jasno, da ohranjajo skupne značilnosti skozi več tisočletij in na tisoče kilometrov daleč: izdelane so bile iz gline, običajno so prikazovale ženske in so bile najdene v naseljih. To je vodilo do medkulturnih primerjav in posledično do različnih pojasnitev uporabe figurativnih upodobitev v neolitiku. Pristop pa je sčasoma dosegel svoje meje, saj so regionalne študije pokazale razlike v značilnostih in razširjenosti med posameznimi kulturnimi skupinami. Figurativne najdbe namreč niso bile enakomerno razporejene po Evropi – nekatere regije so prinesle številne primerke, druge pa nobenega. V članku se ukvarjamo z izzivom medkulturnih primerjav in poudarjamo potrebo po kvantitativnem in kontekstualiziranem pristopu. Z uvajanjem nove relacijske baze podatkov, ki vsebuje več kot 2500 figurativnih upodobitev iz Srednje Evrope in Balkana, primerjamo pogostost najdb med kulturnimi skupinami in regionalnimi skupinami, da bi lahko preučili razvoj glinene figuralike v neolitski Evropi.*

KLJUČNE BESEDE – *neolitik; figurine; Srednja Evropa; Balkan; figurativne upodobitve*

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Introduction

Despite the presence of basic shared practices, Neolithic life manifested itself very differently across the European continent. In Southeastern Europe early farmers lived on densely settled tells with clay-built houses. In Central Europe they settled on fertile loess soils, clearing the dense forest for their wooden longhouses. Western and Northwestern Europe, including the British Isles, were characterized by monumental stone architecture in the form of megalithic burials testifying to very different approaches to Neolithic life throughout Europe (*Fowler* et al. *2015*). These uneven expressions are of course influenced by, among other things, very different landscapes and the deep time scale at play. It took almost 3000 years from the first Neolithic settlers introducing an agrarian economy and lifestyle to Greece and Southeastern Europe around 7000–6500 BCE until farming reached Southern Scandinavia and the British Isles *c.* 4000 BCE. A process that basically ended up dividing the continent into two main populational clusters grouped on each side of a dividing line stretching from the Black Sea to the Baltic. West of this divide, large-scale ancestry shifts occurred with Neolithization, whereas no substantial shifts can be recorded to the east coinciding with a continued hunter-gatherer lifestyle (*Allentoft* et al. *2024).*

One of the striking differences that separated the Northern and Southeastern European Neolithic was the use of figurines, and figurative representations in general. Clay figurines are a characteristic feature of the Neolithic in Southeastern Europe, where they occur in the thousands. Following the Neolithization route from southeast via Central Europe towards the north, we see that figuration had basically disappeared when farming reached Northern Europe (*Becker* et al. *2024; Iversen* et al. *2024; Bristow 2025*). To explain this peculiar aniconic phenomenon, we launched the research project *A World Without Images*. However, when trying to monitor the use of figuration over three millennia, including several archaeologically defined cultural groups, each with their specific and dissimilar chronological and geographical distribution, the definition of comparable measures is indispensable.

In this paper we offer a quantitative approach to figuration that takes the material's uneven distribution into account, which allows us to make comparisons across time and space. The aim is to define comparable measures for figurative representations that go beyond direct, and often misleading, comparisons of numbers of figurines between different cultural groups. Our proposed method for counting and comparing figurative representations enables us to identify with unpreceded accuracy where and when dramatic shifts in the use of figurative imagery took place.

Dealing with figurines: the traditional narratives

The literature about figurative finds in Neolithic Europe rarely deals with numbers, and instead, mainly other lines of questioning are discussed. One is the question of typology, sometimes linked to changing morphological features in the course of time or in terms of geography. This is true, for example, for larger corpora of figurative finds such as works on Körös culture figurines (*Starnini 2014*), Linear Pottery culture (LBK) figurative finds (*Becker 2011*) or Cucuteni-Trypillia figurines (*Monah 2016*). But also publications of both figurative representations from single sites or smaller geographical regions (*Karmanski 2005* on Starčevo figurines from Donja Branjevina, Serbia, as an example for figurative objects from one site; *Insoll 2017* as an example for a compilation of regional studies) and cross-cultural studies mostly focus on typologies (for example *Hansen 2007*; *Schwarzberg 2011*). Here, we could also add the works of Marija Gimbutas (*1974*), who compiled Neolithic figurines over large geographical areas and used some selected features to construct Neolithic societies under matriarchal rule.

Another way of discussing figurative objects is to extract their use and meaning by applying more theoretical approaches. Such works may focus on distinct features such as size, gender or fragmentation studies (*Bailey 2005; 2012; Chapman, Gaydarska 2007*) or comparisons with ethnographic evidence (*Lesure 2011*). This is also true for the non-European corpora of figurines, which have been studied in connection with "*household archaeology, gender studies, performance, materiality, embodiment, animism, political economy, agency, and identity*" (*Marcus 2019.1*), and in such works the making and use-life of these objects and their embedment into their cultural context, as well as their association with other artefacts and their context, have been a focus. Attempts to recreate the use-life have also been pursued for Neolithic figurines. Some of them are concerned with the *chaîne opératoire*, using SfM and/or micro-CT scans to shed light on the complex processes involved in the manufacturing processes (*e.g., Gaydarska* et al. *2007; Kreiter* et al. *2014; Kaňáková, Nosek 2025*).

The quantities of figurines rarely play a role in such research, and in most cases the number of figurative finds in a culture are not mentioned at all. Sometimes a number will be given, and maybe a comment that a particular cultural phenomenon is rich or poor in figurative finds. Comparisons between the numbers of such finds of different cultures or a more in-depth look at their chronological distribution are mostly lacking. A possible exception are the works of John Chapman and Biserka Gaydarska (*Chapman 2000*; *Chapman, Gaydarska 2007*), where fragments were categorized and analysed quantitatively with respect to, for example, their overall occurrence or their context and numbers of fragments of figurative objects were compared from different sites.

Mapping figurative finds from Neolithic Europe

Through the research project *A World Without Images*, we focused on a different approach: we connected data distribution, context and chronology by recording all available figurative representations in the Neolithization path from the Balkans to Northern Europe in a database (Fig. 1 and Fig. S1 supplementary data). Our database and its recorded data (*c.* 2500 finds and 800 sites) are described in detail in an upcoming PhD dissertation, and will be published in open-access form by September 2025 (*Becker* et al. *in preparation; Bristow in preparation*). Drawn from published sources and the grey literature, each figurative representation is described in detail: its type (anthropomorphic or zoomorphic figurine, vessel, application, *etc.*), features (decoration, gender/species identification), dating, and archaeological context (type of context and site). This allowed us to produce several distribution maps highlighting the booms and busts of Central European Neolithic figuration (Figs. 2 and 3).

The maps reveal a progressive decrease of figurative representations as the Neolithic reached Central Europe (*c.* 5500 BCE), and a turn at the start of the Middle Neolithic (*c.* 4900 BCE): while the figurative tradition flourished in the Lengyel culture, it was only represented by a few finds in the Stroked Pottery culture (SBK), Southeastern Bavarian Middle Neolithic (SOB), Hinkelstein-Großgartach-Rössen and Blicquy-Villeneuve-Saint-Germain groups. However, these cultural groups have different time spans and sizes, which should be considered when discussing numbers. Their figurative finds are furthermore often badly dated, or not even published, and these challenges must be addressed in order to move forward.

Comparing figurative finds: biases and challenges

What are we comparing

Comparing figurative finds across several cultural groups implies that each cultural group spanned a similar chronological and geographical area. The Early Neolithic Southeastern Starčevo–Körös–Criş culture and Central European Linear Pottery culture are commonly compared, as they represent the Neolithization path from Southeastern to Central Europe. But although both cultural groups lasted approximately 600 years, they spanned very uneven geographical areas: the Linear Pottery culture covered an area reaching from the Paris Basin to the mouth of the Danube, while the Starčevo–Körös–Criş culture was restricted

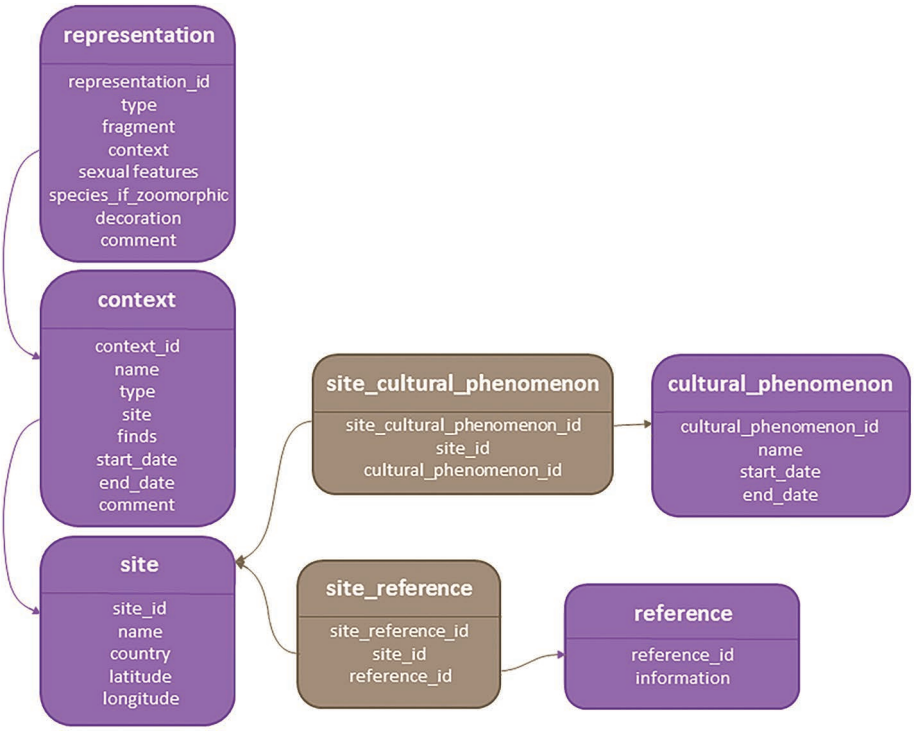

Fig. 1. Data model of the relational database. See also Fig. S1. Data used for the aoristic method. Supplementary file on https://doi.org/10.4312/dp.52.14.

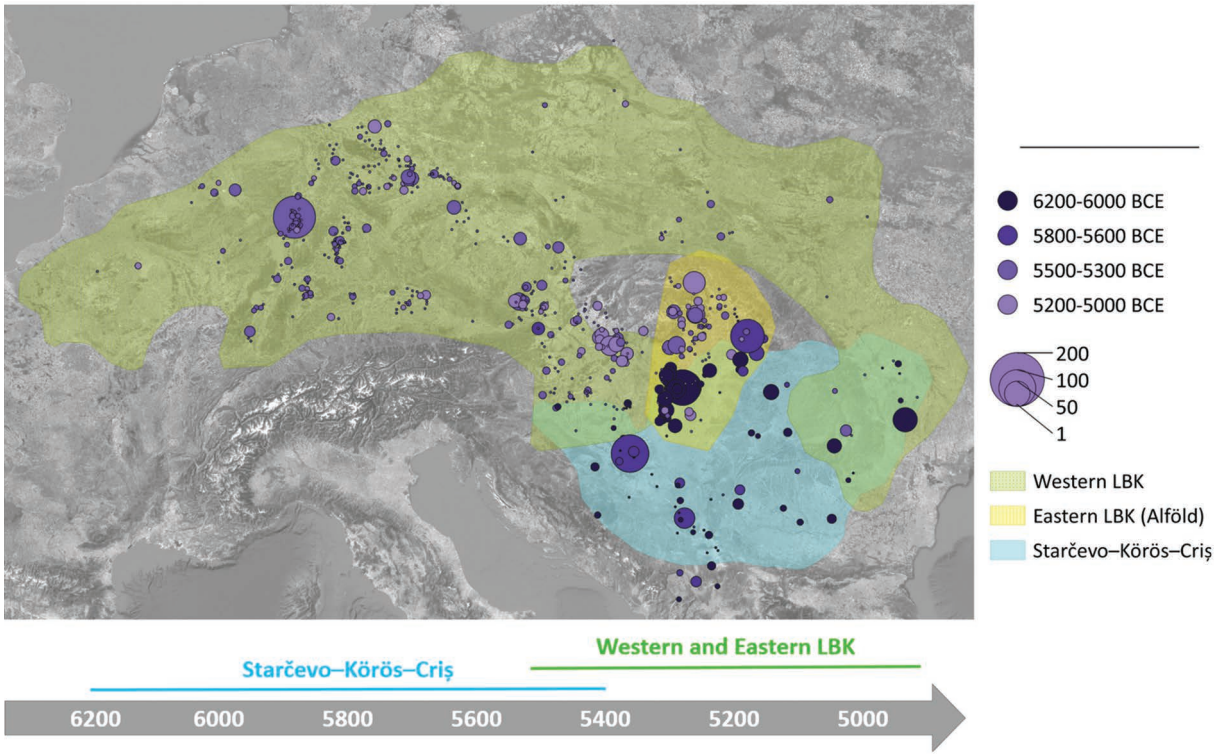

Fig. 2. Distribution of figurative representations from Early Neolithic continental Europe. Timeslots represent the finds' earliest date.

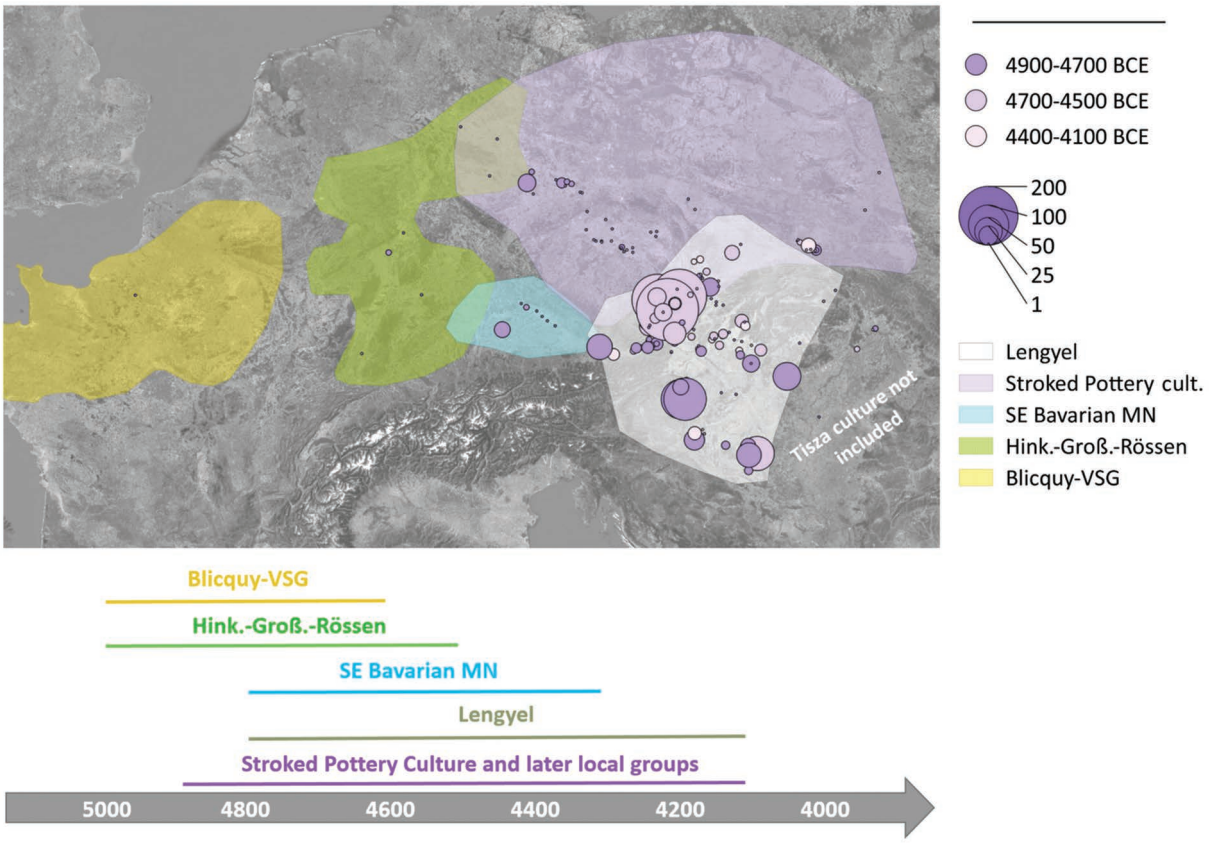

*Fig. 3. Distribution of figurative representations from early Middle Neolithic (fifth millennium BCE) continental Europe. Timeslots represent the finds' earliest date. Chasséen figurines were not included, as their dating is too broad for now (*Becker submitted*).*

to the Balkans. This means each area's find density was very different, but so far this has never been formally calculated.

Cultural area	Mm²	Number	Timespan
Starčevo–Körös–Criș (SKC)	0.730421	836	6200-5400 BCE
Linear Pottery culture (LBK)	1.681515	1338	5500-4900 BCE
- Western Linear Pottery culture	1.538154	1037	5500-4900 BCE
- Eastern Linear Pottery culture	0.143361	301	5500-4900 BCE
Stroked Pottery culture (SBK)	0.902966	53	4900-4400 BCE
Post-SBK local groups	0.902966	8	4400-4100 BCE
Hinkelstein-Großgartach-Rössen	0.36846	3	4900-4500 BCE
Lengyel	0.41	1764	4800-4100 BCE
- Early Lengyel	0.41	945	4800-4500 BCE
- Later Lengyel	0.41	176	4500-4100 BCE

Fig. 4. Number of finds, area (Mm²) and timespan of each cultural group studied in this paper. A few finds from the Early Lengyel were not added as they were too broadly dated.

Comparing figurative finds across different cultural groups further implies that finds represent an accurate sample of Neolithic representations in each area. However, this looks past the fact that some areas may have been more or less excavated than others, or even more or less populated by Neolithic settlers. This is especially meaningful to consider in the case of the Hinkelstein cultural group in the Rheinhessen area, which has so far produced no figurative finds, but also started with a particularly low population density and has to date yielded no buildings – an important detail considering the fact that the clay figurative tradition was tightly linked to settlement contexts (*Bristow 2025*). Furthermore, some specific regions or sites have much greater density than others. In the LBK, finds were clustered in eastern Austria as well as the Rhine-Main and Elbe-Saale regions. In the Rhine area, hundreds were found on the site of Bad Nauheim-Nieder-Mörlen, whose size already led to its interpretation as a central place, or *Zentralort* (*Schade-Lindig 2002. 75*). Figurative representations continued to cluster in certain areas during the Middle Neolithic, with a majority of Stroked Pottery finds in Saxony and Bohemia, while Lengyel finds were mostly uncovered in Moravia and Lower Austria. Here again, certain sites produced a particularly great number of representations, such as Těšetice-Kyjovice in Moravia (*Podborský 1985*).

Dating figurative finds

An additional challenge is the fact that finds often cannot be dated with precision, or might be dated typologically since many finds have been recorded as stray finds. Furthermore, even when dated, they might not all be published. Stroked Pottery culture finds are particularly rare (*c.* 50 finds in total), and therefore published in detail, whereas some of the hundreds of finds from southeastern Europe or even the LBK might not be. This means that when we observe the many Stroked Pottery culture horn-shaped applications and interpret this as an increase of zoomorphic representations, we are not taking into account that not all horn-shaped fragments might have been recorded for the previous cultures – since many 'bigger' finds existed (*Becker 2007.122–123*). In the case of the Stroked Pottery culture, we also need to acknowledge that many rondels were, in fact, not excavated entirely, and our knowledge is still superficial (*Czerniak* et al. *2020.263*). Since hundreds of figurines were uncovered from the neighbouring Lengyel rondels (*Fiutak*

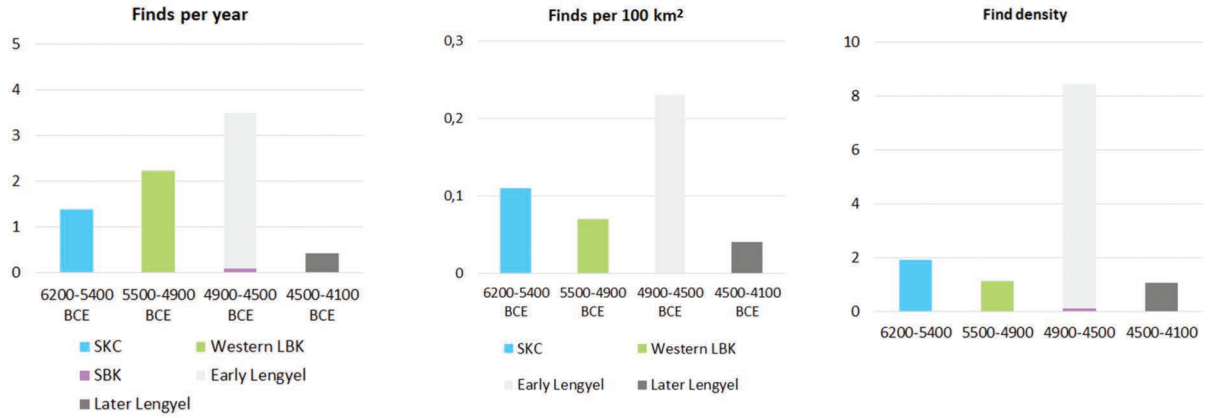

Fig. 5. Figurative find densities. Values too low to be visible were not added to the graphs. Eastern LBK was not included here, as this region retained a strong clay tradition rooted in Körös* (Bánffy 2019.135*), and led to the highly figurative Tisza culture, which extends beyond the scope of our project.

2021), we might actually be missing a lot of data for the Stroked Pottery culture.

What about abstract figuration?

Finally, the so-called 'toad engravings' are often overlooked when talking about the disappearance of figurative representations in Europe during the Neolithic. These incised or impressed stick figures with bent arms and legs were visible on pottery since the LBK, and took over pottery decoration during the Middle Neolithic (*Spatz 2003; Bristow 2025*). We only included in the database the engravings that clearly stood out as figurative from the otherwise geometric pottery decoration. If we were to include every potential stylized toad engraving, our figurative map would look very different but also much questionable. Therefore, it is important to note that when talking about a figurative decline, we are talking about the southeastern clay tradition. Toad engravings as an abstract figurative tradition covering all of Middle Neolithic Central Europe remains to be studied in detail.

Another approach: spatio-temporal densities

In order to compare finds from different cultural groups, we suggest comparing densities rather than total numbers. However, this approach still presents biases, as finds are not distributed homogeneously throughout their cultural areas, and not dated precisely. We will therefore outline regional clusters and use Doris Mischka's (*2004*) aoristic approach to examine find chronologies.

Comparing cultural groups

The chosen timespan (6200–4000 BCE) represents the rise and fall of clay figuration in Central Europe. Therefore we included the first representations from the Balkans and stopped our timeline at the end of the post-LBK groups. Each cultural group was drawn in QGIS using several distribution maps (*Denaire 2009.661, Fig. 4; Bostyn* et al. *2018.28, Fig. 1; Czerniak* et al. *2020.264, Fig. 23.1; Wallner* et al. *2022.2, Fig. 1*). The size of each cultural group in square megametres (Mm^2) was then calculated. We separated the Eastern and Western LBK, as their figurative features were distinct – *i.e.* the so-called centaur figures from the Eastern Carpathian Basin (*Bánffy 2017.710*). But as we will see, their densities were also very different.

For each cultural group, we calculated the density of figurative representations, that is to say the number of finds per square megametre (1 Mm^2 = 1 000 000 km^2) per year (Figs. 4 and 5).

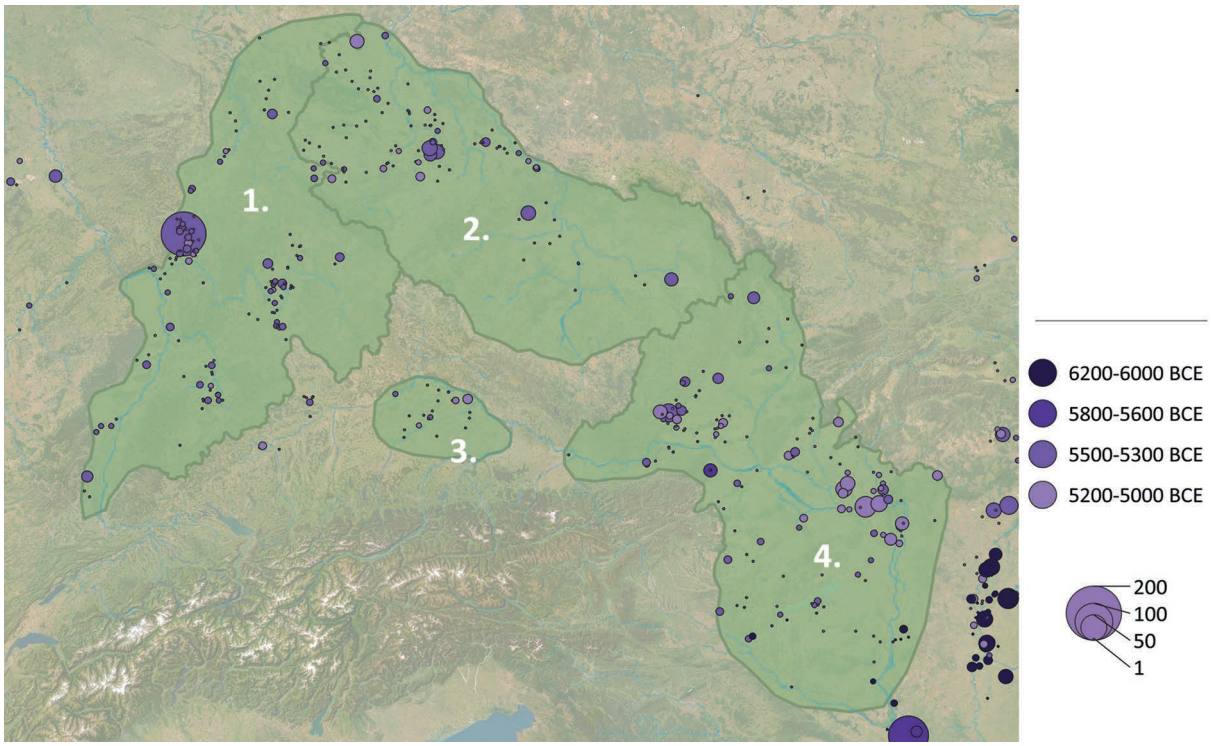

Fig. 6. Regional clusters during the LBK.* 1 *Rhine cluster,* 2 *Elbe cluster,* 3 *SE Bavarian cluster,* 4 *Lower Austria/Moravia/Transdanubia cluster. Timeslots represent the finds' earliest dating.

$$\textit{Find density} = \frac{\textit{Total Number of Finds}}{\textit{Geographic Area (Mm2) x Timespan (years)}}$$

Below, we have calculated finds per year as an overall measure for the presumed number of figurative representations used per year (= number of finds divided by timespan in years). Then, we calculated the density of finds by counting finds per year per megametre. Using megametres allowed us to obtain numbers above 0.00, but this unit is too broad to capture an overview of the finds' spatial distribution. Therefore we added a graph of finds per hundred km², which – equivalent to the city of Paris, France – allows a better readability of how many representations could have been produced in a limited area.

Finds per year:
Starčevo–Körös–Criş (SKC): 1.39
Linear Pottery culture (LBK): 2.23
Western Linear Pottery culture: 1.72
Eastern Linear Pottery culture: 0.50
Stroked Pottery culture (SBK): 0.10
Post-SBK local groups: 0.02
Hinkelstein-Großgartach-Rössen groups: 0.01
Lengyel: 2.54
Early Lengyel: 3.41
Later Lengyel: 0.43

Find density (finds per Mm² per year):
Starčevo–Körös–Criş (SKC): 1.91
Linear Pottery culture (LBK): 1.32
Western Linear Pottery culture: 1.12
Eastern Linear Pottery culture: 3.49
Stroked Pottery culture (SBK): 0.11
Post-SBK local groups: 0.02
Hinkelstein-Großgartach-Rössen groups: 0.02
Lengyel (MBK/MOG I and II): 6.28
Early Lengyel: 8.32
Later Lengyel: 1.05

Finds per hundred km²:
Megametres were converted to hundreds of km² (the equivalent of Paris) for better readability.
Starčevo–Körös–Criş (SKC): 0.11
Linear Pottery culture (LBK): 0.07
Western Linear Pottery culture: 0.06
Eastern Linear Pottery culture: 0.21
Stroked Pottery culture (SBK): < 0.00
Post-SBK local groups: < 0.00
Hinkelstein-Großgartach-Rössen groups: < 0.00
Lengyel (MBK/MOG I and II): 0.43
Early Lengyel: 0.23
Later Lengyel: 0.04

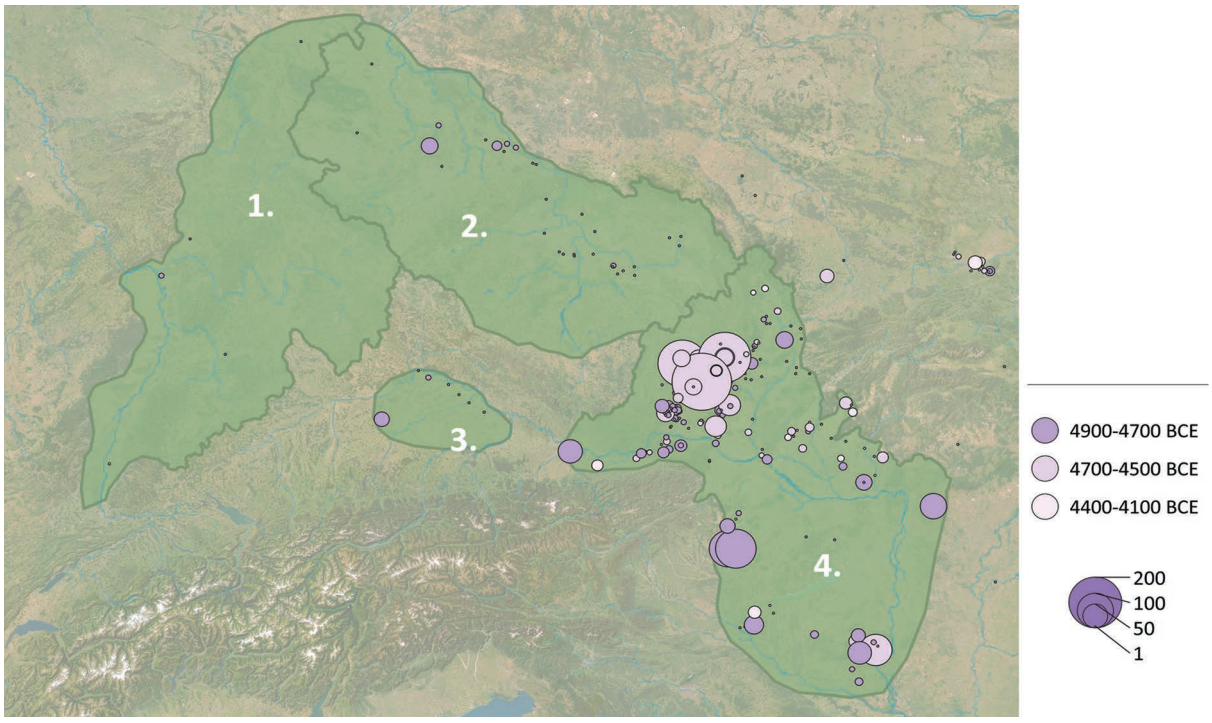

Fig. 7. Regional clusters post-LBK (Hinkelstein-Großgartach-Rössen culture, Stroked Pottery culture and later local groups, Southeastern Bavarian Middle Neolithic group, and Lengyel culture).* 1 *Rhine cluster,* 2 *Elbe cluster,* 3 *SE Bavarian cluster,* 4 *Lower Austria/Moravia/Transdanubia cluster. Timeslots represent the finds' earliest dating.

The densities presented above confirm the decrease in figurative finds from the Starčevo–Körös–Criş group to the Linear Pottery culture. They also highlight the scale of the increase in finds at the start of the Lengyel culture. However, the finds are not evenly distributed. In both the Linear Pottery and Stroked Pottery cultures, finds cluster in the Elbe/Saale and Lower Poland areas. In order to obtain a more detailed picture of the apparent decrease in figurative representations from the LBK to post-LBK groups (Lengyel culture, Stroked Pottery culture, Southeastern Bavarian Middle Neolithic and Hinkelstein-Großgartach-Rössen groups), we outlined and compared regional clusters.

Region	Mm²	Number LBK	Number post-LBK	Timespan LBK	Timespan post-LBK
Rhine-Main	0.19	338	6	5500-4900 BCE	4900-4500 BCE
Elbe	0.12	184	47	5500-4900 BCE	4900-4400 BCE
Lower Austria/Moravia/ Transdanubia	0.22	412	1674	5500-4900 BCE	4800-4100 BCE
Southeastern Bavaria	0.01	31	7	5500-4900 BCE	4900-4400 BCE

Fig. 8. Number of finds, area (Mm²) and timespan of each region.

Comparing regional clusters, from LBK to post-LBK

Using river basin borders,[1] find quantities and cultural homogeneity, we delimited four regional clusters: the Rhine cluster, Elbe cluster, Southeastern Bavarian cluster, and Lower Austria/Moravia/Transdanubia cluster (Figs. 6, 7 and 8).

Find density (finds per Mm² per year):

Rhine-Main:
LBK: 2.96
Post-LBK: 0.05

Elbe:
LBK: 2.55
Post-LBK: 0.78

Lower Austria/Moravia/Transdanubia:
LBK: 3.12
Post-LBK: 11.12

Southeastern Bavaria:
LBK: 5.16
Post-LBK: 1.4

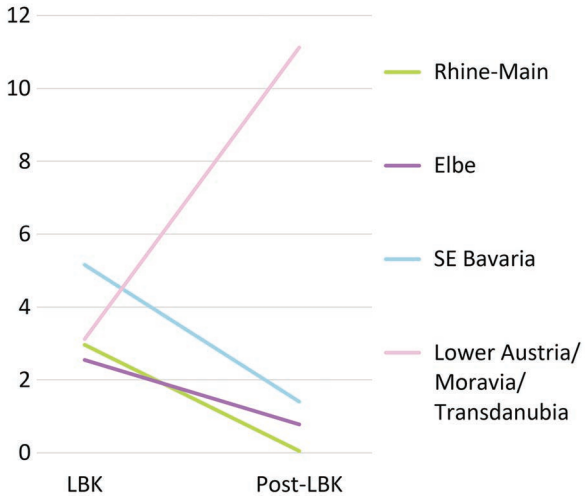

Fig. 9. Regional figurative find density comparisons.

These numbers show that each cluster had comparable find numbers during the LBK (Fig. 9). They further indicate a find decline at the start of the Middle Neolithic in the Rhine-Main, Elbe and SE Bavaria regions parallel to a steep increase in the Lower Austria/Moravia/Transdanubia region. According to these visualizations, the change that took place in figuration during the Middle Neolithic does not seem to have found its roots in the Early Neolithic, as the density of finds for each cluster was rather homogeneous during the LBK before rising or falling drastically at the start of the Middle Neolithic. However, this does not take into account number variations during the LBK, which we explore below.

Comparing regional fluctuations within a cultural group

Chronology is a particular challenge when analysing figurative finds, as many are broadly dated. Under these circumstances, the aoristic method described by Mischka offers a valuable approach (*Mischka 2004*; *Becker submitted*). The method divides find numbers by their timespan: for example, all finds dated from 5500 to 5400 are divided into four generations (each of 25 years). This results in a number of probable finds per generation. The more precise the dating, the darker the colour. We first used the method on the Western LBK dataset (Fig. 10).

The result shown in Figure 10 are quite surprising, as they suggests a spike in figurative finds during the Late LBK. However, this may be due to skewed data:

1 Data provided by the EU-Hydro River Network Database 2006–2012.

finds dated with an accuracy of a hundred years mostly belong to Slovakia (96 finds dated from 5000–4900 BCE while Hungary yielded 39 and Germany 29). We therefore reproduced the method on our regional clusters – with the exception of the SE Bavarian cluster, as its data was insufficient (Fig. 11).

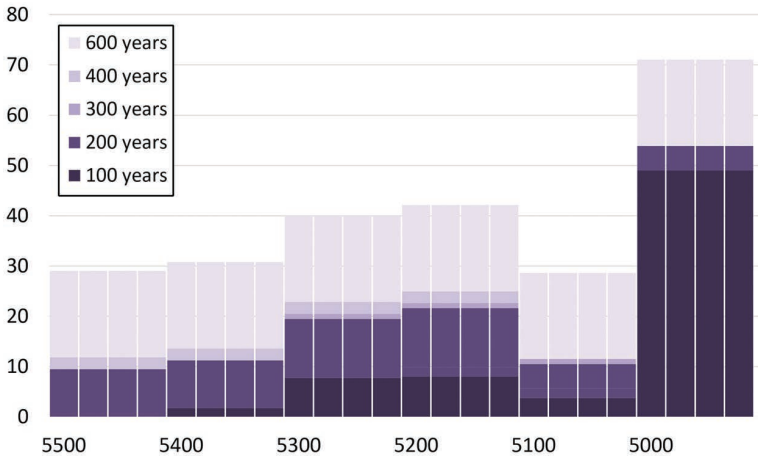

Fig. 10. Aoristic method applied on the Western LBK dataset (n=1068). Colours represent levels of dating accuracy.

Figures 11–13 confirm that the spike in Late LBK finds was caused by the data from the Lower Austria/Moravia/Transdanubia cluster. This may be due to the great number of face vessels in Slovakia during the Late LBK. These vessels were precisely dated due to their distinctive contexts: they belong to the Želiezovce group with its characteristic pottery decoration (*Kuzma 1990; Pavúk 1994; Virág 2000; Cheben 2002; Fábián 2005; Becker 2011.115–119*).

Compared to the Lower Austria/Moravia/Transdanubia cluster, the Rhine-Main dataset shows a more balanced picture, with the majority of data being imprecisely dated, and a potential increase of finds in the Late LBK (Fig. 12). This suggests that figurative objects peaked in the Rhine-Main area during the late LBK, right before dropping abruptly. A development that could be linked to a 'crisis' at the start of the Middle Neolithic (*Bristow 2025*). However, the available data is still too scarce to make any firm interpretation.

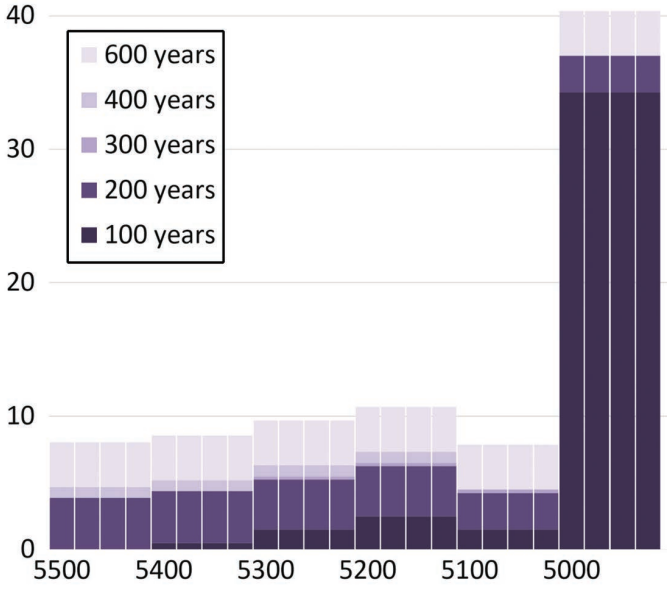

Fig. 11. Aoristic method applied on the LBK data from the Lower Austria/Moravia/Transdanubia cluster (n=412). Colours represent levels of dating accuracy.

Finally the Elbe cluster shows another pattern, with a find increase in the Middle LBK and fewer finds during the Late LBK (Fig. 13).

These results show how diverse the figurative landscape might have been during the Neolithic, and prove that there are still many quantitative issues to explore when taking into account regional clusters.

Discussion: a bright future

There is still much to discover by considering excavation size and preservation biases, as well as the question of fragmented representations and their life-cycles. In the case of the German site of Bad Nauheim-Nieder-Mörlen, fragmentation plays a particularly striking role, as figurative finds were heavily fragmented, and these fragments were scattered around the site. Furthermore, figurative representations were probably not used for identical amounts of time, which means distribution numbers might not accurately reflect their life-cycles. All excavation sites are different in size, preservation and occupation duration. Therefore, cross-site comparisons still need to be addressed, and examining sites with a greater density of finds might lead to interesting insights.

As this article was part of a three-year PhD dissertation, it was not possible to extend the study to include these additional variables. The archaeological and regional context of figurative representations, on the other hand, was further explored in individual articles examining the disappearance of figuration in fifth millennium Central Europe (*Becker* et al. *2024; Bristow*

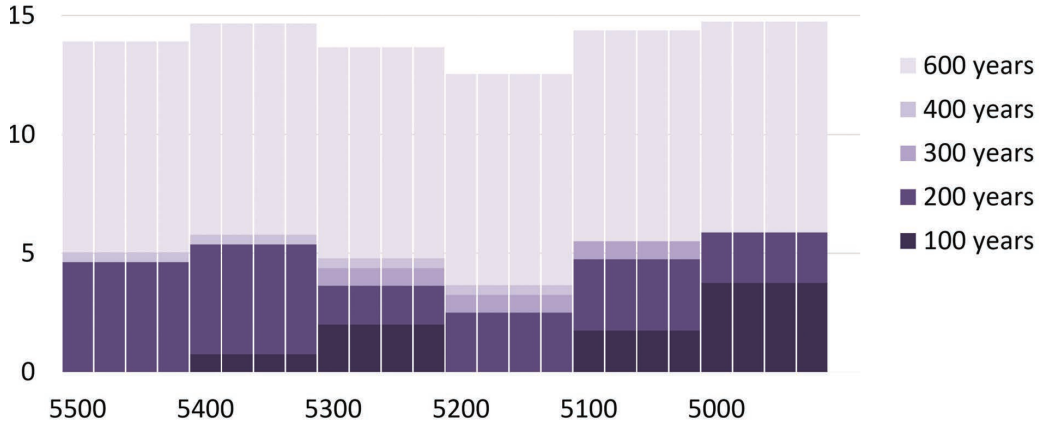

Fig. 12. Aoristic method applied on the LBK data from the Rhine-Main cluster (n=338). Colours represent levels of dating accuracy.

2025; Becker in print; Bristow in review). This article is therefore only the start of deeper analyses to come, as our open access database will hopefully inspire many more studies.

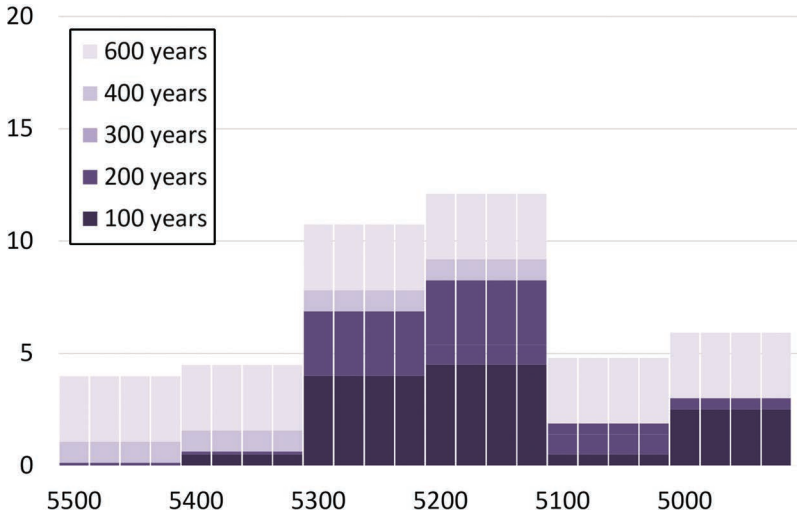

Fig. 13. Aoristic method applied on the LBK data from the Elbe cluster (n=189). Colours represent levels of dating accuracy.

Conclusion

This article brings forward a spatial and statistical approach to the study of European Neolithic figurative representations. We first underlined the biases and challenges of cross-cultural comparisons, and suggested a new method: comparing find densities across regional clusters, and using probability statistics to produce regional chronologies. This was possible due to the creation of a relational database holding more than 2500 figurative finds from Central Europe and the Balkans. Comparing the cultural and regional densities of these finds confirmed the traditional narrative of a boom of finds in the Lengyel culture and a burst in the neighbouring northwestern groups. However, it seems this burst was only delayed in the Lengyel culture, as find numbers fell significantly during its second phase. Furthermore, variations in figuration distribution were already present during the LBK, which we observed through regional chronologies. These revealed local dynamics that challenge the idea of a progressive discard of figuration during the LBK. In contrast, the number of figurative finds might have been in some cases at its highest right before it dropped. Examining the data quantitatively, and through spatio-temporal layers, allows for a more accurate and insightful depiction of the rise and fall of figuration during the Neolithic.

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Stone head tools from the hunter-gatherer Stone Age sites of Dudka and Szczepanki, NE-Poland

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ABSTRACT – *A large collection of 75 stone head tools coming from the Stone Age hunter-gatherer sites of Dudka and Szczepanki in NE-Poland is presented. The tools, which are exceedingly diversified, were divided into 14 taxa. Most taxa reveal a long chronology from the Mesolithic to the Late Neolithic, although the majority of tools belong to the Para-Neolithic Zedmar culture. Tools were characterized regarding shape, proportion, size, mass, raw material and processing. The analysis shows that almost every taxon is intrinsically diversified regarding the position of maximum width and thickness, size and mass or kind and colour of rocks, and these variabilities do not show connections with the chronology. Instead, some secondary stylistic features such as the edge protrusion and separation from the trunk or form of sides and butts reveal chronological trends. Unexpectedly, the contexts in which tools appeared at both sites were different, at Dudka three quarters of finds come from the cemetery, whereas at Szczepanki three quarters come from the lake shore zone. It is argued that in both cases this arose from the custom of the intentional deposition of stone head tools.*

KEY WORDS – *stone head tools; hunter-gatherers; Dudka and Szczepanki; Zedmar culture; NE-Poland*

Kamena orodja v kamenodobnih naseljih lovcev in nabiralcev v Dudki in Szczepanki, SV-Poljska

IZVLEČEK – *Predstavljamo obsežno zbirko 75 kamnitih orodij, odkritih v naseljih lovcev in nabiralcev iz kamene dobe v Dudki in Szczepanki na severovzhodu Poljske. Orodja izstopajo po veliki tipološki raznolikosti in so bila razvrščena v 14 taksonov. Večina pripada para-neolitski kulturi Zedmar, vendar kažejo širok kronološki razpon, od mezolitika do poznega neolitika. Orodja smo tipološko in morfološko analizirali glede na obliko, razmerja, velikost, maso, vrsto surovin ter tehnologijo obdelave. Analiza je pokazala, da je skoraj vsak takson izrazito variabilen glede položaja največje širine in debeline, dimenzij, mase ter vrste in barve kamnin. Variabilnost ni odvisna od kronološkega obdobja, čeprav nekatere stilistične značilnosti – kot so izbočenje roba, način loma od jedra ter oblika stranskih robov in zadnjih delov – kažejo kronološke trende. Zanimivo je, da se najdiščni konteksti razlikujejo, saj je bilo v Dudki tri četrtine orodij najdenih v grobišču, medtem ko so v Szczepanki tri četrtine orodij odkrili na obali jezera. Na podlagi teh podatkov zagovarjamo tezo, da gre v obeh primerih za namensko odlaganje kamnitih orodij.*

KLJUČNE BESEDE – *kamena orodja; lovci in nabiralci; Dudka in Szczepanki; kultura Zedmar; severovzhodna Poljska*

 DOI: 10.4312/dp.52.17

Introduction

Stone (not flint) head tools such as axes and adzes are very rare at the Mesolithic and Para-Neolithic sites in Poland, since barely single finds occurred at dozens of excavated sites. Moreover, such finds have only been superficially reported, so the knowledge regarding this category of tools is poor.

The paper presents a large assemblage of 75 stone head tools (the abbreviation SHT will be used hereafter) from two hunter-gatherer Stone Age sites of Dudka and Szczepanki in Masuria in north-eastern Poland. The number includes two loose finds from the unexcavated neighbouring Zedmar culture site of Malinka (Fig. 1). The study concerns the classification, characterization and dating of SHT, as well as their high diversity and context of occurrence.

The Dudka and Szczepanki sites are located on two islands on the former Staświn Lake, whereas Malinka is situated in the mouth of the Pamer stream to the Staświn Lake, *c.* 1km south from the Szczepanki (Fig. 1).

Dudka was the biggest island of the lake (*c.* 15ha), and the main activity area was located on the south-eastern part of the island close to the shoreline. There were three main settlement zones – at the southern promontory (trenches I, II, XII), at the eastern bay (trench III) and below the cemetery (trench XIII and XI). The cemetery (trench VI) was located on the island plateau between these settlement zones (Fig. 2.A). The cemetery was used from the Late Mesolithic, although mainly in the early and classic Zedmar, and after that the area was inhabited, although funeral practices were still continued there until the Late Neolithic. It should be added that the eastern bay was also the place where numerous loose human bones have been found, which were classified as the remains of temporary burials (*Gumiński 1995; 1999; Bugajska, Gumiński 2016; Gumiński, Bugajska 2016; Bugajska 2025*).

Szczepanki island, located 1km south from Dudka, is smaller (*c.* 2ha) with a central culmination that is 5m above the peat-bog. There were in fact two separate habitation sites. The first, main settlement area was situated below the hill at the southern shore (composed on sectors S and E). The second place, called Szczepanki A, was a small encampment situated *c.* 150m away at the eastern promontory of the island (sector A) (Fig. 2.B) (*Gumiński 2004; 2012; 2016; 2018; 2020*).

The settlement on both islands occurred simultaneously starting in the Late Palaeolithic, endured during the entire Mesolithic and the Para-Neolithic Zedmar culture and lasted until the Late Neolithic, for a total period of *c.* 7500 radiocarbon years or 9000 calibrated years (Tab. 1).

The dwelling places and main activity areas on both islands were located at practically the same places throughout the whole Stone Age. However, the character of occupation of the sites changed over time. In the Late Palaeolithic habitation on both islands was rather occasional, in the Mesolithic it was recurrently seasonal, and from the early Zedmar it was year-round.

The subsistence economy in the region remained predominantly based on hunting and gathering practices until the end of the Neolithic. Isolated remains of domesticated animals – excluding dogs – appear as early as the Early Zedmar phase, although they represent only a small percentage of the total faunal assemblage, with ungulates making up just a few percent.

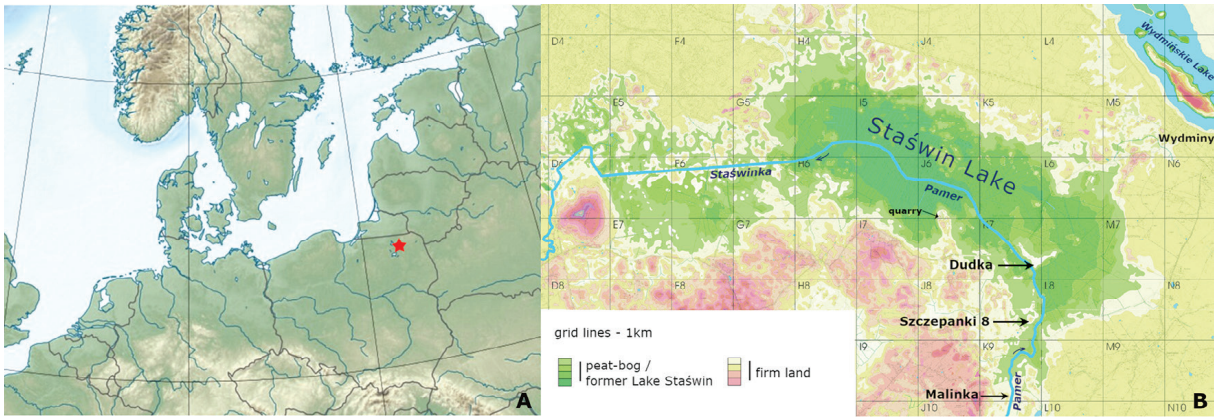


Fig. 1. Localization of Dudka and Szczepanki sites,* A *in Middle Europe,* B *within former Staświn Lake (map by W. Gumiński).

Archaeological period	Climate, Chronozone	Years ^{14}C BP	Years cal BC	Number of stone head tools			
				Du 830m^2	Sz 586m^2	Ma no. exc.	Total 1416m^2
Late Palaeolithic	Allerød Younger Dryas	11200 – 11000 11000 – 9800	11200 – 11050 11050 – 9250				
Early Mesolithic	Preboreal Boreal	9800 – 9000 9000 – 8000	9250 – 8250 8250 – 7000		1		1
Late Mesolithic	early Atlantic middle Atlantic	8000 – 7000 7000 – 5600	7000 – 5850 5850 – 4500	1	3		4
Early Zedmar	late Atlantic	5600 – 5100	4500 – 4000	3	12	+1	15+1
Classic Zedmar	Atlantic/ Subboreal	5100 – 4700	4000 – 3500	10	13	+1	23+1
Post-Zedmar	early Subboreal	4700 – 4200	3500 – 2800	5	10		15
Late Neolithic	early/middle Subboreal	4200 – 3700	2800 – 2200	10	5		15
	Total	7500 years	9000 years	29	44	+2	73+2
	Frequency toward excavated area			1/29m^2	1/13m^2	-	1/19m^2
	Frequency in relation to common stone finds			1.5%	1.8%	-	1.6%

Tab. 1. Periodization, chronology and number of stone head tools at Dudka (Du), Szczepanki (Sz) and Malinka (Ma). Loose finds from Malinka were added as + to the more probable period.

Fish bones make up *c.* 40% of all animal bones from the time of the Mesolithic and Zedmar culture, and the amount of these decreased significantly in the post-Zedmar and Late Neolithic, down to 15% and then 10% respectively, most probably caused by overgrowing and hypertrophication of the lake in the early Subboreal. As a result the islands were abandoned at the end of the Neolithic (*Gumiński 1995; 1998; 1999; 2003; 2004; 2008; 2012; Gumiński, Michniewicz 2003*).

Stone head tools in general

Terminology and basic classification

Head tools made of stone or other raw materials are intended for cutting, splitting or hammering using the kinetic energy of a blow dealt with the support of a wooden helve, which is an integrated part of the tool. The head ought to be always set crosswise to the shaft (Fig. 3.C). Wooden shafts from the Stone Age survive extremely rarely, so in practice only stone heads are available for research. Nevertheless their proper parameters, symmetry and thorough elaboration make it possible to distinguish SHT from much more common hand-stones or cleavers/choppers, which have similar functions to a hammer or axe, but were held directly in the hand when used. Chisels and punches were also held in the hand, but during use their backs were struck by other heavy items.

The SHT of hunter-gatherers are usually divided into several categories, which as a rule are distinguished according to three attributes. The first is the symmetry of the edge toward both walls in the longitudinal section, which determines the position of the working edge toward the helve. If the edge keeps the symmetry the tool can be fitted to the helve parallel, as with an axe, and if not then the edge should be set transversely to the helve, as with an adze (Fig. 3). The second attribute is the form of the working end, which can be a sharp edge as with an axe and adze, pointed as with a pickaxe and mattock, or blunt as with a hammer and mace. The third aspect is the presence or absence of a shaft-hole (Fig. 3.A)

According to above mentioned attributes, SHT are usually divided into eight basic kinds:

(a) an axe – generally symmetrical in the longitudinal section, so the cutting edge was set on the symmetrical plane and then presumably parallel to the helve;
(b) an adze – with the flatly convex shape in the longitudinal and cross-sections, so the edge is moved down toward the flat lower wall and the cutting edge was set presumably transversally to the helve (Fig. 3.C);
(c) a hammer – like an axe or adze, but with a blunt working end;
(d) a pickaxe – with a pointed working end;
(e) a mattock – like a pickaxe but with a shaft-hole;
(f) a hatchet – also called a shaft-hole axe;
(g) a hoe – like an adze with a shaft-hole;
(h) a mace – in which the blunt working end goes around the shaft-hole.

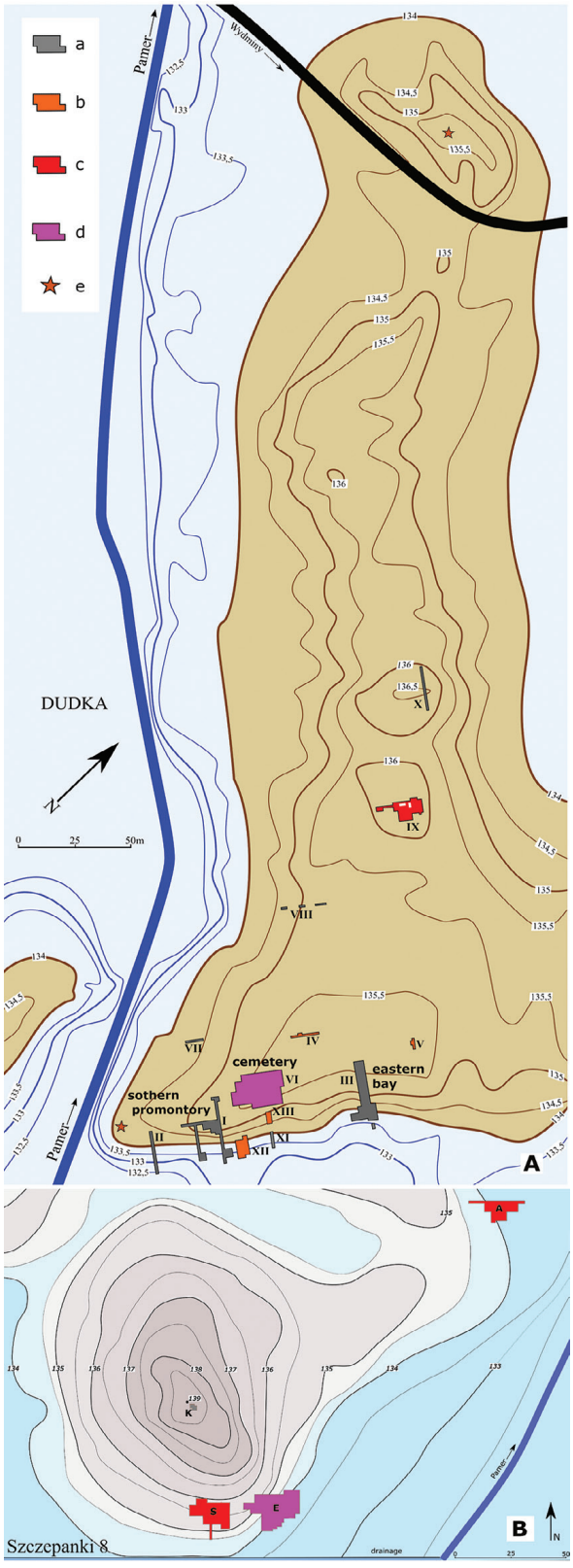


Fig. 2. Distribution of stone head tools,* A *at Dudka,* B *at Szczepanki,* a *trenches without stone head tools,* b *trenches with one tool,* c *trenches with 3–9 stone head tools,* d *trenches with over 20 stone head tools,* e *single loose find of a stone head tool (plan by W. Gumiński).

The studied assemblage contains the first six kinds, and lacks a hoe or a mace (Fig. 3.A).

It should be stressed that the above names of the various kinds of SHT are conventional and do not determine the function of a certain tool. For instance, the designation 'mattock' or 'hoe' does not mean that the tool was used just for earth works, although it may have been. Similarly, both axe and adze are good for cutting trees, though with an axe it should be done obliquely or transversely to the tree trunk, whereas it is done parallel to it with an adze.

The terms 'axe' and 'adze' are often used synonymously or both kinds are designated by the more general term 'axe'. However, a 'proper' axe should be symmetrical in the longitudinal section, so the cutting edge and the centroid are situated on the vertical plane of symmetry. When an axe is set parallel to the helve (Fig. 3.C), then its strike ought to be accurate. Instead, the working edge of an adze is purposely moved toward a lower and flatter wall (Fig. 3.B), so the centroid is set higher than the edge. The transverse position of the cutting edge of the adze in relation to the helve (Fig. 3.C) induces a tendency to turn up the edge of the tool at the moment of striking. This is especially desirable in carpentry, because it can prevent holes being made through the wood, something which was crucial when producing dug-out boats.

The determination of a particular tool as an axe or an adze is not always evident. Some specimens look intermediate if the edge is slightly out of the symmetry plane and/or both walls are not symmetrical, or if the item is insufficiently preserved. In both cases they will be termed as an adze-axe.

Formally, the next level of classification divides into types (adjectival denomination) based on a specific shape or other important features of the designated kind. As a matter of fact, in many cases the specific shape of an item seems to be more appropriate for use as the characteristic of a given tool than its formal attribution to a particular kind – axe or adze.

Previous classifications of pre-Neolithic stone head tools

Mesolithic SHT are extremely varied (*Ahlbeck, Gill 2010.62*), something that was already noticed more than 150 years ago by the Swedish archaeologist Knut Stjerna (*1871*), who researched a large collection of such tools from central Sweden. He noted that "*no*

two axes look the same" and "*no axe is like the other*" (cited after *Carlsson 2007.159; 2008.233*). Since then, many attempts to systematize the classification of such tools have been undertaken, and these have usually been based on different attributes, such as the general shape or cross-section (*Walzenbeil*, round-sectioned), shape of the butt (round- or thin-butted), shape of the sides (round, narrow, faceted), technique of production (pecked, flaked, ground), kind of rock (greenstone, slate), as well as using the region of occurrence or affiliation with a particular culture (Lihult, Nøstvet, Limhamn). As a result, a given tool can be assigned to two or more categories simultaneously, depending on what feature is being taken into account.

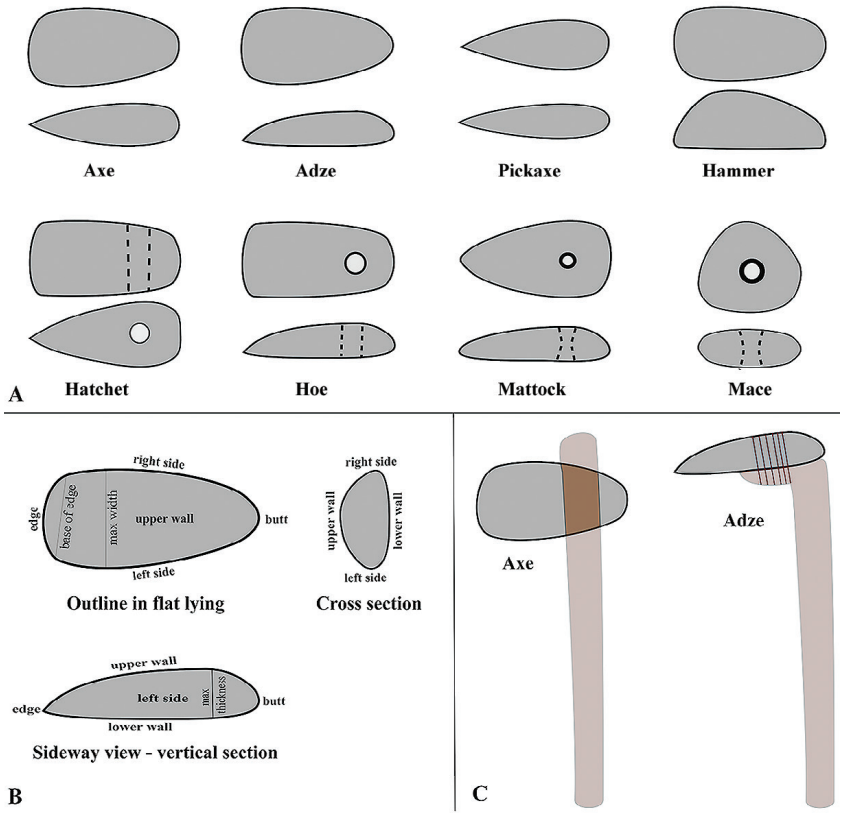


Fig. 3.* A *Kinds of stone head tools,* B *scheme of an adze and its parts,* C *the position of the working edge and flat walls against the shaft in an axe – parallel and in an adze – transversally (schemes by W. Gumiński).

For the Mesolithic of middle-north Europe, *i.e.* for the Maglemosian tradition, including the Ertebølle and Swifterbant cultures, the three most common forms that have been distinguished are cylindrical or round-sectioned adze-axes (*Walzenbeile*), Lihult-Nøstvet adzes and Limhamn axes.

One reasonably unambiguous designation is cylindrical adze-axes (*Walzenbeile*), though in fact they are not cylindrical, but rather 'cigar'-like, and they will be referred to as such in this paper. This type is easily distinguishable considering its specific round or slightly oval cross-section. Such forms are also called 'round-butted' axes, but only if the butt is rounded, and this is in contrast to the 'thin- or pointed-butted' axes which are typical for the Neolithic Danubian and Funnelbeaker culture (*Gramsch 1973.29–31; Sørensen L. 2014. 126–169*).

Lihult or Nøstvet adzes (rarely axes) are remarkably oblong and unilaterally flattened, and thus their cross-section is usually D-shaped, *i.e.* flatly convex, so they can be called 'tongue'-shape. Most Lihult-Nøstvet adzes were only ground next to the edge, whereas the rest of the tool usually exhibits the flake-knapping technique. For that reason they are also called '*flaked or knapped axes*' (*Ahlbeck, Gill 2010; Carlsson 2008.232–245; Glørstad 2011; Knutsson* et al. *1999.Fig. 7; Lindgren, Nordquist 1997*).

In contrast, the Limhamn type is a very vague category of SHT. These tools are proportionally shorter, with an oval cross-section, so are generally bulging forms. About three-quarters of such tools, at least in Zealand, are symmetric in longitudinal and cross-sections, so they are categorized as axes. Unlike Lihult or Nøstvet axes and adzes, Limhamn tools are usually polished on the whole surface, so they are also called '*polished axes*' (*Becker 1939; Faxholm 2020; Nicolaisen 2009; Nordman 1918; Sørensen L. 2014.126–169*).

Some Mesolithic adzes and axes were not been polished, but instead worked with a pecking technique (*i.e.* thorough crushing), and thus they are known as '*pecked axes*'. This term is used for various forms of axes and adzes, but only if they were made with only this technique (*Nordman 1918; Becker 1939; Lindgren, Nordquist 1997; Knutsson* et al. *1999.102; Sørensen S. A. 2007; Carlsson 2008.232–245; Nicolaisen 2009; Glørstad 2011; Sørensen L. 2014.126–169; Faxholm 2020.8–34*).

It should be stressed that a particular way of manufacturing SHT could arise for different reasons, such as the kind of rock, the state of implement finishing, or the way it was planned to set it with the helve. The rough surface of the back part of the tool was certainly more of a requirement if the aim was to firmly fasten the head to a wooden shaft (Fig. 3.C).

The short review of the definitions of different types of axes and adzes presented above shows that they are not universal and often misleading, and the technique of manufacture, shape of butt or regional distribution should not be taken as crucial traits for distinguishing a particular type of tool. One notable recent example of the problems that can arise because of this was an attempt to distinguish another type of stone axe, called '*Oringe axes'*, which were poorly defined as "*a hybrid between pecked axe and Limhamn axe"* (*Nicolaisen 2009.854; Faxholm 2020.34*).

In this context it serves well to recall that already in 1906 Anton Wilhelm Brøgger, when defining the Nøstvet type stone adze, pointed out that each specimen should be presented and distinguished on the basis of three views-sections – flat outline, sideway view and cross-section (after *Glørstad 2011.22*). Unfortunately, this rule was then rarely practised, and even today is widely ignored (Fig. 3.B).

Stone head tools in neighbouring regions and cultures

SHT related to hunter-gatherers are unequally distributed in north-central Europe. In Masuria and the Prussian Lowland, where the Zedmar culture existed, they are rare finds, and barely a dozen examples connected with the Mesolithic or Para-Neolithic are known from this area, although the ones we have are very diverse. There are 'cigar'-shaped adze-axes (*Walzenbeile*), 'tongue'-shaped adzes (refer to Lihult or Nøstvet), so-called 'bulgy' axes (equivalent of Limhamn axes), 'flat' and 'small' adze-axes, and a mace (*Gaerte 1929.Figs. 11,12; Okulicz 1973.Figs. 22,26,35; Timofeev 1996; 1998; Pawłowski 1999*). It is worth noting, that flint adzes of the Mesolithic type do not occur in this region.

SHT are quite common in the East Baltic territories, from southern Finland up to the coast of Gdansk Bay in north-eastern Poland. However, in Estonia and Latvia they were made mostly from a slate, which is considerably easier to process, particularly for splintering thin slabs and smoothing. Most of those tools are symmetrical 'flat' or 'little' axes. Further to the south other rocks were also used and 'bulgy' adze-axes (similar to Limhamn) and some additional types also appeared. It seems that stone axes, and in particular little ones, became more common in the later periods of the Stone Age (*Żurek 1954.Pl. XIV; Jaanits 1959.Figs. 21–30; 1965.Figs. 10,19,22–24; 1968; 1984; Loze 1979.Pls. 10–15; 1988.Pls. 30–34; Rimantienė 1979.Figs. 35,36; 1980.Figs. 14,15; 2005.159–160, 377–379; 2016.196–212; Girininkas 1990.Figs. 77–81; Matiskainen 1988; Zalcman 2010.Figs. 21–24; 2014; Czubla, Woźniak 2018; Butrimas 2019.Figs. 5,6,10; Petrović* et al*. 2024*).

In contrast to the finds in Baltic countries, Mesolithic or Para-Neolithic SHT are very rarely found in Belarus and Poland (except in Masuria and coast of Gdansk Bay), with just one or even no examples found at many excavated sites. Even so, those that have been found come in a variety of shapes: 'cigar', 'tongue', 'bulgy', 'flat' and 'little' adze-axes, as well as maces. On the other hand, unlike in Masuria, flint adzes are found in Belarus and Poland (*Kobusiewicz 1970.Pl. XXXV.2; Więckowska, Kempisty 1970.Fig. 16; Grygiel 1973. Fig. 2.12; Czarniauski 1979.Figs. 8,46; Kempisty, Więckowska 1983.Pl. IV.13; Bagniewski 1987.Fig. 18; Ilkiewicz 1989.Figs. 6.22,10:3; Galiński 1992a.Fig. 2.27; 1992b.Pl. CI; 2022; Czarniauski, Kalečyc 1997. Fig. 118*). While some SHT occur in the Polish Lowland as loose finds, as a rule they are connected with the Neolithic, although at least some of them could be linked with hunter-gatherers, too (*Smoczyńska 1953; Prinke, Wiślański 1972.Figs. 24.6,49.7; Ilkiewicz 2005.Figs. 11–13*).

SHT are very common in east Germany and southern Scandinavia. However, in Brandenburg and Mecklenburg 'cigar'-shaped adze-axes (*Walzenbeile*) definitely predominate, with *c.* 250 such specimens from 205 sites known (*Gramsch 1973.29–32, Karte 7*). In eastern Denmark and south Sweden stone adze-axes are even more common, and in Scania 633 examples of Limhamn axes (also called polished axes) have been found, and over 450 in Denmark (*Becker 1939; Jennbert 1984.102; Vang Petersen 1984.Fig. 11; Sørensen S. A. 2007.184; Nicolaisen 2009*). Additionally, 'cigar'-shaped adze-axes, and particularly 'tongue'-shaped adzes (named Lihult or Nøstvet), occur in south-western Sweden and south-eastern Norway in the hundreds, and already appeared in southern Scandinavia in the Early Mesolithic (*Althin 1954; Florin 1959; Larsson 1978.101–103; 1983.45–47; 1990.Fig. 7; Jennbert 1984. 102–105; Taffinder 1998.64–66; Kindgren, Schaller Åhrberg 1999; Knutsson* et al. *1999.Figs. 7,14; Nord-*

qvist 1999.Figs. 4–7; Boas 2001; Nielsen 2001; Vang Petersen 2001; Bengtsson 2003; Bergsvik, Olsen 2003; Sørensen S.A. 2007; 2017.54–56; Carlsson 2008.232–245; Ahlbeck, Gill 2010; Glørstad 2010.Tab. 3.1; Faxholm 2020).

It is interesting that SHT are rare just west of the Great Belt, in Funen and Jutland, as well as in north-western Germany and the Netherlands, although 'cigar'-shaped, 'tongue'-shaped, 'bulgy' and 'flat' adze-axes are known. On the other hand, perforated mace-heads and mattocks are comparatively more frequent in the Netherlands (*Raemaekers 1999.102–105; Verhart 2012; Devriendt 2014.271, Tab. 4.16, Figs. 3.5,4.7; Andersen 2018.74–76*).

Stone head tools from Dudka and Szczepanki

General chronology and frequency of stone head tools

The presented collection comprises 75 SHT, 29 from Dudka, 44 from Szczepanki and two from Malinka (Tab. 1). In relation to the excavated area, one such tool appears on average in each 19m^2. Surprisingly, their frequency at Dudka is two times lower than at Szczepanki, since at the former one tool occurs on averagely at each 29m^2, whereas at Szczepanki at each 13m^2 (Tab. 1). The proportion of SHT to the rest of stone finds[1] is more similar at both sites, at 1.5% at Dudka and 1.8% at Szczepanki (Tab. 1).

SHT in the micro-region of Lake Staświn already appear in the Early Mesolithic (late Preboreal), which is confirmed by a radiocarbon date of 9140±50 BP (8540–8270 cal BC, Poz-147474) obtained from charcoal found with the 'tongue'-shaped adze (#13) in the coarse gyttja layer at Szczepanki (Tab. 1). Besides, a shaft-hole socket for adze made of elk antler also comes from the late Preboreal at Szczepanki, which is confirmed by the direct date of 9450±50 BP (9118–8609 cal BC, OxA-26653). On the other hand, SHT were generally rare in the Mesolithic, since only five such items have been found. They became three times more frequent (16 tools) in the early Zedmar, a number which rises to 24 in the classic Zedmar. Their number then falls to 15 pieces in the post-Zedmar and Late Neolithic period (Fig. 4, Tab. 1).

Surprisingly, the occurrence of SHT in the following periods is different at each site. At Dudka, the number of SHT generally increased from the Late Mesolithic to the Classic Zedmar, with up to 10, and after a decline to five items in the post-Zedmar they return to the previous level in the Late Neolithic of 10 pieces (Fig. 4, Tab. 1). SHT appeared at Szczepanki in the Early Mesolithic, became most frequent in the early and classic Zedmar (12–13 specimens), then their number decreased slightly (to 10 items) in the post-Zedmar period and then significantly (to 5) in the Late Neolithic (Fig. 4, Tab. 1).

This decreasing trend in occurrence of SHT from the Zedmar toward the end of the Stone Age is unexpected, because head tools made of stone or flint had better properties regarding hardness, fault-tolerance and weight, so they should supersede the antler-bone head tools which dominated in the Mesolithic and earlier Para-Neolithic. Indeed, ground flint flakes broken off flint axes arose in the classic Zedmar and became twice as frequent in the last two periods (Fig. 4).

It is worth noting, that flint axes or adzes do not occur at the examined sites and only ground flakes – mostly from imported flints (from Krzemionki, Świeciechów, and Volhynian) appear – but these raw materials do not occur among the chipped flint inventory at the sites (*Gumiński 2004.Fig. 20; 2012.Fig. 7q*). It is thus most likely that the ground flint flakes broken off flint axes belonged to Neolithic visitors and not to local hunter-gatherers (*Gumiński 1997; 1999; 2001; 2011*).

The majority of the presented tools come from well-dated layers, for which the chronology was elaborated based on stratigraphy, radiocarbon dates and co-occurrence with pottery of well-established chronology (Tab. 1) (*Gumiński 1995; 1997; 1999; 2004; 2008; 2011; 2012; 2020*). However, some of the artefacts found in higher levels could have been redeposited by ploughing. By contrast, the wet layers of the former littoral zone (peat, detritus, coarse gyttja) were compact enough to support items that fell on the contemporary lake bottom, after which they were gradually covered by younger sediments. This is confirmed by the fact that in the earliest Zedmar level, together with the first pottery, there is a sudden increase in the number of

1 These are mainly hand-stones and anvil-slabs. However, three exceptional items, most likely imported, were also found – a dagger made of schist dated to the early Zedmar (*Gumiński 2012.107–112, Figs. 14,15*), a similarly dated slate ring (*Gumiński 2004.74,75, Figs. 18i,19f*) and a slate pendant probably re-worked from a Bell Beaker wrist-guard (*Gumiński, Kowalski 2011.472–476, Figs. 6g,7b*).

all finds, including stone artefacts, compared to the Mesolithic layers, which is a consequence of population growth and extensive settlement, all year round at both sites (*Gumiński 1995; 1999; 2004; 2012; Gumiński, Michniewicz 2003*). As such, tools coming from the littoral layers can be considered correctly dated (Tab. 2, available online as supplementary file at http//doi.org/10.4312/dp.52.17).

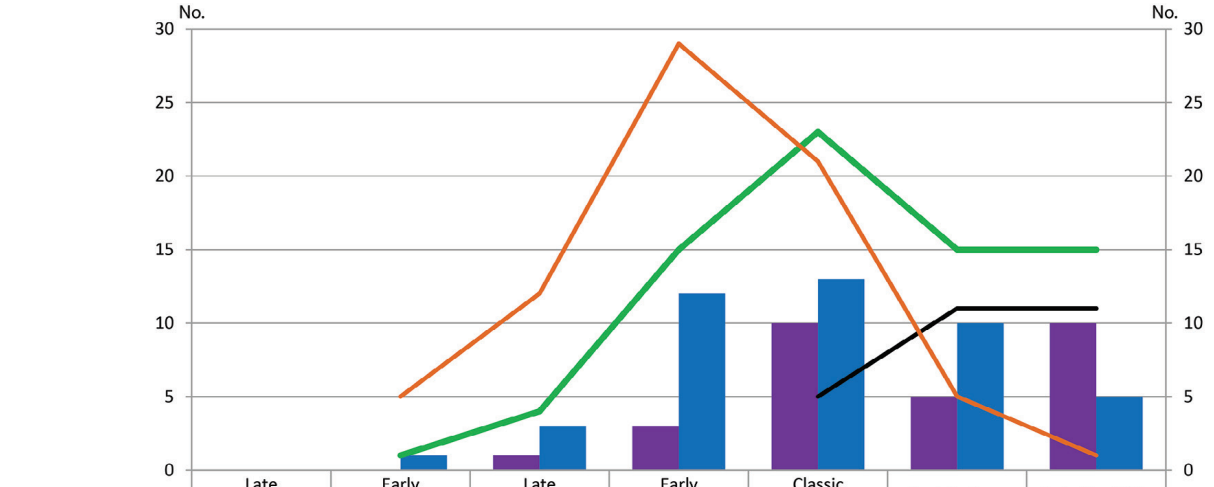
The less secure determination of chronology and context of deposition concerns finds from trench VI at Dudka. As was mentioned above, there was a cemetery that was mainly used in the Zedmar period, after which the area was inhabited, although funeral activity continued up to the end of the Neolithic. The upper layers, generally above graves, are more or less mixed and destroyed by ploughing, so the chronology of the finds at this site is not certain (*Bugajska, Gumiński 2016; Gumiński, Bugajska 2016; Bugajska 2023*).

Methods of classification and description

The SHT from Dudka and Szczepanki are very diverse and belong to six basic kinds – axe, adze, hammer, pickaxe, mattock and hatchet (Fig. 3.A). The next classification concerns the general shape, which defines the type, although the classification that has been applied considers both kind and type simultaneously. Each specimen has been attached to a compound taxon, which includes the kind of tool (nominal term) and its type, which reflects the general shape (adjectival term). As a result 14 compound taxa were distinguished: (1) 'cigar'-shaped axe-adze, (2) 'tongue'-shaped adze, (3) 'kidney'-shaped axe-adze, (4) 'bulgy' axe-adze, (5) 'lenticular' axe, (6) 'flat' axe-adze, (7) 'little' axe-adze, (8) 'claw'-like adze, (9) 'hump' hammer, (10) 'axe'-hammer, (11) 'thick-butted' pickaxe, (12) 'dagger' pickaxe, (13) 'almond' mattock and (14) 'simple' hatchet (Tabs. 2,3).

The shape of the tool is presented in three views – outline of lying flat (horizontal plane), a sideway view (longitudinal-vertical section) and in cross-section (Fig. 3.B). Three main dimensions – length, width and thickness – are given and the proportions between them are used to define the slenderness and flatness of the item (Tab. 3). The slenderness is calculated as the length-width index (LWI), which is the total length of tool divided by its maximum width. The flatness is calculated as width-thickness index (WTI) which is the maximum width divided by maximum thickness of tool. According to the first index (LWI) two main groups of head tools were distinguished – slender when the LWI is higher than 2, and short when the LWI is lower than 2. Similarly, tools with a WTI higher than 2 will be categorized as flat, and those with a WTI lower than 2 as thick (Fig. 5).

Another important feature is the position of the maximum width and thickness of the tool toward the working edge (Fig. 3.B). The maximum width index (MWI) is calculated as the distance from the edge to the maximum width divided by the total tool length and



	Late Palaeolithic	Early Mesolithic	Late Mesolithic	Early Zedmar	Classic Zedmar	Post-Zedmar	Late Neolithic
stone Dudka			1	3	10	5	10
stone Szczepanki		1	3	12	13	10	5
stone total		1	4	15	23	15	15
flint ground chips					5	11	11
antler-bone		5	12	29	21	5	1

Fig. 4. Stone, flint and antler-bone head tools from Dudka and Szczepanki in periods (graph by W. Gumiński).

multiplied by 100. Similarly, the maximum thickness index (MTI) is the distance from the edge to the maximum thickness of the tool divided by the total length and multiplied by 100. In both indexes a result lower than 50 means that the point of the maximum width or thickness is closer to the working edge than to the butt, and closer to the butt when the result is higher than 50 (Fig. 6).

	Groups				Taxa															
Period	thick slender	thick short	flat short	flat slender	cigar	tongue	kidney	bulgy	lenticular	flat	little	claw	hump hammer	axe-hammer	thick pick-axe	dagger pick-axe	mattock	hatchet	taxa/ no. of tools
Early Mesolithic	1					1													1/1
Late Mesolithic	2	1		1	1	1		1		1									4/4
Early Zedmar	7+1	5		1	2+1	2	2	4		1		1		1	1		1		9/16
Classic Zedmar	9	6	4+1	4		5	1		2+1	4	2	3	1	2	3				9/24
Post-Zedmar	6	1	4	3	3	2	1			2	4		2			1			7/15
Late Neolithic	3	5	4	1		2	1		2	2	2	1		3	1			1	9/15
No. of tools	29	18	13	10	7	13	5	5	5	10	8	5	3	6	5	1	1	1	14/75
% of tools	41%	26%	19%	14%	9%	17%	7%	7%	7%	13%	11%	7%	4%	8%	7%	1%	1%	1%	100%

Tab. 3. Groups and taxa of stone head tools according to periods. Loose finds from Malinka were added by + in the most probable for them period. More frequent occurrences are shaded appropriately darker.

The presumed forms for not fully preserved specimens were reconstructed according to the geometric shape tendency, and then the metric data and indexes were adequately estimated. Similarly, the original mass (weight) was calculated according to the percentage of the preserved length and width. Precisely known data are written in the catalogue in bold and the estimated ones in italics (Tab. 2).

The last parameter – the edge protrusion index (EPI) is calculated as the distance from the top to the base of the edge, divided by the edge wide measured at its base and multiplied by 100 (Fig. 3.B). Almost straight edges will have a low EPI (<15), and more distinctly protuberant edges have at least a two-three times higher EPI (Tab. 4).

The rest of the analysed traits have a descriptive character and include the edge separation from sides – gentle or angular; the shape of both sides – flat, oval, faceted or edge; and the shape of the butt – flat, convex, edge or pointed (Tab. 4). Finally, the kind and colour of rock raw material, manufacturing technique (grinding, pecking, flaking and drilling), the state of preservation and additional manipulation with the tool are noted. The first few columns of the catalogue (Tab. 2) provide documentation data, *i.e.* place, depth and number of find, context and chronology according to the layer or feature in which the tool was found.

The SHT were grouped in the compact catalogue according to the distinguished taxa (type-kind). Each tool has got a subsequent number (#) which is used if needed in the text, and the same number is included in the figure caption of the particular tool.

Characteristics of stone head tools

Each of the 75 SHT was included in one of 14 compound taxa. They will be similarly presented within the appropriate taxon.

'Cigar'-shaped adze-axes (Tab. 2.#1–7, Fig. 9)

'Cigar'-shaped adze-axes in the outline and longitudinal section are 'cigar'- or 'torpedo'-shaped, and the cross-section is basically round. They are clearly oblong (LWI>2) and at the same time 'bulky' tools (WTI<2). This taxon occurs as axes or adzes; in the case of axes the edge is symmetric in plane, while in adzes it is set asymmetrically closer to one side.

The collection comprises seven such specimens. One is almost whole with a broken off edge, the next two were adapted into pestles, another two are back-halves, and they are also a fragment of a trunk and butt. They appeared in different places: at the Dudka interior (trench IX, two items), at the post-Zedmar settlement (trench IV) and on the main cemetery. Two finds came from the shore zone at Szczepanki and one from Malinka.

They are 'cigar'-shaped and nearly round in cross-section, so they keep triple symmetry as axes. However, the cutting edges are not preserved, so they could be equally oblique from both walls, as in axes, or slant from one side like in adzes. Probably the second case applies to the best preserved specimen (#1, Fig. 9.a).

These tools are markedly slender and thick; the length is nearly three-times greater than the width (LWI=2.9–3.0), and the width is only slightly bigger than the thickness (WTI=1.1–1.2) (Fig. 5). The maximum width can be set closer to the edge, just before the half, or in the back part of the tool (MWI=30, 45 or 70), and the maximum thickness is usually situated around the

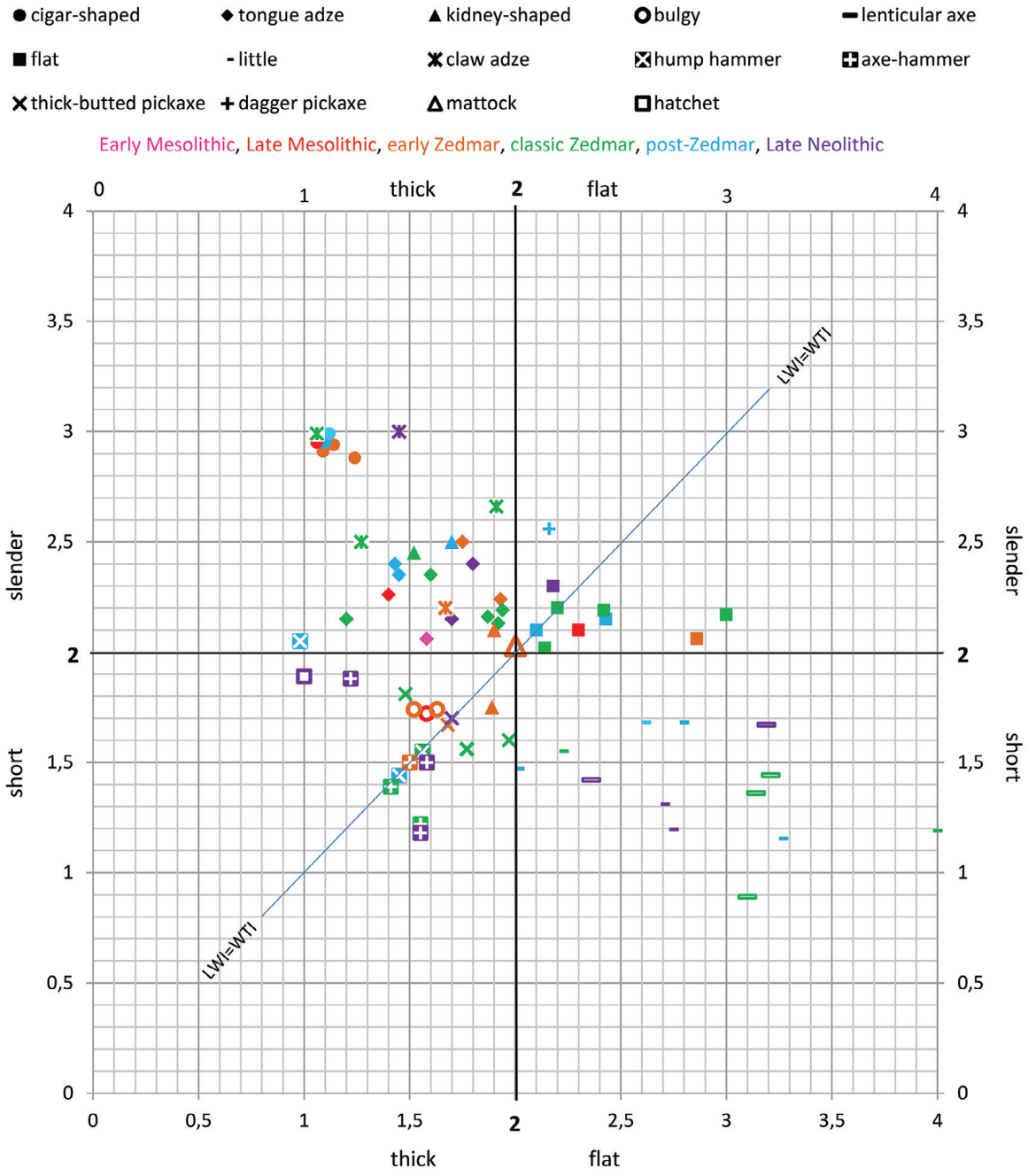


Fig. 5. Slenderness and flatness of stone head tools (graph by W. Gumiński).

middle of length (MTI=45–50) (Fig. 6). In two cases the maximum width and thickness are set just at the same distance from the edge (MWI and MTI=70 and 45). The trunks are completely rounded, so sides and walls are practically indistinguishable. Butts are convex or flat.

Period		Edge protrusion				Edge separation from trunk sides			Form of sides* both the same/ only one side				Shape of butt			
		EPI <15	EPI 15-29	EPI 30-50	EPI >50	gentle 2 sides	gentle/ angular	angular 2 sides	oval	flat	edge	faceted	convex	edge	flat	pointed
Early Mesolithic									-/1	-/1			1			
Late Mesolithic				2		2			6/-	2/-			1	1	1	
Early Zedmar			1	6	1	6	2		14/2	6/2	-/2	2/-	7	4	4	
Classic Zedmar			7	8	4	11	8		4/4	16/5	8/5	2/4	3	12	7	
Post-Zedmar		1	3	3	1	6	1	2	6/3	14/2	2/1	-/2	3	4	7	1
Late Neolithic		5	4	1			2	8	4/3	14/2	2/2	-/1	2	3	7	2
Total		6	15	20	6	25	13	10	34/13	52/12	12/10	4/7	17	24	26	3

Tab. 4. Stylistic traits of stone head tools according to periods: the edge protrusion and separation, form of sides and butt. More common forms are adequately shaded darker. * Two sides were counted for each tool, so the number of sides is two times higher than the number of tools.

'Cigar'-shaped adze-axes are middle-sized tools measuring 7 to 11cm in length (Fig. 7). Their mass ranges from *c.* 50 to 230g (Fig. 8). They are made of sandstone and only one specimen is made of gneiss (Tab. 5, available online as supplementary file at http//doi.org/10.4312/dp.52.17). They were made by pecking and fully ground. Two items, probably after damage, were changed into pestles (Fig. 9.d-e).

This taxon is generally considered as typical for the Late Mesolithic, including the Ertebølle culture, and at least three of the presented tools confirmed a similar age, although the next three are younger, dated to the post-Zedmar (Tab. 3).

'Cigar'-shaped adze-axes were quite common in south Scandinavia up to central Sweden and south-east Norway (*Jørgensen 1956.Fig. 5.1; Lund Hansen* et al. *1972; Larsson 1978.128; Knutsson* et al. *1999.102; Nielsen 2001.86; Bengstsson 2003.Fig. 51.3; Sørensen S. A. 2007.184; 2017.54–56; Carlsson 2008.233–241; Nicolaisen 2009.854; Faxholm 2020.9–10,27–29; Reitan 2022.Fig. 12*). Further to the west in western Norway and the Netherlands they are less frequent (*Fokkens 1998.93–94; Raemaekers 1999.102–106; Bergsvik, Olsen 2003*). In north-eastern Germany they are definitely the dominant type of any adze-axes, since *c.* 250 such tools are known in this area (*Gramsch 1973.29–31; Hartz 1998.Fig. 25; Goldhammer* et al. *2012.Figs. 10–12*). Interestingly, just east of the Oder River, in the Polish Lowland, they are very rare, and only a few examples are known (*Smoczyńska 1953.Figs. 39,215; Rajewski 1958.23; Kobusiewicz 1970.123, Pl. 35.2; Prinke, Wiślański 1972.Figs. 24.6, 49.7; Grygiel 1973.Fig. 2.12; Ilkiewicz 2005.Figs. 11, 12*). Yet they still occur in Masuria and Prussian Lowland (*Gaerte 1929.Figs. 11a,b,12a,b; Okulicz 1973. Figs. 26i,33a,b,35d; Pawłowski 1999.Fig. 8b; Zalcman 2010.Fig. 28*), and the north-eastern extension of this taxon reaches the lower Neman and Neris rivers in south and west Lithuania (*Bagušienė, Rimantienė 1974.Fig. 16.7, Map 19; Rimantienė 1984.Fig. 109.1; 2016.203–204, Figs. 163.1,2; Girininkas 2018.Fig. 4*).

'Tongue'-shaped adzes (Tab. 2.#8–20, Figs. 10–12)

'Tongue'-shaped adzes are usually wider near the edge and gently taper toward the butt, although they can be thickest and widest in the back part. The longitudinal and cross-section is flatly-convex, roughly D-shaped. The edge is moved toward the lower flattened wall, typical for adzes (Fig. 3.B). They are slender and thick tools (LWI>2 and WTI<2).

This is the most numerous taxon, comprising 13 specimens (Tab. 3). One of them is entirely preserved (#8, Fig. 10.a), four are partly damaged at the cutting edge (#9–12), one is heavily corroded from the bottom wall and six are back-halves. Six 'tongue'-shaped adzes were found at the Dudka cemetery, four in the shore zone at Szczepanki, and three at encampment areas at both sites.

'Tongue'-shaped adzes are usually wider in the front part of the tool (MWI=32–48) and thicker at the back (MTI=52–82), although some exceptions occur (Fig. 6). In three cases the maximum width and thickness are the same distance from the edge (LWI=WTI=40 or 80), and in the next two they are placed conversely, *i.e.* the distance of maximum width from the edge is just like the maximum thickness from the butt (MWI and MTI=34 and 66 or 48 and 52) (Fig. 6). All these tools are flatly convex in the cross-section and in the side view. They are moderately slender (LWI=2.1–2.5) and fairly thick (WTI=1.2–1.95) (Fig. 5). The cutting edges gently turn to the trunk and the edge protrusion is distinct (EPI=30 to 45) (Tabs. 2,4). The sides of the trunk are flat, oval or faceted and can be variously

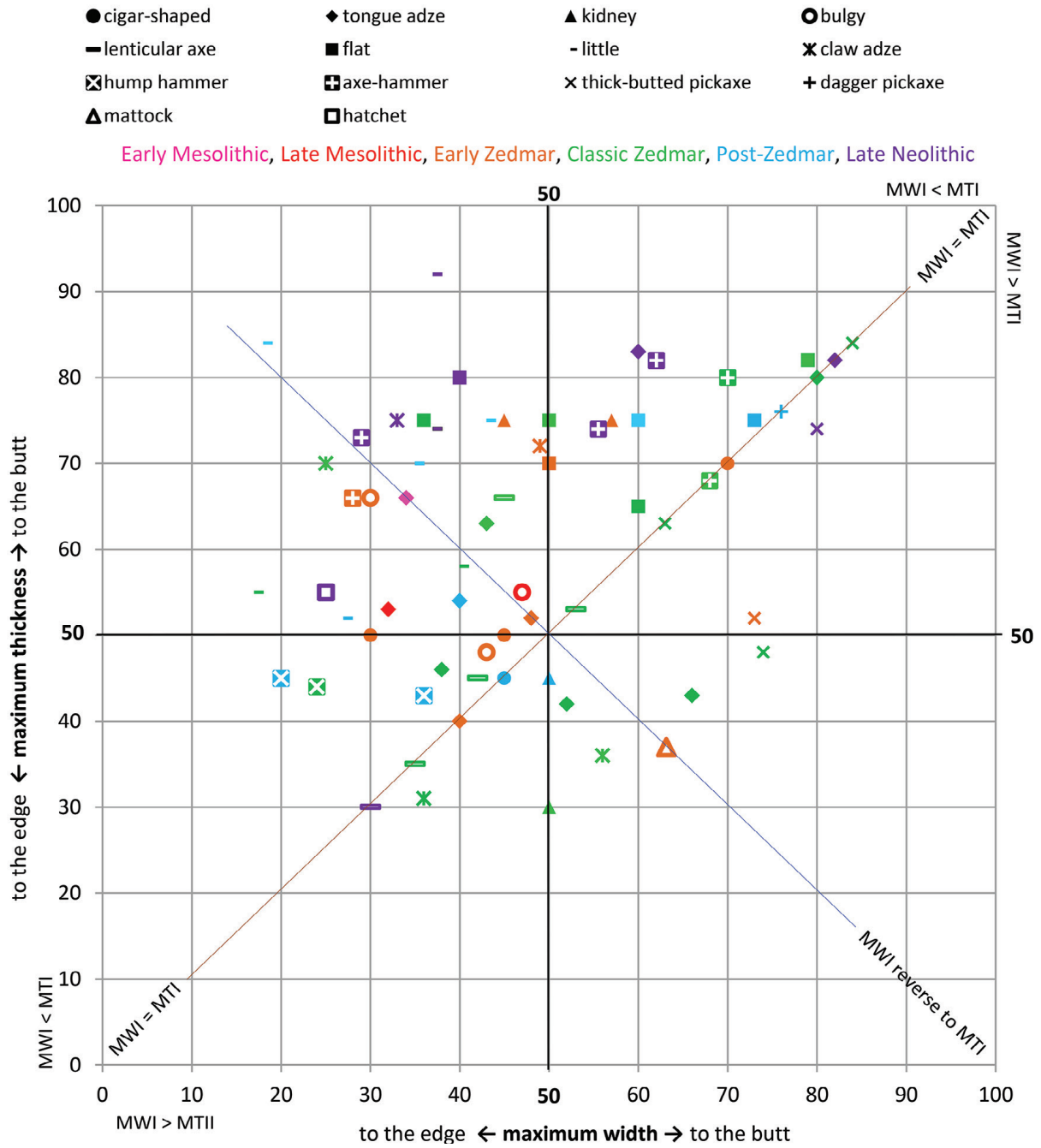


Fig. 6. Maximum width and thickness of stone head tools toward the edge (graph by W. Gumiński).

fashioned on the same specimen. The butts are convex, edge or flat (Tabs. 2,4).

The diameters and masses of the 'tongue'-shaped adzes are evenly spread between 9.5 and 14cm and from 170 to 415g, respectively (Figs. 7,8). However, one intact specimen (#8) is significantly small and light, at 6.8cm long and 54g (Figs. 7,8,10.a). They were made of various kinds of rocks, mainly metamorphic, particularly gneisses, but also sandstone, granite and trachyte, which have a variety of grains and technical features (Tab. 5). The rocks are also varied in colour. Eight specimens are made of moderately grey stones, whereas five are from rocks of other shades: yellowish, reddish, greenish and black (Tab. 5). All these tools were ground, but pecking and flaking are also visible. Five 'tongue' adzes were probably purposely destroyed, one was reshaped, and three were changed into hand-stones (Tab. 2).

'Tongue'-shaped adzes are the oldest form, since they already appeared in the Early Mesolithic and occurred up to the Late Neolithic, although they were most numerous in the classic Zedmar period (Tab. 3).

'Tongue'-shaped adzes correspond to the Lihult-Nøstvet type, which are considered as the oldest type in Southern Scandinavia, occurring from the Early Mesolithic to the end of the Mesolithic (*Althin 1954; Lindgren, Nordquist 1997; Kindgren, Schaller Åhrberg 1999; Knutsson* et al. *1999; Nordqvist 1999; Bengtsson 2003; Bergsvik, Olsen 2003; Nicolaisen 2009; Glørstad 2011; Sørensen S. A. 2017.54; Reitan 2022; Guinard, Sundström 2023*). It should be noted that similar adzes, but with pointed butts, are common also in the Danubian Neolithic, particularly in the Rössen and Brześć Kujawski cultures (*Smoczyńska 1953; Grygiel 1976.102–114; Wiślański 1987; Merkel 2000.Fig. 3; Pétrequin, Rzepecki 2016*).

'Kidney'-shaped adze-axes (Tab. 2.#21–25, Fig. 13)

'Kidney'-shaped adze-axes can be distinguished based on the outline, with one side concave or straight and the opposite side being convex. The thicker part of the tool usually corresponds with the convex side and the thinner with the concave. The asymmetric outline and sections hinder the assignment of them to axes or adzes. Possibly, these tools were set obliquely with the helve, *i.e.* intermediately between axe and adze.

To this taxon belong five tools, of which three are almost whole. They are slightly slender or short, since LWI varies between 2.5 and 1.8 (Fig. 5). The maximum

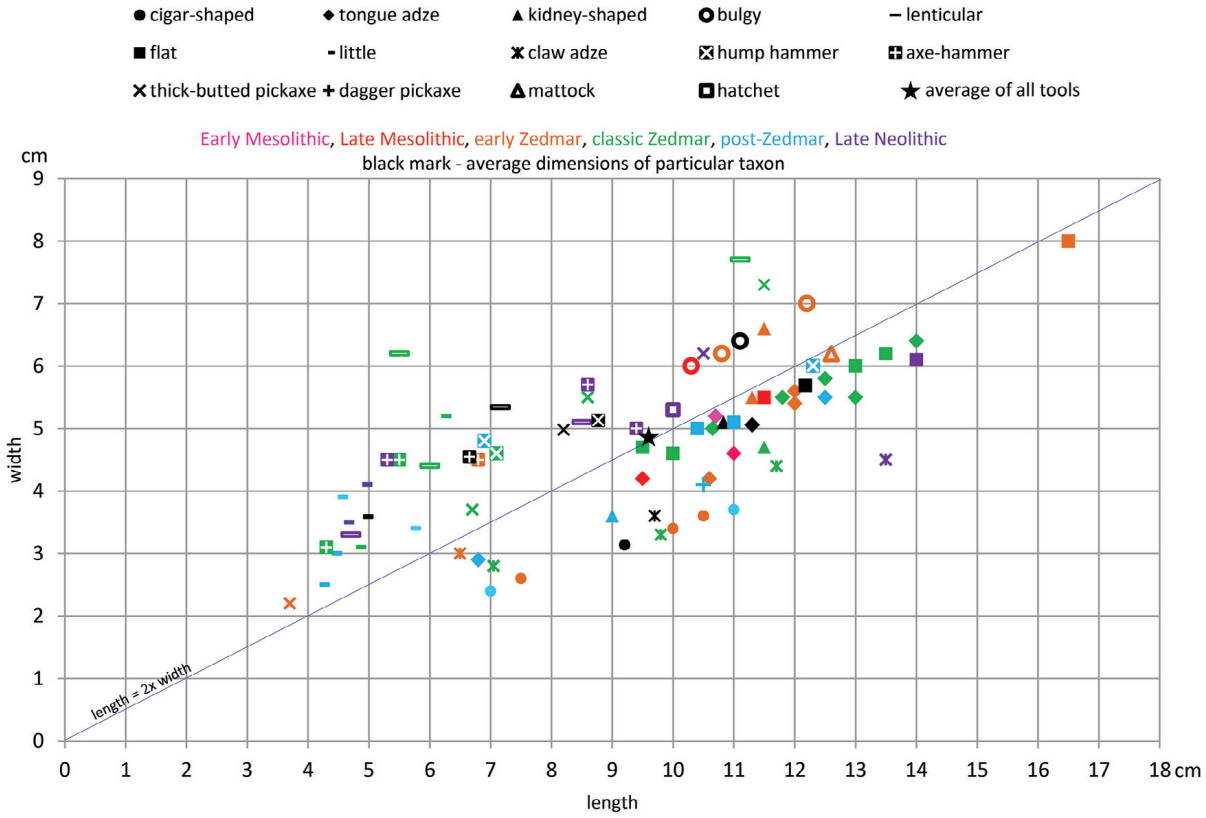


Fig. 7. Length-width diagram of stone head tools (graph by W. Gumiński).

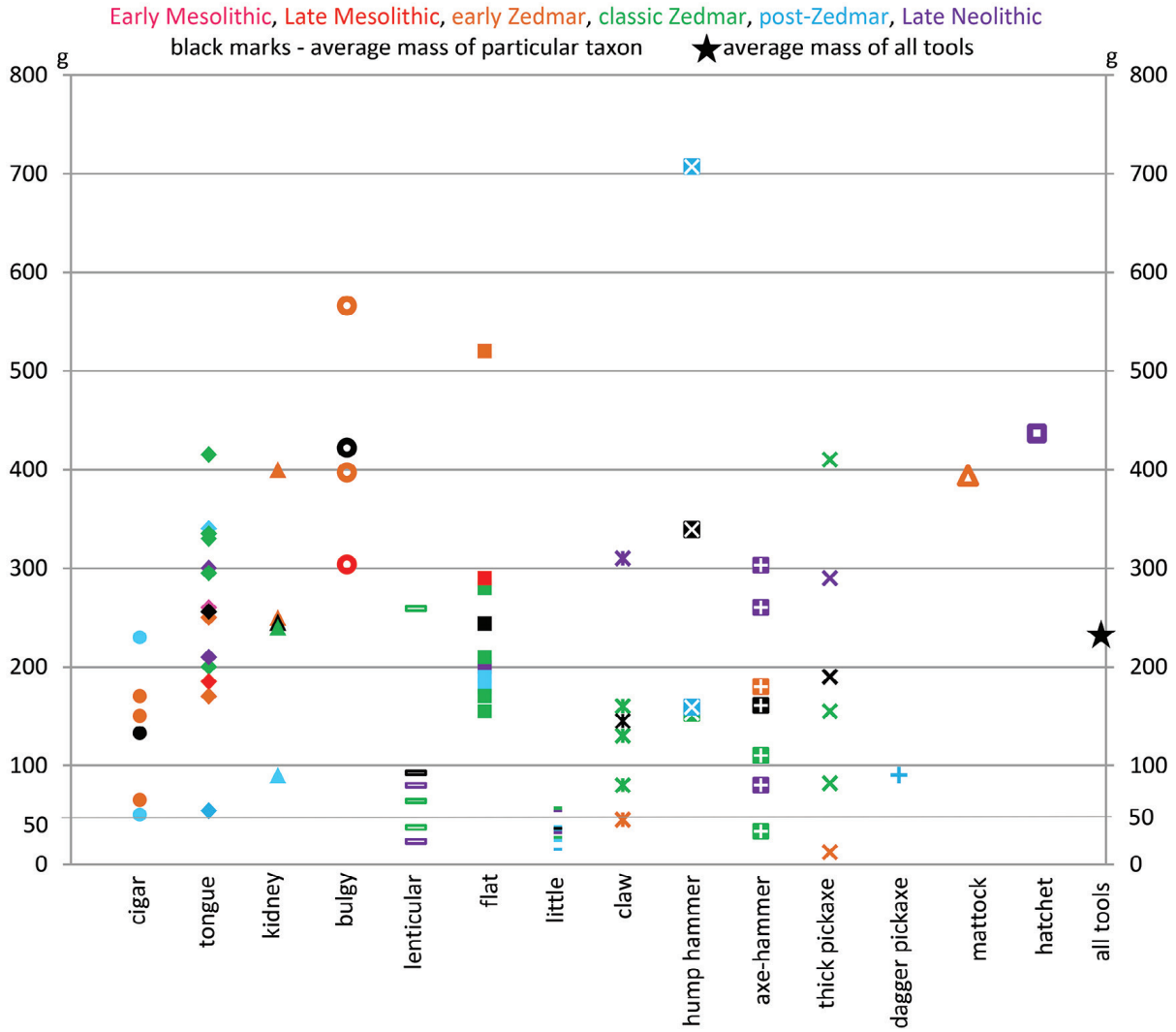


Fig. 8. Mass of stone head tools (graph by W. Gumiński).

width falls near half of the length (MWI=45–57) (Fig. 6), whereas the position of the maximum thickness considerably varies from the front to the back part of the tool (MTI=30–75) (Fig. 6). The edges are well protruding (EPI=28–43) and at least from the convex side turn gently to the trunk. The form of each side varies with each particular specimen, and can be edged, faceted, oval and flat. Butts are edged (Tabs. 2,4).

'Kidney'-shaped adze-axes are moderate in size, with a length of 9–11.5cm and width of 3.6–6.6cm (Fig. 7). The mass is more diverse, one specimen is below 100g, two are within the average range (240–250g) and one is heavy, as *c.* 400g (Fig. 8). They were made of very different kinds of rock, from the soft and easy to work siltstone, intermediate gneiss, metasandstone and greenschist, to the very hard and difficult to work quartzite (Tab. 5). The last specimen (#23) was almost completely re-worked or damaged by pecking, but small scraps of polishing still exist at the upper wall. In contrast, the bottom flat wall is generally natural, though it could be slightly ground (Fig. 13.b).

'Kidney'-shaped adze-axes were found in the lake shore and at the settlement at Szczepanki, and a chip of an edge appeared at the periphery of the Dudka settlement. They occurred from the early Zedmar to the Late Neolithic (Tab. 3).

Similar tools have been attributed by Faxholm to the type 4 and Bb or H of the Limhamn axes (*Faxholm 2020.30–31,135*). Apart from Denmark they appeared at the Strandvägen site in eastern central Sweden, at Schipluiden in the Netherlands, at Rzucewo and Nida on the south-east Baltic coast, and also at the Zedmar culture site Utinoe Boloto in the Prussian Lowland *(Żurek 1954.Fig. 32; Timofeev 1998.Fig. 4.29; Carlsson 2008.234,375–378; van Gijn, Houkes 2013.Figs. 8. 9–10; Rimantienė 2016.Fig. 162.3*). Such tools are reported from a wide range of areas, although they are

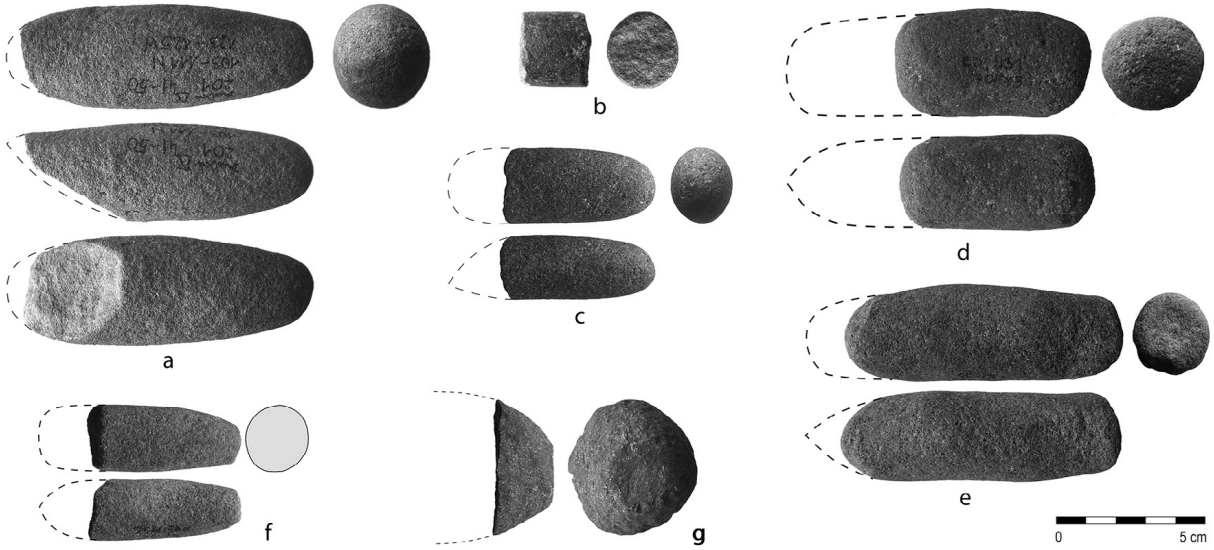


Fig. 9. 'Cigar' shaped adze-axes: **a(#1)*** ***Dudka, early Zedmar;*** **b(#2)** ***Dudka, Late Mesolithic;*** **c(#3)** ***Malinka, early Zedmar (?);*** **d(#5)** ***Szczepanki, early Zedmar;*** **e(#6)** ***Szczepanki, post-Zedmar;*** **f(#4)** ***Dudka, post-Zedmar;*** **g(#7)** ***Dudka, post-Zedmar (photos by K. Bugajska, W. Gumiński). * The codes correspond to the numbers in the catalogue (Tab. 2), see supplementary file at http//doi.org/10.4312/dp.52.17).***

not common. On the other hand, distinct 'kidney'-shaped adze-axes, but made of flint, occurred more often than stone ones (*e.g., Gramsch 1973; Sørensen S. A. 2017.Fig. 22*).

'Bulgy' axes and adzes (Tab. 2.#26–30, Fig. 14)

'Bulgy' axes and adzes are short and thick (LWI and WTI <2), so they are generally 'bulky' tools with an oval cross-section and convex walls and sides.

This taxon is represented by three intact specimens and two fragments of butts. All five items come from the shore zone, one from Dudka and four from Szczepanki.

Bulgy tools have very similar indexes of LWI (1.72–1.74) and WTI (1.52–1.63) (Fig. 5). Most specimens are oval in outline, but one is slightly narrowed after half of the length the tool (Fig. 14.c). Two examples with a flattened bottom wall represent adzes (Figs. 14.b-c), whereas at least one reveals triple symmetry like an axe (Fig. 14.a). The maximum width falls before the half of length (MWI=30–47) and the maximum thickness is in the middle or in the back part of the tool (MTI=48–66) (Fig. 6). The edges are well protruded (EPI=29–40) and gently turn to the trunk. Butts are flat or convex.

The length of these tools ranges within average dimensions (10.3–12.2cm), but the width is relatively greater (6–7cm) than seem with the other tools (Fig. 7). They are rather heavy, at 300g to 400g, and one even weighing 565g (#28), which is the second heaviest tool in the whole collection (Fig. 8). 'Bulgy' axes-adzes were made of gneisses, amphibolite and diorite, of which some exhibit greenish or bluish shades (Tab. 5). Three axes were thoroughly polished, whereas two adzes were made using the pecked technique (Fig. 14).

Bulgy forms correspond with the Limhamn axes regarding the overall shape, proportions and usually exhaustive polishing. At Dudka and Szczepanki they occurred only in the Late Mesolithic and early Zedmar, when they prevailed (Tab. 3). Their chronology agrees well with the age of Limhamn axes, which are generally related with the Late Mesolithic, including with the Ertebølle culture (*Jenbert 1984.102–105; Vang Petersen 1984; Nordqvist 1999.249–250; Carlsson 2008. 240–241; Nicolaisen 2009; Faxholm 2020*). In fact, the bulgy type already appeared in the early Boreal of the Early Mesolithic (*Gramsch 2000.Fig. 16:1*).

'Lenticular' axes (Tab. 2.#31–35, Fig. 15)

'Lenticular' axes are distinguished by the round arris going through the cutting edge, both sides and a butt. They are generally oval in outline and thin lenticular both longitudinally and in cross-sections.

The assemblage contains five entirely preserved specimens. They come from the Dudka cemetery, shore at Szczepanki and from Malinka.

'Lenticular' axes are distinctly short and flat (LWI=0.9–1.7 and WTI=2.4–3.2), so they are opposite to the 'cigar'- and 'tongue'-like taxa (Fig. 5). The maximum

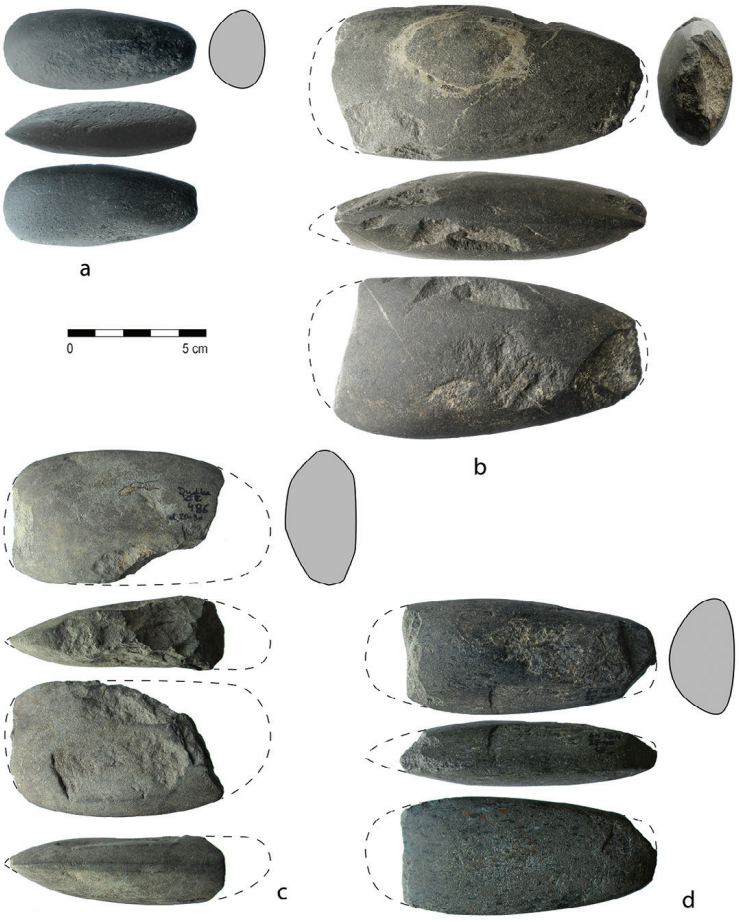


Fig. 10. 'Tongue' shaped adzes: **a(#8)** ***Dudka, post-Zedmar;*** **b(#10)** ***Dudka, classic Zedmar;*** **c(#11)** ***Dudka, classic Zedmar;*** **d(#9)** ***Dudka, early Zedmar (photos by K. Bugajska, W. Gumiński).***

width falls before or near half of the length (MWI=30–53) and the maximum thickness occurs in a wider range (MTI=30–66) (Fig. 6). In three cases both maxima appear just at the same distance from the edge (MWI=MTI), which rarely happens within local SHT (Fig. 6). The cutting edges are well protruded (EPI=26–38) and turn evenly to the trunk.

'Lenticular' axes are rather small (4.7–8.5cm in length) and markedly light (23–80g). Only one specimen (#31) is significantly bigger (11.1x7.7cm) and heavier (260g) than the others (Figs. 7,8). They were mainly made of schistous metamorphic rocks by pecking and flaking, and not grinding, although three examples are substantially eroded. Only one specimen (#35) was made of a flake of reddish Jotnian sandstone and then ground (Fig. 15.e, Tab. 5).

'Lenticular' axes are one of the youngest taxa occurring in the classic Zedmar and the Late Neolithic (Tab. 3). Axes with a thin lenticular profile are included in Faxholm's monograph as the type 3 of Limhamn axes, but most of the presented examples are slenderer than our tools (*Faxholm 2020.30–31, Figs. 23,24*). Besides, a 'lenticular' axe is known from the Nida site of the Rzucewo culture in western Lithuania (*Rimantienė 2016.Fig. 162:6*).

'Flat' adze-axes (Tab. 2.#36–45, Figs. 16,17)

'Flat' adze-axes are flat and slender (LWI and WTI >2) of roughly rectangular outline and cross-section.

This is the second most common taxon, containing 10 specimens (Tab. 3). They are mainly axes and at least three adzes. One of them is almost whole (Fig. 16.a) and another (Fig. 17.e) was mended by grinding at the front part. Other examples are preserved in halves or only as part of a butt. They were found in different contexts – at the shore and campsite at Szczepanki, at the Dudka cemetery and in the Dudka periphery.

These tools are moderately slender (LWI= 2.0–2.3), although their flatness is of wide range (WTI=2.1–3) (Fig. 5). They are slightly trapezoidal or oval-rectangular in outline and roughly flattened-rectangular in cross-section. The position of maximum width varies significantly (MWI=36–79), but in most cases it falls near the half of length (MWI=40–60). The maximum thickness is set clearly in the back part of the tool (MTI=65–82) and further from the edge than the maximum width (MWI<MTI) (Fig. 6). The sides are mainly flat and butts are edged, flat or convex (Tab. 2).

The best preserved specimen (#36) is almost plain and symmetric in the side view, although its cutting edge (purposely blunt) was clearly moved down to the flat bottom wall, as in an adze (Fig. 16.a). Its upper wall is slightly concave in the middle, so the maximum thickness appears in two spots – at one and three quarters of the total length, and the latter position is typical for this taxon (Fig. 6, Tab. 2).

'Flat' adze-axes are rather long and mostly range from 9.5–14cm, with a moderate mass of 170–290g (Figs. 7,8). Only one specimen (#40, Fig. 17.a) was distinctly bigger and heavier, calculated at 16.5x8cm and *c.* 520g, which makes it the longest and the widest tool in

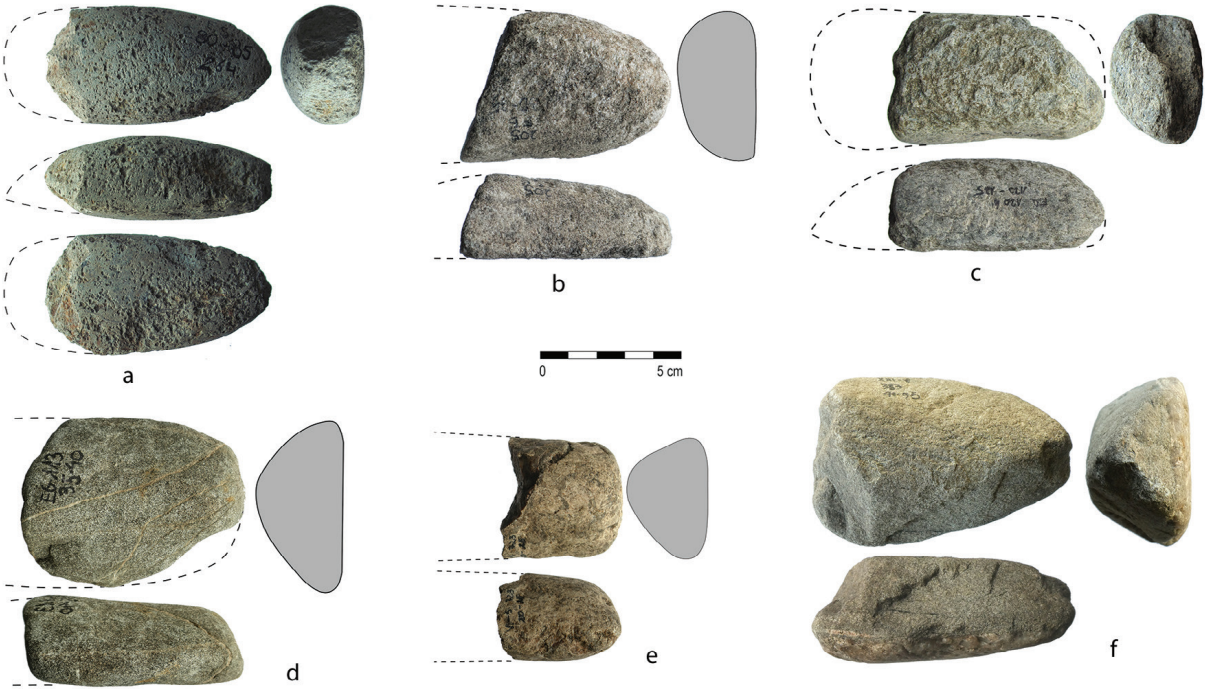


Fig. 11. 'Tongue' shaped adzes: **a(#12)** ***Szczepanki, Late Mesolithic;*** **b(#14)** ***Szczepanki, early Zedmar;*** **c(#13)** ***Szczepanki, Early Mesolithic;*** **d(#15)** ***Szczepanki, classic Zedmar;*** **e(#20)** ***Dudka, post-Zedmar;*** **f(#16)** ***Dudka, classic Zedmar (photos by K. Bugajska, W. Gumiński).***

the whole collection, and the third heaviest (Figs. 7,8). 'Flat' adze-axes were made of an exceptionally varied selection of rocks, from soft and workable siltstone or friable sandstone, through fine grained and dense rocks like greenschist, diabase or metasandstone, up to very hard crystalline quartzite (Tab. 5). The colours of stones also varied considerably, including yellow-beige, greenish, bluish, grey and almost black (Tab. 5). All the tools were ground, although partly and rather roughly.

'Flat' adze-axes occurred from the Late Mesolithic until the Late Neolithic, but they were most numerous in the classic Zedmar (Tab. 3). The adze (#45) from the grave VI-13 is dated by cremated bones to 4832±24 BP (3651–3529 cal BC, GrM-29989) (*Bugajska 2023*).

'Flat' adzes-axes in southern Scandinavia and the Middle European Plain are less common than other types, but certainly occurred in the Mesolithic there (*Althin 1954.38, Pl. 11.3; Hartz 1998.Fig. 25.2; Carlsson 2008. Figs. 49a-b; Nicolaisen 2009.855; Goldhammer* et al. *2012.Fig. 13; Verhart 2012.Fig. 1; Grünberg* et al. *2016. 296–297; Sørensen S. A. 2017.54–55; Faxholm 2020; Guinard, Sundström 2023.Fig. 8*). However, some authors assumed that such tools are imports from the Early Neolithic Danubian ecumene, even though they do not have any special traits which indicate a Neolithic origin, and the sites where they were found have not yielded any additional evidence to supporting such connections (*Kotula 2011.284–286; Galiński 2022*). On the other hand, similar adze-axes occurred within the Danubian cultures, so distinguishing Mesolithic from the Neolithic ones is problematic (*Smoczyńska 1953; Grygiel 1976; Merkel 2000; Ilkiewicz 2005; Verhart 2012*). Besides, 'flat' adze-axes were quite common in the eastern Baltic countries from the Mesolithic

Fig. 12. 'Tongue' shaped adzes: **a(#17)** ***Dudka, Late Neolithic;*** **b(#18)** ***Dudka, classic Zedmar;*** **c(#19)** ***Szczepanki, Late Neolithic (photos by K. Bugajska, W. Gumiński).***

until the Late Neolithic (*Jaanits 1959. Figs. 24,25; 1965.Fig. 10; 1968.Fig. 6; 1984.Fig. 3; Loze 1979.Pls. 10–13; 1988. Pls. 30–32; Matiskainen 1988; 1989.Fig. 15; Girininkas 1990.Figs. 78–81; Timofeev 1996; Zalcman 2010.Figs. 21–24; Rimantienė 2016.196–198, Figs. 157, 158; Butrimas 2019.Figs. 5,6*).

'Little' adze-axes (Tab. 2.#46–53, Fig. 18)

'Little' adzes and axes are short and flat (LWI<2 and WTI >2), and distinctly small and light. They are usually trapezoidal or rectangular in outline and roughly flat rectangular in cross-section. It should be stressed that small dimensions are not enough for assigning a particular tool to this taxon, since among other taxa also have similarly small specimens.

This taxon is represented by eight practically whole specimens, of which five are adzes and three are axes. They were found at the Dudka cemetery, at Szczepanki settlement and in the littoral zone there.

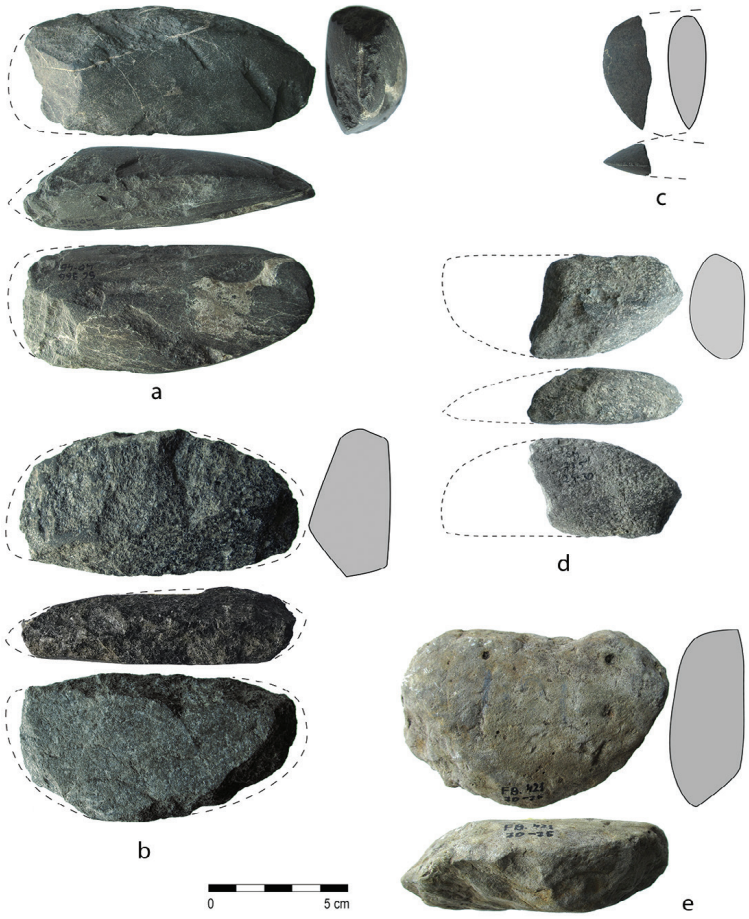


Fig. 13.'Kidney' shaped adze-axes: **a(#21)** ***Szczepanki, classic Zedmar;*** **b(#23)** ***Szczepanki, early Zedmar;*** **c(#22)** ***Dudka, Late Neolithic;*** **d(#25)** ***Szczepanki, post-Zedmar;*** **e(#24)** ***Szczepanki, early Zedmar (photos by K. Bugajska, W. Gumiński).***

These tools are markedly short and flat, LWI=1.15–1.7 and WTI=2–4 (Fig. 5). The maximum width is placed in the front part of the tool (MWI=17–43), while the maximum thickness falls distinctly in the rear part or around the middle (MTI=70–92 or 52–58) (Fig. 6). The protrusion of cutting edges varies markedly and can be almost straight (EPI=7–8), moderate (EPI=21–25) or well developed (EPI=33, 42) (Tab. 2,4). The edges turn to the sides angularly or gently, while the sides and butts are in most cases flat (Tab. 2).

All specimens of this taxon are indeed small, between 4.2 and 6.2cm long, and very light, from 15 to 55g (Figs. 7,8). Most of them were made of dark dense rocks like amphibolite, diorite and andesite, and they are carefully polished, although two items are from yellow-beige limestone and are carelessly made (Fig. 18.f-g, Tab. 5).

Two specimens clearly stand out from the rest. One of them is an adze (#50) with a hexagonal outline of which three sides make the trapezoidal cutting edge (Fig. 18.h). The back half of the upper wall was thinned by a flat flake chipped-off from the butt. As a result a curved threshold appeared running across the centre and roughly parallel to the base of the cutting edge. This was a secondary treatment, since some polished spots on the upper wall near the butt remained. The thinning was certainly desirable for fastening the adze in a narrow chink of the helve, because the threshold prevented perforating the shaft during a blow.

The other exception is the axe (#53) of which the edge is extraordinarily bilaterally extended and the trunk is distinctly narrow with a square cross-section (Fig. 18.g). A similar form made also of limestone with a clearly fan-shaped extended edge and narrowing trunk was found in the Pitted Ware Kainsbakke site on east Jutland. However, it is in part perforated so that it resembles a hatchet, but it has been interpreted as a non-finished bead. It is *c.* 4cm long (*Wincentz 2020.110–111*), so 1.5cm less than the example from Szczepanki. Both items are similarly dated.

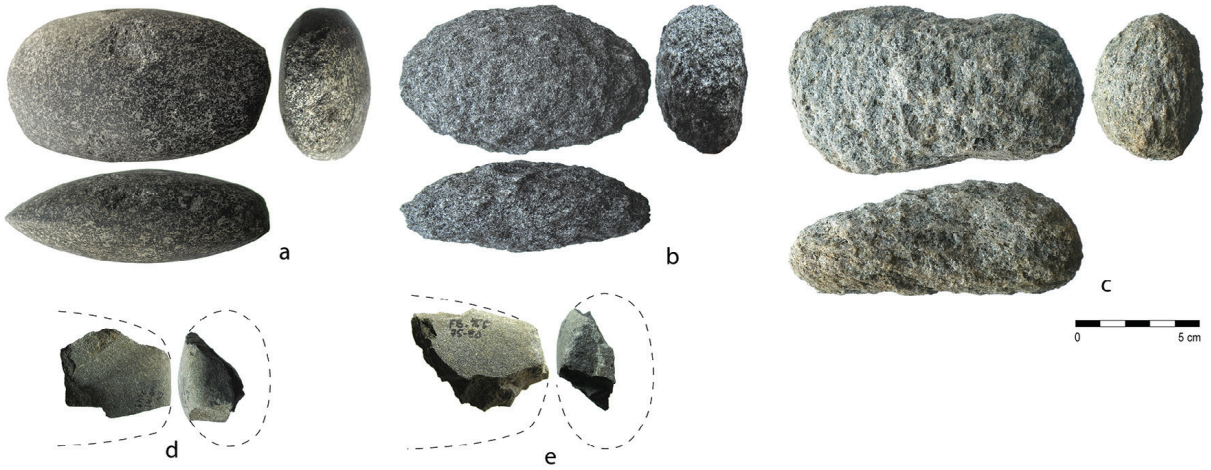


Fig. 14. 'Bulgy' adzes and axes: **a(#26)** ***Szczepanki, early Zedmar;*** **b(#27)** ***Szczepanki, Late Mesolithic;*** **c(#28)** ***Dudka, early Zedmar;*** **d(#29)** ***Szczepanki, early Zedmar;*** **e(#30)** ***Szczepanki, early Zedmar (photos by K. Bugajska, W. Gumiński).***

'Little' adze-axes occurred from the classic Zedmar until the Late Neolithic, but they were most common in the post-Zedmar period (Tab. 3). The lime axe (#52, Fig. 18.f) from the grave VI-6 is dated by cremated bones at 4999±26 BP (3940-3657 cal BC, GrM-29984) (*Bugajska 2023*).

'Little' adzes or axes are rather scarce in the Mesolithic of middle-north Europe (*Boas 2001.Fig. 12; Flaxholm 2020.106,110,115,136,173*). Instead, they were quite common in the east Baltic countries from the Mesolithic to the Late Neolithic, and often occurred together with 'flat' adze-axes (*Żurek 1954.Pl. XIV.1–18; Jaanits 1959. Figs. 26–30; 1965.Fig. 10; 1984.Fig. 3; Loze 1979.Pls. 14,15; 1988.Pls. 32–34; Matiskainen 1988.Pls. 1–6; Girininkas 1990.Fig. 77; Rimantienė 2005.Figs. 101, 262; 2016.195–200, Figs. 157–159; Zalcman 2010.Figs. 22,23; 2014.Fig. 2; Butrimas 2019.Figs. 5,6*). However, 'little' adzes or axes became particularly numerous in the later periods of the Stone Age, and according to this trend they appeared mainly in the later stages of the Zedmar culture (*Timofeev 1996.Figs. 51.32,33*). On theother hand, similar miniature forms also occurred in the Danubian Neolithic (*Smoczyńska 1953; Grygiel 1976; Merkel 2000*).

'Claw'-like adzes (Tab. 2.#54–58, Fig. 19)

'Claw'-like adzes are slender and thick (LWI >2 and WTI<2), with an elongated cuboidal shape and square or rectangular cross-section. Additionally they are somewhat bent in the side view, because the lower wall is slightly concave or flat and the upper wall convex. The working edge is set down to the lower wall. As a result the tool resembles a thick claw.

This taxon contains five pieces, four are almost whole and one is a back-half. They were found at the Dudka cemetery and in the shore zone at Szczepanki.

'Claw'-like adzes are slender and thick, the LWI ranges from 2.2 to 3.0 and WTI from 1.1 to 1.9 (Fig. 5). The working edges are relatively massive and blunt, and butts are flat or edged. A specific trait of these tools is that at least one side is exactly flat and set vertically to both walls (Fig. 19). The maximum width occurs closer to the edge (MWI=25–36) or near the half of length (MWI=49–56), whereas the maximum thickness falls in the front part of the tool (MTI=31–36) or clearly in the back (MTI=70–75) (Fig. 6).

The length and mass of 'claw'-like adzes vary significantly, from 6.5 to 13.5cm and from 45 to 310g, respectively (Figs. 7,8). They are mainly made of gneiss, in one case of sandstone, and they are entirely ground. One specimen (#58) is made of quartzitic metasandstone and was worked exclusively with flaking (Fig. 19.b, Tab. 5).

It is worth noting that 'claw'-like adzes are partly comparable to the 'cigar'-shaped tools, due to their similar proportions, *i.e.* slenderness and thickness (Fig. 5), diameter and mass (Fig. 7,8), as well as generally light rocks being used for both taxa (Tab. 5), while they also chronologically complement each other (Tab. 3). It seems that at least some of them could be used as earth tools, since two 'cigar'-shaped tools (#1 and 2) were found in the interior of Dudka island, where flint, rocks, ochre and lime were obtained, and two 'claw'-like adzes from the Dudka cemetery (#54,55) could be good tools for digging graves.

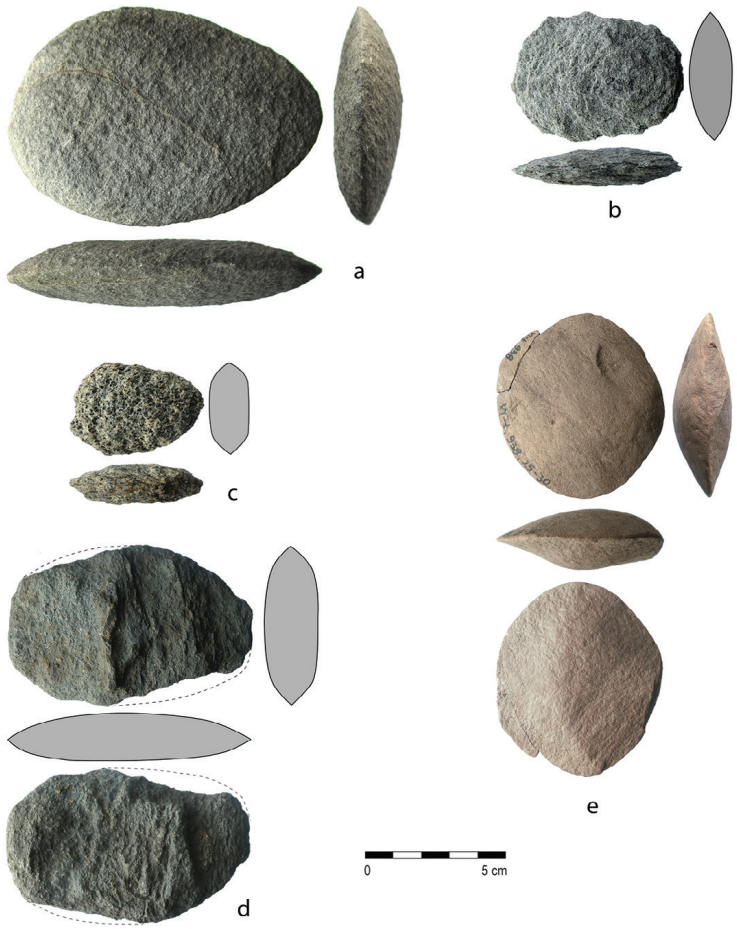


Fig. 15. 'Lenticular' axes: **a(#31)** ***Malinka, Zedmar (?);*** **b(#32)** ***Szczepanki, classic Zedmar;*** **c(#33)** ***Szczepanki A, Late Neolithic;*** **d(#34)** ***Dudka, Late Neolithic;*** **e(#35)** ***Dudka, classic Zedmar (photos by K. Bugajska, W. Gumiński).***

'Claw'-like adzes occur from the early Zedmar to the Late Neolithic, but most are from the classic Zedmar (Tab. 3). One of them (#55) from a grave (VI-1) is radiocarbon dated at 4772±26 BP, 4730±40 BP and 4690±40 BP (3636-3519 cal BC, GrM-29981, Ki-5720, Ki-5718) (*Gumiński 1999; Bugajska 2023*).

'Claw'-like adzes occur in the Late Mesolithic in east central Sweden and eastern Norway. They are distinctly slender, of roughly square cross-section with a slightly concave or wavy bottom wall (*Ahlbeck, Gill 2010.Fig. 3; Glørstad 2010.Fig. 9.1.10*).

'Hump' hammers (Tab. 2.#59–61, Fig. 20)

'Hump' hammers are distinguished by clearly blunt working ends and the presence of a distinct hump set before the half of length on the upper wall. In contrast, the bottom wall is totally flat.

This taxon is represented by three entirely preserved specimens. All come from the shore zone at Szczepanki and are dated to the classic and post-Zedmar periods (Tab. 3).

One tool (#59, Fig. 20.c) is slightly slender (LWI=2.05) and markedly thick, and is even slightly thicker than wider (WTI=0.98) (Fig. 5). Two other hammers (#60–61) are short and thick, and the length is longer than the width in the same proportion as the width toward the thickness (LWI=WTI=1.55 or 1.45) (Fig. 5). The maximum width and thickness are in the front part of the tool (MWI=20–36 and MTI=43–45) (Fig. 6). Blunt working ends are distinctly protruded (EPI=28–39) and gently turn to flat sides. Butts are convex (Tab. 2).

It is interesting that two 'hump' hammers are relatively small and very similar in length (±7cm) and mass (153–157g), and they were found at Szczepanki A very close to each other (Figs. 7,8, 20.a-b). In turn, the third hammer (#59, Fig. 20.c) from the littoral zone at Szczepanki E is markedly large (12.3x6x6.1cm) and extremely massive – weighing 707g, which makes it the heaviest tool in the whole collection (Figs. 7,8). All 'hump' hammers were made of diabase and the big one is in dark greenish shade (Tab. 5). They are entirely ground.

'Hump' hammers are occasional items. One such tool comes from the grave at Bad Dürrenberg in Saxony-Anhalt and is dated to the early Atlantic (*Grünberg* et al. *2016.Fig.4*). Another two are known from Denmark, one is connected with the Kongemose culture and the second with the Ertebølle (*Andersen 2018.Fig. 202; Faxholm 2020.93, Fig. 100_0411*). Another comes from north-west Poland, although it was related to the Danubian Neolithic (*Smoczyńska 1953.Fig. 68*). They are also found at the Nida site of the Rzucewo culture in south-western Lithuania (*Rimantienė 2016. Figs. 163.5–6,8*).

'Axe'-hammers (Tab. 2.#62–67, Fig. 21)

'Axe'-hammers generally resemble short and 'thick-butted' axes of roughly rectangular cross-section. Their working ends are blunt and even purposely ground transversally to both walls and sides.

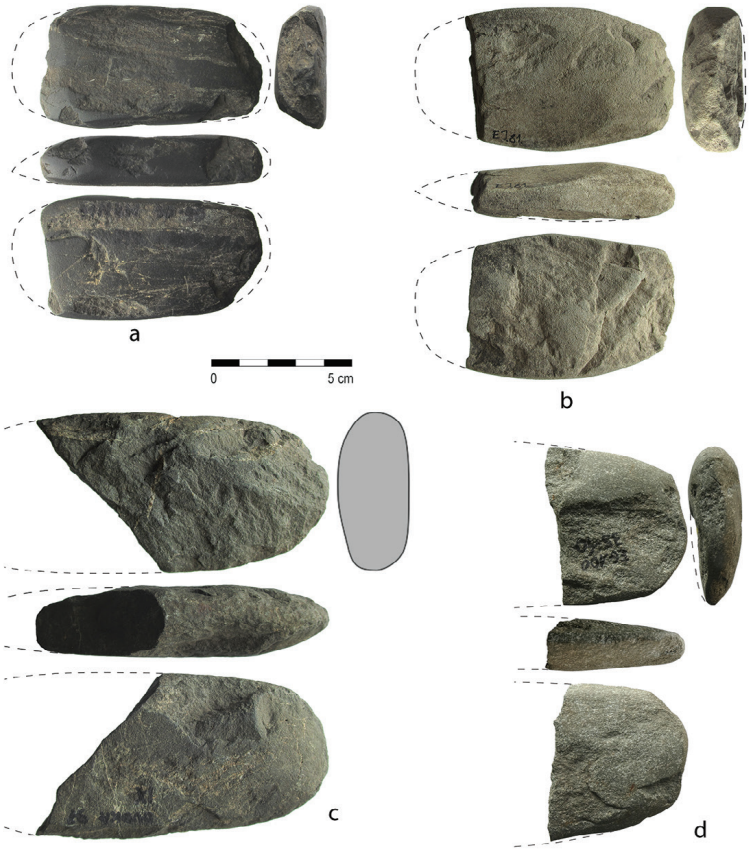


Fig. 16. 'Flat' adze-axes: **a(#36)** ***Dudka, classic Zedmar;*** **b(#38)** ***Szczepanki, post-Zedmar;*** **c(#37)** ***Dudka, Late Neolithic;*** **d(#39)** ***Szczepanki, classic Zedmar (photos by K. Bugajska, W. Gumiński).***

This taxon contains six entirely preserved or almost whole items, which were found in the shore zone at Szczepanki and at the Dudka cemetery.

'Axe'-hammers are short (LWI=1.2–1.9) and thick (WTI=1.2–1.6) (Fig. 5). The position of maximum width ranges from the front to the back part of the tool (MWI=28–70), but maximum thickness falls clearly in the rear part of the tool (MTI=66–82) (Fig. 6). Butts are markedly thick and usually flat, although convex or somewhat pointed also occur (Tab. 2). Three hammers are blunted on the working end by transverse grinding up to *c.* 1cm width (Fig. 21.a,c,e).

They are significantly varied in size (4.3 to 9.4cm in length) and mass, from very light (33g) to very heavy specimens (303g) (Fig. 7–8). They were made exclusively from coarse grained hard rocks including reddish granite (three examples) or greenish gabbro (Tab. 5). All these tools were ground, although carelessly.

'Axe'-hammers occurred from the early Zedmar to the Late Neolithic, when they were most common (Tab. 3). One Late Neolithic specimen (#67, Fig. 21.e) stands out due to its slightly curved outline view. Its upper (right) side is convex, while the lower (left) side is accordingly

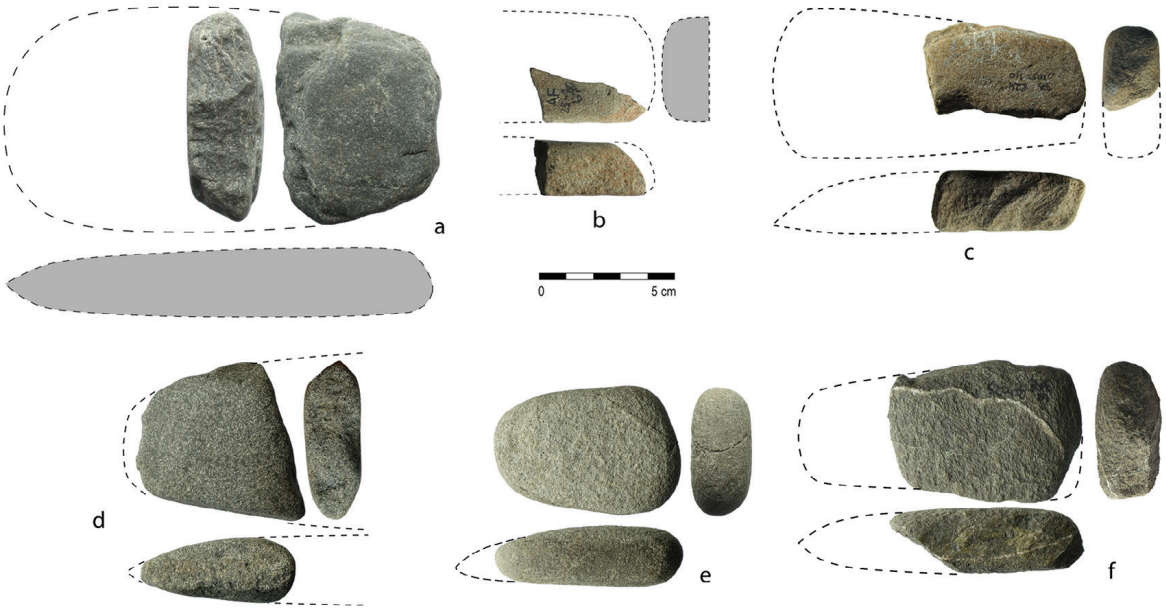


Fig. 17. 'Flat' adze-axes: **a(#40)** ***Szczepanki, early Zedmar;*** **b(#42)** ***Szczepanki A, Late Neolithic;*** **c(#41)** ***Szczepanki, Late Mesolithic;*** **d(#43)** ***Szczepanki A, classic Zedmar;*** **e(#45)** ***Dudka, classic Zedmar,*** **f(#44)** ***Szczepanki, post-Zedmar (photos by K. Bugajska, W. Gumiński).***

concave. However, most of the lower side was secondarily reworked by pecking, and it is uneven and not ground, although a smoothed fragment beside the working end shows that it was originally dropped as in the typical Corded Ware '*battle axes*'. It is worth noting that hole-less 'battle axes' are known from Denmark (*Ebbesen 1982–83*).

'Thick-butted' pickaxes (Tab 2.#68–72, Fig. 22. a-e)

'Thick-butted' pickaxes have clearly pointed working ends and thick butts.

This taxon comprises five implements, of which three are intact and of two back halves are preserved. They appeared at the settlement and shore zone at Szczepanki and at the Dudka cemetery.

'Thick-butted' pickaxes are short and thick with similar LWI and WTI indexes (1.6–1.8 and 1.5–1.95), which were even the same in two cases (#69 and 72) (LWI= WTI=1.7) (Fig. 5). The maximum width and thickness usually fall in the back part of the tool, and in two cases in the same distance from the edge (MWI=MTI=63 or 84) (Fig. 6). Preserved pointed working ends are very

Fig. 18. 'Little' adze-axes: **a(#46)** ***Dudka, Late Neolithic;*** **b(#47)** ***Dudka, Late Neolithic;*** **c(#48)** ***Szczepanki, post-Zedmar;*** **d(#49)** ***Szczepanki, post-Zedmar;*** **e(#51)** ***Dudka, post-Zedmar;*** **f(#52)** ***Dudka, classic Zedmar;*** **g(#53)** ***Szczepanki, post-Zedmar;*** **h(#50)** ***Szczepanki, classic Zedmar (photos by K. Bugajska, W. Gumiński).***

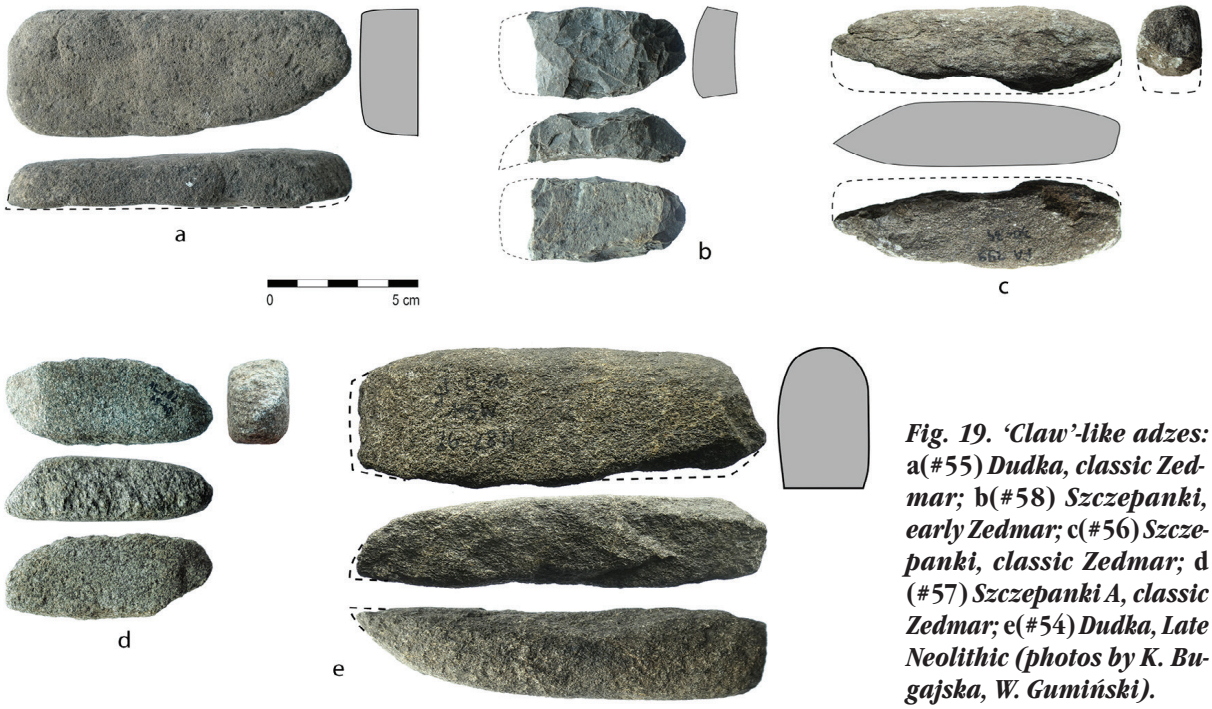


Fig. 19. 'Claw'-like adzes: **a(#55)** ***Dudka, classic Zedmar;*** **b(#58)** ***Szczepanki, early Zedmar;*** **c(#56)** ***Szczepanki, classic Zedmar;*** **d (#57)** ***Szczepanki A, classic Zedmar;*** **e(#54)** ***Dudka, Late Neolithic (photos by K. Bugajska, W. Gumiński).***

sharp (Fig. 22.c-d) or bluntly ground (Fig. 22.b). Sides are mostly rounded and butts are distinctly thick, flat or oval. One specimen (#71, Fig. 22.d) stands out by the rounded arris going from the top along both sides to the butt, which resembles 'lenticular' axes.

Sizes and masses are varied. One specimen (#72, Fig. 22.c) is the smallest and the lightest example of all SHT, at 3.7cm long and weighing 12g (Figs. 7,8). The next item is still relatively small and light (6.7cm and 82g), another weighs 155g, but two bigger tools (*c.* 10.5–11.5cm) were quite heavy, at *c.* 300–400g (Figs. 7,8).

'Thick-butted' pickaxes were made of different rocks: sandstone, metasiltstone, granite-gneiss, granite and pegmatite, of which three are yellow-beige and one is reddish (Tab. 5). Except for one tool prepared by pecking (#71, Fig. 22.d), all others are ground. The smallest specimen (#72) made of metasiltstone was worked with flaking at the top part, though the rear part was polished (Fig. 22.c).

Pickaxes occurred from the early Zedmar to the Late Neolithic (Tab. 3). One example from the grave VI-2 is ^{14}C dated by cremated bones to 4968±26 BP (3796-3652 cal BC, GrM-29982) (*Bugajska 2023*).

'Thick-butted' pickaxes, made of flint and not ground, appear at many Mesolithic sites in Middle North Europe. As a rule they are distinctly slender tools.

'Dagger' pickaxe (Tab. 2.#73, Fig. 22.f)

The 'dagger' pickaxe is distinctly flat and slender, with an elongated triangular outline resembling a dagger and an arris that runs from the pointed top through both sides to the butt.

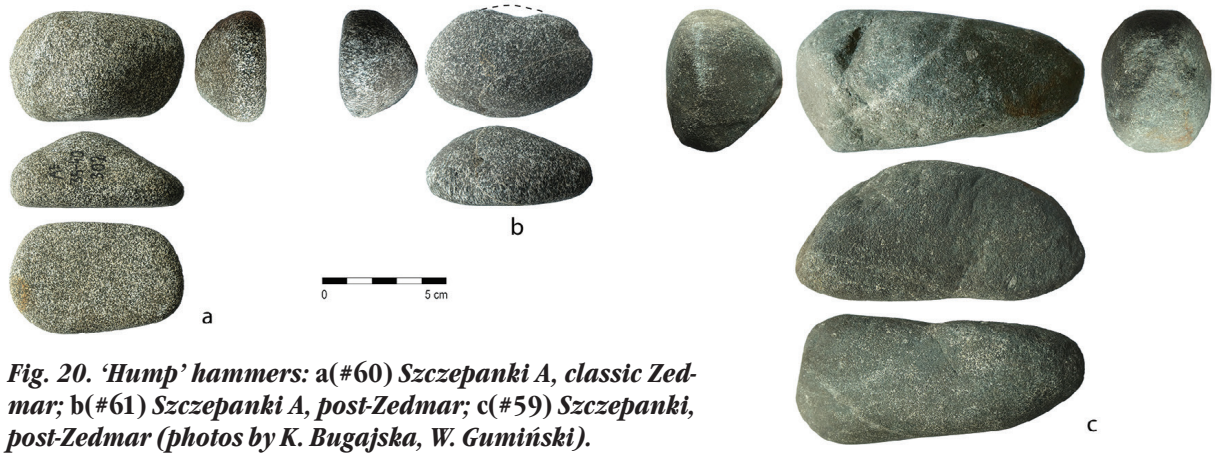


Fig. 20. 'Hump' hammers: **a(#60)** ***Szczepanki A, classic Zedmar;*** **b(#61)** ***Szczepanki A, post-Zedmar;*** **c(#59)** ***Szczepanki, post-Zedmar (photos by K. Bugajska, W. Gumiński).***

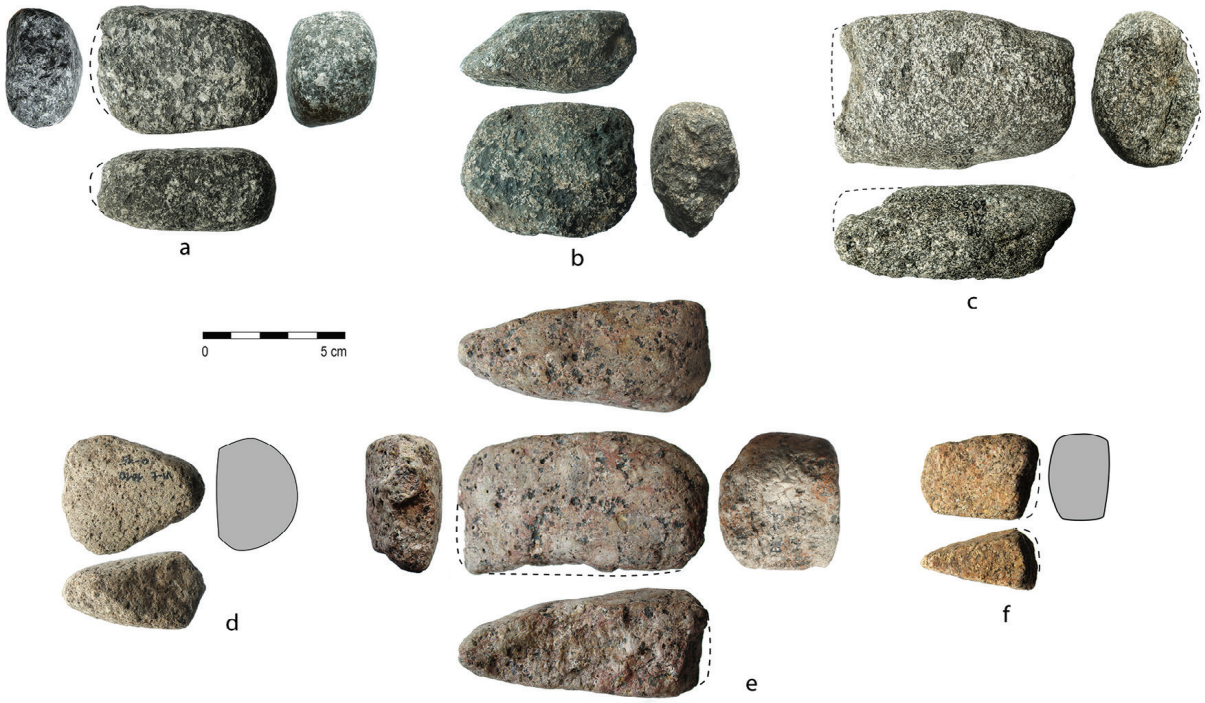


Fig. 21. 'Axe'-hammers: **a(#62)** ***Szczepanki, early Zedmar;*** **b(#64)** ***Szczepanki A, classic Zedmar;*** **c(#63)** ***Szczepanki A, Late Neolithic;*** **d(#66)** ***Dudka, Late Neolithic;*** **e(#67)** ***Szczepanki, Late Neolithic;*** **f(#65)** ***Szczepanki, classic Zedmar (photos by K. Bugajska, W. Gumiński).***

This taxon is represented by one whole specimen, which was found in the shore zone at Szczepanki in the layer dated to the post-Zedmar (Tab. 3). It is a distinctly slender and flat tool (LWI=2.6 and WTI=2.2) (Fig. 5). Its outline forms an elongated triangle with slightly wavy sides. Longitudinal and cross-sections are thin lenticular, so the arris goes all around, including the butt. The maximum width and thickness fall at the same point in the back part of the tool (MWI=MTI=76) (Fig. 6). The specimen is moderately long (10.5 cm),

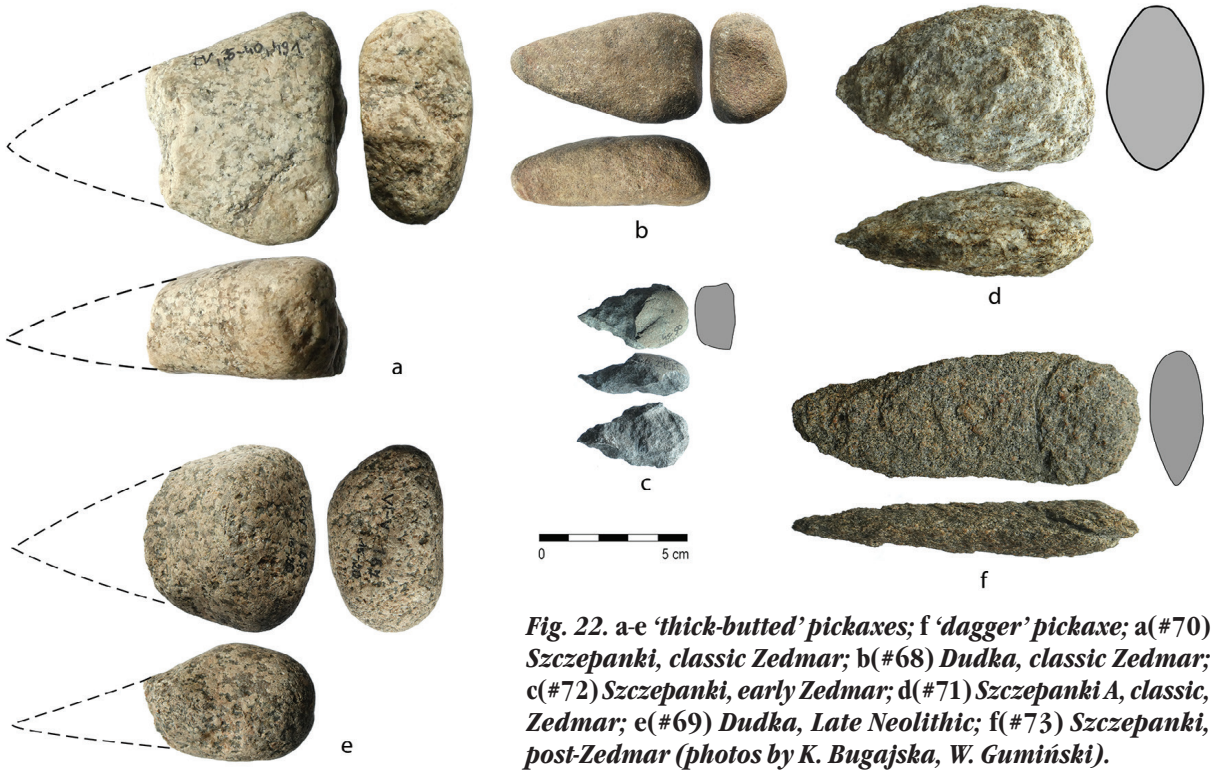


Fig. 22. **a-e** ***'thick-butted' pickaxes;*** **f** ***'dagger' pickaxe;*** **a(#70)** ***Szczepanki, classic Zedmar;*** **b(#68)** ***Dudka, classic Zedmar;*** **c(#72)** ***Szczepanki, early Zedmar;*** **d(#71)** ***Szczepanki A, classic, Zedmar;*** **e(#69)** ***Dudka, Late Neolithic;*** **f(#73)** ***Szczepanki, post-Zedmar (photos by K. Bugajska, W. Gumiński).***

but light (90g) (Figs. 7,8). It was made of slightly glittering beige gneiss by pecking and was not ground, although the whole surface is corroded (Tab. 2).

Only two stone 'dagger' pickaxes have been published at present, and both come from the Kongemose sites in Zealand. One is very similar to our specimen considering the slim triangular outline with slightly wavy sides. The second is more regular and elongated in outline. Both are thin and made of glittering mica schist (*Mathiassen 1946.30, Fig. 4.14; Sørensen S. A. 2017. 56, Fig. 37*).

'Almond'-shaped mattock (Tab. 2.#74, Fig. 23.a)
The mattock is like an adze, but with the pointed working end as in the pickaxe and drilled a shaft-hole.

The only one such tool is generally almond-shaped, although in a sideway view it is slightly 'claw'-like bent, because the lower wall is somewhat concave and the upper convex (Fig. 23.a). The working end is pointed, but blunt and massive. This specimen is exactly two times longer than the width and two times wider than the thickness (LWI=2 and WTI=2), so it is just intermediate between the short and slender, as well as the thick and flat groups of tools (Fig. 5). The maximum wide falls in the rear part of tool (MWI=63), while the maximum thickness at the front part (MTI=37), and the maximum width is the same distance from the butt as the maximum thickness is from the edge (Fig. 6).

The pointed edge and convex butt gently turn to the oval sides and walls of the trunk. The mattock is markedly large and massive, being 12.6cm in length and weighing almost 400g (Figs. 7,8).

The tool is made of dark bluish hornblende gneiss and made using only the pecked technique, and its symmetry, parameters and surfaces are precisely worked (Fig. 23.a). The mattock was subjected to drilling, although this was abandoned near the very beginning of the process. The initial bore is hardly 4mm deep and only 8mm in diameter, and it is set at the slightly concave part of the upper wall at a distance of 71/100 from the pointed edge, so just behind the maximum width of the tool (MWI=63). The bore is slightly displaced from the tool axis toward the right side, and is 2.5cm and 3.1cm from the left side. It is significant that it was drilled using a compact (not tubular) borer, after which a typical hourglass hole appeared (if it was drilled from both sides). Such hourglass holes are rare in SHT, and appeared almost exclusively in the Mesolithic. The mattock was found very close to the 'bulgy' axe #26 in the littoral zone at Szczepanki, at the bottom level of the early Zedmar layer.

Stone mattocks are sporadic finds in the Mesolithic, and occurred in two types. One is oblong and narrow with a distinctly widened middle part where the shaft-hole was drilled (*Gramsch 1973.28, Fig. 11; Nordqvist 1999.Fig. 4E; Nordin, Gustafsson 2010.Fig. 6*). The second type is simpler and flat, with an almond-shaped outline like the mattock from Szczepanki (*Althin 1954. Pl. 12.2; Schuldt 1961.Pls. 39–40; Fokkens 1998.Figs. 42a-b; Gerken 2001.Pl. 113; Gramsch 2009.Figs. 3,4; Drenth, Niekus 2010.Fig. 38–2.3; Biermann 2011. Fig. 5.5; Verhart 2012.25–28, Fig. 13*). At Friesack in Brandenburg two 'simple' mattocks were found, one with the shaft-hole drilled at the slightly thinner part of the tool, and the second with unfinished drilling (*Gramsch 2000.Fig. 16.3; 2009.Fig. 3*). The mattock from Szczepanki is the most eastern example in Europe, and suggests its western connections.

'Simple' hatchet (Tab. 2.#75, Fig. 23.b)
A hatchet is an axe with a shaft-hole (Fig. 3.A), and they were very diversified in the Neolithic. In the Late Neolithic two main types occurred simultaneously. The first, called '*battle axes*', are distinguished by the drooped cutting edge and elongated butt, and they are usually oval in cross-section. The second type is quite simple, of trapezoidal or rectangular outline and almond-pentagonal in the sideways (upper) view, and they are roughly square in cross-section. Such 'simple' hatchets are also known as 'type II' or 'working shaft-hole axes'.

The sole 'simple' hatchet is entirely preserved. It is somewhat short (LWI=1.9) but markedly thick, since its width (high) and thickness are equal (WTI=1) (Fig. 5). The maximum width is set significantly in the front part of the tool (MWI=25) and the maximum thickness is just behind the middle of the tool (MTI=55) (Fig. 6). The hole, with a diameter of 24–26mm, was drilled from the bottom (left) side just in the thickest spot of the tool (MTI=55), somewhat moved toward the back.

The tool outline is trapezoidal-rectangular, slightly narrowing toward the butt, whereas the sideways view is almond-pentagonal. The cutting-edge is almost straight (EPI=8) and turns angular to both flat sides. The butt is flat and square (Fig. 23.b). The uneven shape of the back part – with gentle concavity of the upper wall (left side) and the hole displaced from

the tool's symmetry axis – probably arose from the modification of the tool from a 'battle axe' with an elongated butt.

The hatchet is markedly heavy, at 437g, though not long, at 10cm (Figs. 7,8). It is made of dark greenish-grey amphibolite and thoroughly polished, although the butt and both walls at the maximum convexness show traces of impacts. It is worth noting that the cutting-edge has a very large angle *c.* 80°, and it was deliberately frontally blunted by crosswise grinding at a width of *c.* 3mm (Fig. 23.b).

The hatchet comes from the Late Neolithic grave (destroyed by ploughing) situated at the northern promontory of the Dudka island, *c.* 500m away from the main cemetery and settlement zone (Fig. 2.A). Such hatchets were widespread in the Late Neolithic, particularly in the Corded Ware culture, but are rather rare in the Para-Neolithic cultures, even in the youngest Late Neolithic stages of their existence (*Gumiński, Kowalski 2011.483–487*).

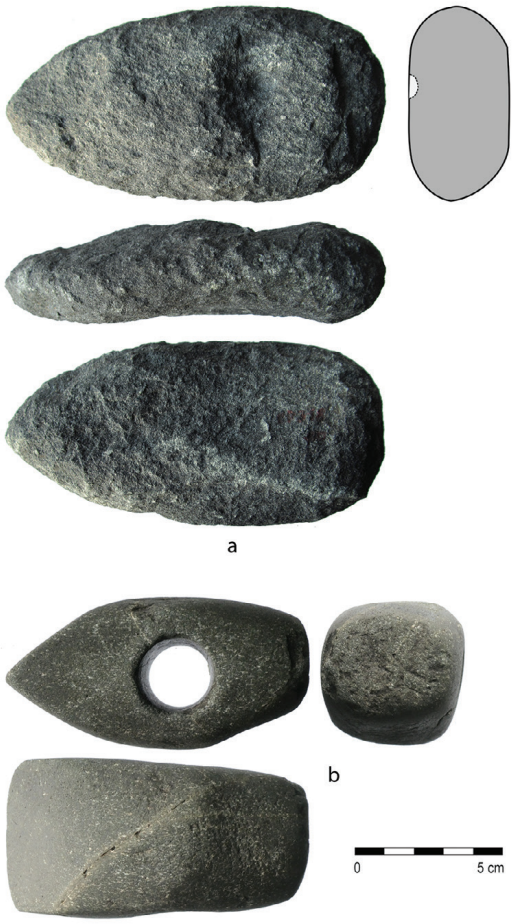


Fig. 23. **a** ***'almond' mattock;*** **b** ***'simple' hatchet;*** **a(#74)** ***Szczepanki, early Zedmar;*** **b(#75)** ***Dudka, LateNeolithic (photos by K. Bugajska, W. Gumiński).***

Analysis and discussion

Stone head tools from Dudka and Szczepanki with regard to neighbouring regions and cultures

The collection of 75 SHT from Dudka and Szczepanki presented here is one of the largest among hunter-gatherer sites in north-central Europe, with the exception of sites where they were produced on a large scale (*cf. Carlsson 2007.157; Sørensen S. A. 2007.184; Nicolaisen 2009.Fig. 127.4; Glørstad 2010.Tab. 3.1*). Only a few typical settlement sites from the East Baltic Countries have yielded more such tools (*Loze 1979. Tab. 7; 1988.34; Rimantienė 2016.196*). Most of the discussed SHT assigned to particular taxa have counterparts in southern Scandinavia and the Middle European Plain, so they correspond with the Maglemosian tradition and its followers, including the Ertebølle and Swifterbant cultures. However, it must be emphasised that at no other site have so many different types of SHT been found as at Dudka and Szczepanki. Only two taxa – 'flat' and 'little' adze-axes occurred more often in Eastern Baltic Countries dominated by the Kunda tradition and then by the Narva, Comb-Pit Ware and Rzucewo cultures. On the other hand, flat and little forms were also quite common within the Danubian Neolithic.

Diversity and frequency of stone head tools

One of the peculiarities of the local SHT is their high diversity. The 75 tools presented here represent six different kinds – the axe, adze, hammer, pickaxe, mattock and hatchet (Fig. 3.A), and they are divided into 14 taxa (Tab. 3). However, most of these tools are axes and adzes (58 items, 77%), which are generally considered as used chiefly for cutting trees and working with wood, but they are still very diversified, divided into eight different taxa (types) occurring simultaneously, at least in the both Zedmar periods (Tab. 3). Moreover, most tools of a given taxon are also dissimilar (Figs. 5–8, Tab. 2). Although the diversity of SHT amongst hunter-gatherers is normal, their large variety at sites of one lake is remarkable.

Apart from three taxa represented by a singular find ('dagger' pickaxe, mattock and hatchet), others are represented by from three to 13 pieces (Tab. 3). Surprisingly, most of them exhibit unexpectedly long chronologies, at least through three or four periods, and the most numerous taxa – 'tongue' adze and 'flat' adze-axes – occurred from the Early or Late Mesolithic until the Late Neolithic, *i.e.* over several thousand years

(Tab. 3). It is significant, that each taxon which had already appeared in the Mesolithic still occurred in the later periods, which indicates the continuity of local hunter-gatherer societies from the Mesolithic to the Para-Neolithic Zedmar culture (*Gumiński 1995; 1999; 2004; Gumiński, Michniewicz 2003; Gumiński, Bugajska 2016; 2023*).

Taking into account the long chronology of the settlement at Staświn Lake, it appears that SHT were not so common there, which is striking because flint axes or adzes were not used by the local hunter-gatherers. Instead, the frequency of stone and antler-bone head tools remains rather similar from the Mesolithic to the post-Zedmar period, and they were most numerous and diversified in both Zedmar periods (Fig. 4, Tab. 3, *Gumiński, Bugajska 2023.Tab. 3*). So the SHT did not replace the tools made of antler-bone, but categories complemented each other. If this is the case, then the question arises as to why they were so differentiated, or whether there were just as many work specialisations with stone and antler tools.

Main proportions of stone head tools

Based on the slenderness (LWI) and flatness (WTI), SHT can be divided into four groups (Fig. 5, Tab. 3). The most numerous are thick and slender tools (LWI >2 and WTI <2) comprising 29 specimens (41%) of four different taxa: the 'cigar'-shaped, 'tongue' adze, 'kidney'-shaped and 'claw' adze. One of 'hump' hammers and an 'almond' mattock can be affiliated to this group too, although the parameters of the mattock are in fact just intermediate between each of the possible four groups (LWI=WTI=2) (Fig. 5).

The second group of thick and short tools (LWI and WTI <2) includes 18 pieces (26%) belonging to five taxa: 'bulgy' adze-axes, 'hump' hammers, 'axe'-hammers, 'thick-butted' pickaxes and 'simple' hatchet (Fig. 5, Tab. 3). The third group of flat and short tools (LWI <2 and WTI >2) includes 13 specimens (19%) representing two taxa: 'lenticular' axes and 'little' adze-axes (Fig. 5, Tab. 3). The least frequent (10 pieces, 14%) are flat and slender tools (LWI and WTI >2), with 'flat' adze-axes and the'dagger' pickaxe (Fig. 5, Tab 3).

Thick tools are two times more numerous (67%) than flat ones (33%), and they represent most of the distinguished taxa (10 to 4) (Tab. 3). However, the proportions accounted for by the slender and short tools are more similar, as the first group contains 39 specimens (55%) and the second 31 (45%) (Fig. 5, Tab. 3).

The most slender and thick tools are 'cigar'-shaped adze-axes and most of the 'claw' adzes, whereas the flattest and shortest are some of the 'little' adzes and 'lenticular' axes (Fig. 5). The shortest and thickest tools are both types of hammers and the hatchet, and the most longest and thinnest are some of the 'flat' adze-axes and the 'dagger' pickaxe (Fig. 5). Interestingly, the proportions of the mattock are just in the middle of those for all the tools, which might suggest that it is a typical local artefact. In fact, it is a very rare and specific form of tool in the European Mesolithic, for which the closest analogues occur in the Netherlands (*Fokkens 1998.Figs. 42a-b; Drenth, Niekus 2010.Fig. 38-2.3; Verhart 2012.Fig. 13*).

The maximum width and thickness

The position of maximum width and thickness in relation to the edge (MWI and MTI) are significant stylistic features, but also affect the point of the centroid of the stone head, the form of wooden shaft and the manner of binding them together. It is thus surprising that the position of maximum width and maximum thickness are remarkably varied, MWI from 17 to 84 and MTI from 30 to 92 (Fig. 6). The maximum width appeared more often in the front half of the tool (MWI ≤50) than in the back (MWI >50), in the ratio of 42 to 24, whereas the maximum thickness was more often in the rear part (MTI>50), with the ratio 46 to 20 (Fig. 6).

The maximum width falls much more frequently closer to the edge than the maximum thickness (MWI<MTI), in a ratio of 44 to 10, and both maxima were at the same distance in 12 cases only (MWI=MTI) (Fig. 6). The mirror position of both indexes, *i.e.* when the distance from the maximum width (MWI) to the edge is like the distance from the maximum thickness (MTI) to the butt, occurs with three items (Fig. 6).

Greatness and mass

The average length and width of all tools is 9.5 x 4.9cm (Fig. 7). Nevertheless, the tools display a broad range of length and width, from extremely small specimens to relatively large ones, *i.e.* from 3.7cm up to 16.5cm in length and from 2.2cm to 8cm in width (Fig. 7). It is significant that tools of the same taxon might differ in length by 100%, or up to 6 to 8cm.

Due to the small gap in lenght at 8cm (Fig. 7), all tools can be categorised as small. According to this, 17 tools (23%) of nine taxa can be determined as small. Moreover, the 10 (13%) smallest tools with a length below 5cm represent four different taxa, in which 'little' adze-

axes are the most common (seven specimens), but 'lenticular' axe, 'axe'-hammer and 'thick-butted' pick-axe also appear in this group (Fig. 7).

The length of most tools is roughly two times larger than the width. However, only two specimens, a 'flat' axe and the mattock (#45 and 74), have this exact ratio, whereas the rest of tools are either slender (length >2 x width) or short (length <2 x width) (Fig. 7).

The utility of SHT certainly depended also on their mass. The average mass of all tools is 228g, which seems to be suitable for such implements (Fig. 8). Nevertheless, their mass varies evenly from exceedingly light at 12g ('thick-butted' pickaxe), up to quite heavy at 437g ('simple' hatchet) (Fig. 8). Additionally, three specimens of different taxa were even heavier: a 'flat' axe *c.* 520g, a 'bulgy' adze 566g and a 'hump' hammer 707g (Fig. 8). On the other hand, the discussed assemblage contains a surprisingly high number – 23 (31%) – of markedly light tools weighing less than 100g, representing nine different taxa (Fig. 8). Moreover, 12 specimens (16%) are extremely light, below 50g, and they belong to six different taxa of which 'little' adze-axes are the most numerous, at six items (Fig. 8). Such a large and diverse representation of light implements may suggest that a substantial proportion of SHT did not have a utilitarian usage, but were destined for a symbolic or ritual role, or maybe they were children's toys. However, 'little' adze-axes and most other light tools were carefully made, which does not support the last hypothesis.

The wide range of masses within a particular taxon is another peculiarity. Each taxon contains specimen(s) that vary considerably from the average mass and from the main sequence of evenly spread masses (Fig. 8). The difference between the lightest and heaviest tool in a particular taxon can come be six to eight times (Fig. 8). Tools of such outmost greatness and mass were probably destined for other purposes, although they belong to the same taxon.

Stylistic features

The protrusion of the working edge is one of the stylistic features of minor importance, but subjected to chronological changes. Barely protruded or almost straight working edges (EPI <15) appeared in the post-Zedmar and prevailed in the Late Neolithic (Tab. 4). Moderately protruded edges (EPI=15–29) arose in the early Zedmar, dominated in the classic Zedmar and occurred in following periods (Tab. 4). Distinctly protruded edges (EPI=30–50) then appeared in the Late Mesolithic, became most common in the early and classic Zedmar, and then decreased to the Late Neolithic (Tab. 4). More protruded edges (of the EPI=60 or 85) appeared from the early to post-Zedmar, but they were only connected with three specific taxa – 'claw'-like adzes and both pickaxes (Tab. 2,4). In short, distinctly protruded edges are typical for older periods, and almost straight edges for the youngest.

The turn between the working edge and sides of the trunk can be gentle or angular. The bilateral gentle forms occurred from the Late Mesolithic to the post-Zedmar, but prevailed in the classic Zedmar (Tab. 4). Mixed forms, *i.e.* gentle from one side and angular from the second, also dominated in the classic Zedmar, although they appeared from the early Zedmar until the Late Neolithic. By contrast, an angular turn to both sides occurred exclusively in the two youngest periods, prevailing in the Late Neolithic (Tab. 4).

The form of the sides is the next stylistic trait, but was also related to the type of shaft and binding. It is interesting to note that in 21 tools (29 %) each side was shaped in a different way (Tab. 4). Oval (convex) and flat sides were most common and occurred from the Early Mesolithic until the Late Neolithic, although oval sides distinctly prevailed in the early Zedmar, whereas flat prevailed from the classic Zedmar to the Late Neolithic (Tab. 4). Edge and faceted sides were markedly less frequent and occurred from the early Zedmar to the Late Neolithic, with a slight predominance in the classic Zedmar (Tab. 4). It is worth noting that edge and faceted sides applied more often only on one side of the tool than simultaneously on both (Tab. 4).

The shape of the butt is another stylistic feature which reveals chronological trends. Convex (rounded) butts occurred from the Early Mesolithic until the Late Neolithic, but they dominated in the early Zedmar (Tab. 4). Edge butts were applied from the Late Mesolithic until the Late Neolithic, with a predominance in the classic Zedmar (Tab. 4). Flat butts occurred in the same periods, although they were equally frequent from the classic Zedmar to the Late Neolithic (Tab. 4). Surprisingly, pointed butts (typical for the Danubian stone axes and adzes) were remarkably rare (4% of finds), and only from the two youngest periods (Tab. 4).

The forms of working edge, sides and butt are stylistic traits which exhibit chronological tendencies. It is notable that all features which appeared in the Mesolithic

were continued at least to the post-Zedmar; moreover, they were most frequently used (Tab. 4). On the other hand, some features which appeared for the first time in the post-Zedmar – such as an almost straight working edge, angular turn between the edge and both sides, and pointed butt – were later more common in the Late Neolithic (Tab. 4).

Selection of raw rock material

Determination of rock raw materials was done macroscopically,[2] so the results are not certain, all the more so as most of the artefacts are polished or with weathered surfaces (Tab. 2).

Rocks used in tool production belong to four main classes – sedimentary rocks, metamorphic rocks, intrusive and extrusive igneous rocks. Altogether at least 20 kinds of rocks were used to make 75 local SHT (Tab. 5). These kinds were combined into seven groups of partly similar rocks, which do not thoroughly follow any established petroglyphic division, but are based on specific properties which were presumably most desirable for prehistoric people when it came to choosing a particular rock for a certain SHT.

The most frequently used group of rocks contains six following kinds: metasiltstone, metasandstone, greenschist, amphibolite, diabase and diorite (Tab. 5). They formally belong to different classes of rocks, but are similar in some essential traits, such as durability, a dense, homogeneous matrix and being generally fine grained. Usually they are dark and often reveal greenish or bluish shades, and thus axes or adzes made of such rocks are often named 'greenstone axes' (as opposed to flint axes). In total 27 tools (36%) of nine taxa were made of greenstones, in which greenschist, amphibolite and diabase prevailed (Tab. 5).

The second most often used group of rocks consists of gneisses and similar schistous rocks, which seem to be desirable for preparing axes or adzes, although they are prone to peeling off. These rocks are distinguished by the unidirectional composition of mineral grains, from fine grained schist, through medium grained gneisses, up to coarse grained granite-gneiss. From these rocks a total of 20 tools (27%) of nine different taxa were made (Tab. 5).

Sandstone, which seems to be unsuitable for head tools due to its friable and crumbly nature, was used for 10 tools (13%) of five different taxa, mainly for 'cigar'-shaped adze-axes (six specimens) (Tab. 5). Unexpectedly, even softer rocks were used, such as limestone and siltstone, which are flimsy and effaceable, although easy to grind. Four tools (5%) of three different taxa were made of such rocks (Tab. 5).

Quartzite and quartzitic metasandstone are very hard rocks with a dense crystal matrix that lack grains. Quartzite demands special treatment in processing, while quartzitic metasandstone is fissile, similar to a flint. Jotnian sandstone, although a sedimentary rock, has a similar character, since it is a very hard and dense rock with homogeneously fine grains. Four different tools were made from these rocks (Tab. 5).

The next group contains gabbro, granite and pegmatite, which are hard and coarse crystalline rocks, although prone to crumbling. Eight tools (11%), mostly 'axe'-hammers (five items), were made of them (Tab. 5).

The last group comprises andesite and trachyte (extrusive igneous rocks) characterized by sparse minerals scattered within a dense, homogeneous matrix, which in trachyte is glazy. These rocks were used for two different tools (Tab. 5).

It is striking that almost every taxon contains tools made of completely dissimilar kinds and groups of rocks (Tab. 5). For instance, 'kidney' and 'flat' adze-axes were made, among others, of especially soft, flimsy and effaceable siltstone, and also of very hard and difficult to process quartzite (Tab. 5). Similarly, 'little' adze-axes were made of hard and dense greenstones, but also from soft limestones (Tab. 5).

On the other hand, the use of similar rocks for certain items is also apparent. For instance, 'cigar'-shaped adze-axes are almost exclusively from sandstone, 'lenticular' axes mainly from schistous rocks, 'flat' and 'little' adze-axes from greenstones, and 'hump' hammers only from diabase, whereas 'axe'-hammers are chiefly from coarse grained rocks (Tab. 5).

Besides the technical and grain characteristics, the colour of rocks perhaps also played an important role in choosing a particular stone for making a given head tool (*Gumiński 2014; Gumiński, Bugajska 2016*). Forty-two percent of the rocks used are generally grey, whereas 58% are other shades: yellow-beige (11), red

2 I am grateful to Dr Marcin Górka from the Geological Faculty, University of Warsaw, for the identification of the rocks used to make the head tools.

(six), greenish (10), bluish (five) and almost black (11 times) (Tab. 5). It is notable that each taxon contains tools of clearly different colours, so the rocks were deliberately selected in this respect, too.

This extremely high diversity of rocks, even within particular taxa – considering their physical traits, technical properties, texture and colour – is a surprising characteristic of the local SHT. Two possible explanations can be suggested: one that local people picked the first suitable stone for any head tool, or more probably, that each produced and held SHT should be distinguished by individual traits, which could also be related to the different characteristics of the various raw materials.

Finding as many different kinds of stones would be quite easy in this area. Northern Poland, including Masuria, is covered by very thick glacial sediments, which were transported by the ice sheet from different regions of Fennoscandia, so many erratics occur there and are often just on the surface, as well as in stone quarries (*Czubla 2015*). The nearest gravel heap and quarry (still exploited even a few decades ago) is located just 1–2km to the north-west from Dudka and Szczepanki at the peninsula of the firm land (Fig. 1.B). As such, it can be stated that all the rocks are most probably of local origin.

Technics of manufacture

Most tools were made with at least two different techniques (Tab. 2). Grinding (66 cases, 88%) and pecking (67 tools, 89%) definitely prevailed, although knapping was also used 31 times (41%).

Grinding-polishing was already applied from the Early Mesolithic, but its thoroughness varied significantly. The most carefully polished item is a 'bulgy' axe made of diorite from the early Zedmar (#26, Fig. 14.a) and one 'tongue' adze of metasandstone from the post-Zedmar (#8, Fig. 10.a). In contrast, the most roughly ground items are some 'flat' and 'little' axes from the Late Neolithic and post-Zedmar made of greenschist, siltstone and limestone (#37–39, 53, Fig. 16.b-d,18.g), although these rocks are suitable for grinding. It appears that the appearance and quality of polishing were not connected with the chronology, taxon, or kind of rock.

Grinding usually obliterates previous processing, so possible pecking and flaking can be barely noticeable or completely invisible on a particular item. On the other hand, some impacts that occured during tool use can be mistaken for having been deliberately pecked and flaked. Nine tools (12%) were not ground at all: four 'lenticular' axes, a 'bulgy' adze, 'claw' adze, 'thick-butted' pickaxe, 'dagger' pickaxe and the mattock (Tab. 2). Only one of them, a 'claw' adze (#58, Fig. 19.b) made of quartzitic metasandstone, was worked exclusively by flaking, which is appropriate for this rock. Other tools were produced by pecking (six examples) or pecking and flaking (two cases). All of them are from schistous rocks: schist, gneiss and granite-gneiss (Tab. 5), which are generally easy for grinding. It should be stressed that tools that were not ground were usually precisely shaped, with steady surfaces.

Only two SHT were drilled, but each in a different manner. The Late Neolithic hatchet (#75) made of amphibolite was probably drilled from one side with a bone tubular borer. In contrast, the mattock (#74, Fig. 23.a) made of hornblende gneiss was only initially drilled, possibly with a flint burin 8 mm wide. Such a drilling technique was normally carried out from two opposite walls of stone tool and resulted an hourglass hole. This type of hole appeared in the Mesolithic, but was rare (*Gramsch 2009*). The mattock from Szczepanki is firmly dated to the beginning of early Zedmar. It is significant that the mattock was made by pecking alone and was not intended for grinding at all, because the drilling of holes was always done as the last stage of tool processing.

The state of preservation and intentional modification

Twenty-eight specimens (37%) are entirely preserved (Tab. 6), while 19 tools (25%) are almost whole, although slightly damaged mostly owing to intentional blunting or reshaping. Another 13 pieces (17%) are halves, presumably purposefully broken and in few cases turned into a pestle, hand-stone or fire-striker. There are also eight (11%) accidentally damaged tools and seven fragments (9%) from the edge, butt or trunk. This is strange, because just small chips were found from flint axes (Fig. 4).

Intriguingly, that only two fragments come from the front (edge) part of a tool and one is from the middle part of a trunk, with these constituting 4% of the total, while all the other 72 tools (96%) are intact or are represented the back parts, including butts (Tab. 6). Such a proportion does not seem to be random. Moreover, slightly damaged specimens were not repaired at the working edge, although this would be quite simple and

not lengthy work. Instead, almost all the intact tools were intentionally bruised at the working edge or even blunted by transverse frontal grinding.

The distribution of stone head tools within sites

The distribution of SHT at Dudka and at Szczepanki are very different, and in both sites clearly non-accidental (Fig. 2, Tab. 6). At Dudka 21 tools, 72% of the site, were found within the cemetery and graves (Figs. 2.A,24), however this area (trench VI) was inhabited in the post-Zedmar and Late Neolithic. In other parts of the site SHT are quite seldom, since only three fragments come

Site	Dudka				Szczepanki			Dudka & Szczepanki +Malinka total
zone / condition	graves and cemetery	settlement and outskirts	island/ lake shore	total	settlement and outskirts	island/lake shore	total	
entirely preserved	10/7		1/1	11/8	3/2	13/8	16/9	27+1 37%
almost whole, purposely blunted or reshaped	8/4			8/4	4/4	7/5	11/6	19 25%
half of tool, purposely broken or turn to a stamp			1/1	1/1	4*/4	8/4	12*/6	13 17%
accidentally damaged tool	2/2	4/3		6/4	1/1		1/1	7+1 11%
fragment from the edge, butt or trunk	1/1	2*#/2		3*#/2		4/2	4/2	7 9%
total	**21/9**	**6/4**	**2/2**	**29/11**	**12/7**	**32/13**	**44/13**	**73+2**
% of tools	**72%**	**21%**	**7%**	**100%**	**27%**	**73%**	**100%**	**100%**

Tab. 6. Condition and localization of stone head tools in particular sites and zones. No. of tools/No. of taxa; * front (edge) part of tool, # part of trunk.

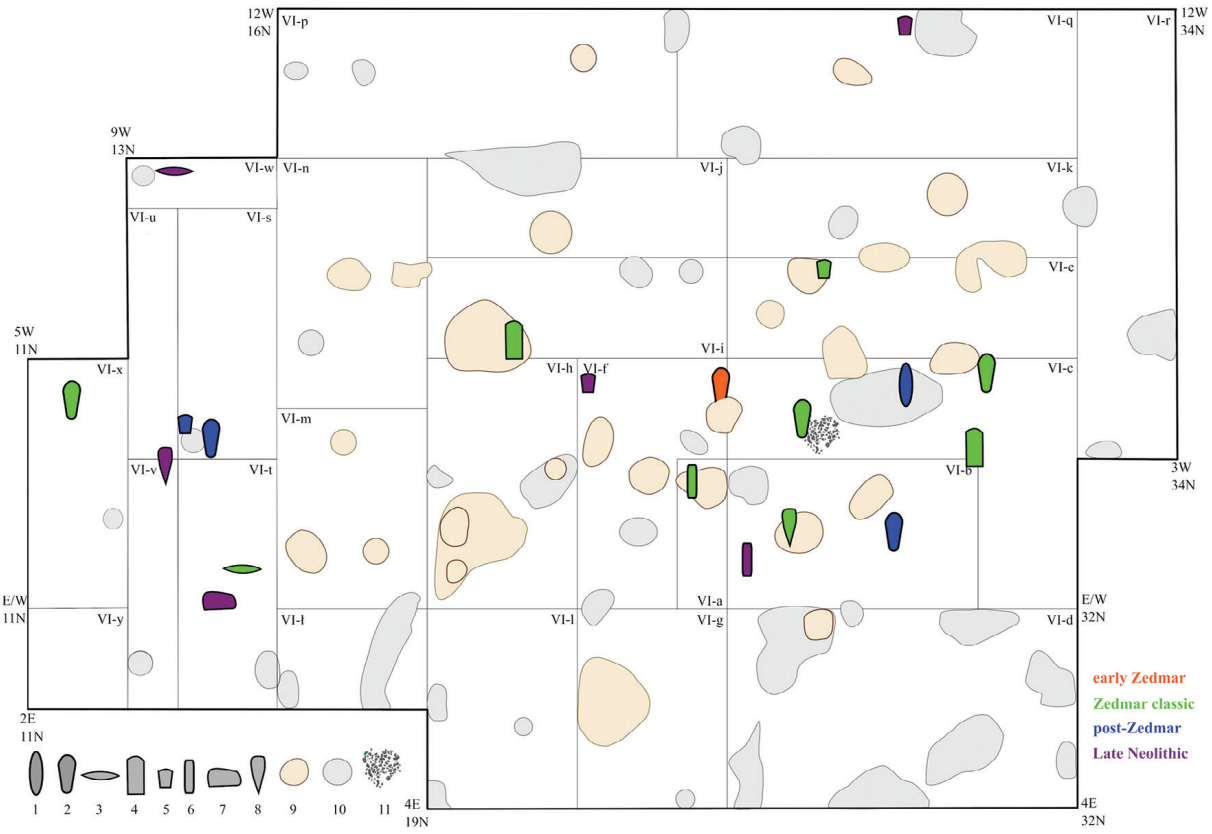


Fig. 24. Dudka, trench VI, distribution of stone head tools within cemetery:* 1 *'cigar' shaped adze-axe;* 2 *'tongue' shaped adze;* 3 *'lenticular' axe;* 4 *'flat' adze-axe;* 5 *'little' adze-axe;* 6 *'claw'-like adze;* 7 *axe-hammer;* 8 *'thick-butted' pickaxe;* 9 *grave;* 10 *pit,* 11 *heart-shaped stone pavement (plan by W. Gumiński).

from the dwellings (trenches IV, V and XIII) and the next three from the island interior (trench IX), which was most likely the base for supplying the settlement with wood, stones and different minerals (Fig. 2.A). Unexpectedly, SHT did not occur at either of the main settlements at the southern promontory (trench I) and at the eastern bay (trench III), which were inhabited through the whole Stone Age (Fig. 2.A), even though the bulk of all sorts of other finds were found there (*Gumiński 1999*). If SHT were connected with human burials one can expect that at least in trench III, where temporary burials are numerous, SHT should appear, but they do not. Besides, only two SHT were found at the Dudka shore zone (Fig. 2.A, Tab. 6).

By contrast, at Szczepanki 73% of tools (32 pieces) come from the lake shore, while the habitation areas yielded 12 tools (27%) (Figs. 2.B,25, Tab. 6). It is intriguing that the same proportion of SHT (72–73%) comes from the cemetery at Dudka as from the shore zone at Szczepanki.

Condition and localization of stone head tools in particular zones

Most of SHT from the cemetery and graves at Dudka – 18 of 21 – are intact or almost whole, and only three were casually damaged like all tools from the settlements and outskirts (Tab. 6). Considering the distinct difference in abundance and condition between tools from the cemetery and dwellings at Dudka, one can assume that all intact or almost whole specimens found within the cemetery were in fact connected with a funeral custom, but not with the routine works at the settlement. On the other hand, half of the tools there were found in the top layers, suggesting the post-Zedmar or Late Neolithic chronology, so they could have been used in normal, everyday activities. However – as was already pointed out – a great many of the finds in the cemetery were disturbed by modern ploughing, so their actual position and chronology are not certain. It is significant that in the same top layers many fragments of human craniums were found, which belong to several individuals. This phenomenon was already

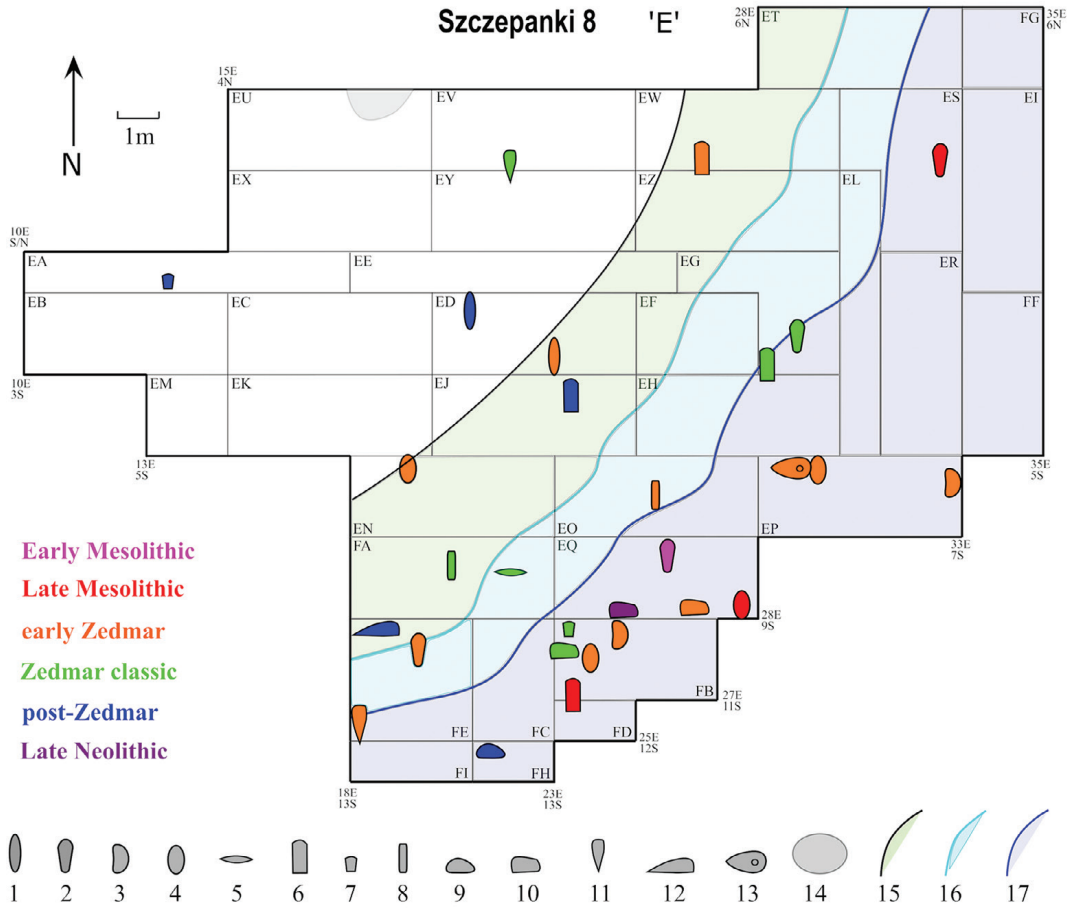


Fig. 25. Szczepanki, sector E, distribution of stone head tools:* 1 *'cigar' shaped adze-axe;* 2 *'tongue' shaped adze;* 3 *'kidney' shaped adze-axe;* 4 *'bulgy' adze-axe;* 5 *'lenticular' axe;* 6 *'flat' adze-axe;* 7 *'little' adze-axe;* 8 *'claw'-like adze;* 9 *'hump' hammer;* 10 *'axe'-hammer;* 11 *'thick-butted' pickaxe;* 12 *'dagger' pickaxe;* 13 *'almond' mattock;* 14 *pit;* 15 *island shore;* 16 *epi-littoral;* 17 *littoral lake zone (plan by W. Gumiński).

interpreted as due to the depositing of skulls over graves or at the graveyard (*Bugajska, Gumiński 2016*). It thus seems plausible that the SHT could also have been ritually deposited at the cemetery, perhaps as an identifier of the deceased or substitute for a missing person.

This supposition can be additionally substantiated by the unusual stone structure located in the centre of the cemetery. This was a heart-shaped paving (*c.* 1m in diameter), in which one of the stones was a 'tongue' adze (#10) placed on the left margin of the heart (Figs. 24,26). It was an almost intact tool, but purposely blunted at the edge (Fig. 10.b). It is significant that the heart-shaped paving did not contain human remains, although plenty of human bones were scattered over the cemetery (*Bugajska, Gumiński 2016*).

It is particularly interesting that the SHT from the shore zone at Szczepanki and at the Dudka cemetery are in about the same proportion with regard to all the SHT from the site, at 72–73%. Moreover, they are in similar condition – mainly intact or purposely blunted specimens, although at Szczepanki back halves are also numerous (Tab. 6). Apart from the tool preservation or modification, it is astonishing that within 25m along the shore at Szczepanki as many as 13 different SHT taxa occurred (Fig. 25, Tab. 6). It seems to be unreasonable that 13 diverse SHT were really required for works performed just on the lake shore, all the more so as the corresponding zone at Dudka is nearly without SHT (Tab. 6). This suggests that the south-eastern lake shore at Szczepanki was used as a ritual zone for offering SHT, just as it was practised at the Dudka cemetery, and in both cases they could be considered as a substitute for a particular person. It is significant that almost all of the deposited SHT were intact or blunted at the edge, or they are just back halves of the items. Perhaps it was important that a tool which was an offering should not be sharp.

The custom of offering SHT on the lake shore at Szczepanki was practised for a very long time – at least from the Late Mesolithic to the Late Neolithic, although it was most common in the early Zedmar (Fig. 25). In contrast, at the Dudka cemetery this ritual is only confirmed from the early Zedmar to the Late Neolithic, and was most prevalent in the classic Zedmar (Fig. 24). It should be added that the dogs and certain artefacts, such as bone and amber pendants, antler-bone tools and remarkable pots, were buried on the same shore of the lake in Szczepanki (*Gumiński 2020; 2021; 2025; Gumiński, Bugajska 2023*).

The suggestion that these tools were offerings does not mean that they were made only for ritual purposes, because they were clearly also used, as indicated by the signs of impacts at the edges, butts and walls. However, such traces could arise during daily work, but also – if they were used as weapons – in ceremonies or fights. It is appropriate to recall here that stone and flint head tools, as well as other things, were intentionally drowned in bogs or lakes in southern Scandinavia from the Early Mesolithic. Moreover, deposited items were often deliberately destroyed or exposed to unusual treatments (*Larsson 1978.163–164; 1990.286; 2011a; 2011b; Koch 1998.158,237; Sørensen L. 2014.129; Bjørnevad-Ahlqvist 2020*).

Conclusion

The Dudka and Szczepanki hunter-gatherer sites located on a former lake stand out due to the numerous SHT (75 items) that have been found there. These are exceptionally diverse in terms of taxa and other features, such as forms, kind and colour of rocks, size and mass, processing and later modification. These differences make almost every tool significantly dissimilar from the others. Unexpectedly, most of the particular traits occurred over a very long time, *i.e.* in the Mesolithic, Para-Neolithic up to the Late Neolithic, and only some secondary features, such as the shapes of the edge, sides and butt, exhibit chronological trends over time.

Fig. 26. Dudka, trench VI – cemetery, heart-shaped stone pavement with the 'tongue' adze (#10) in the left upper margin (photo by W. Gumiński).

The great diversity of SHT was not connected with the special requirements for specific implements, but primarily arose from the strong, indigenous tendency for manifesting personal individuality within local hunter-gatherer society. This trend was exhibited by exceptional differentiation of burial forms and by marking bone and antler items with individual signs (*Gumiński, Bugajska 2016; 2023*).

Almost three-quarters of the tools come from two different, but specific locations – the main cemetery at Dudka and the lake shore at Szczepanki. At both places they were ritually deposited, probably as a substitute for a deceased or lost person. If it is true, then certain features of SHT could be the emblem of a clan or family, or express personal individuality.

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Celt production processes and loci in Neolithic Greece: the evidence from the Thracian site of Makri

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ABSTRACT – *For reasons pertaining more to aesthetics than frequencies, celts represent the most studied macrolithic,* i.e. *ground stone, type from Neolithic Greece. Reports of varying length and thoroughness are available for roughly 50 assemblages. Due to archaeological biases, however, these assemblages are not evenly distributed geographically. Most derive from the regions of Macedonia and Thessaly, with other areas represented minimally or not at all. Equally important, research has shed light on the related types of raw material and acquisition methods, manufacturing techniques, aspects of use, practices of discard, as well as non-utilitarian dimensions. However, very little is known about the whereabouts of celt production. In this paper, we attempt to address both gaps by turning our attention to the northeastern region of Thrace and focusing on the celts excavated at the Middle-Late Neolithic tell site of Makri. We discuss these tools' forms, lithologies, and* chaînes opératoires*, revisit a structure identified by the excavators as a 'celt workshop', bring in relevant data from other sites, and, last but not least, problematize the celt workshop concept itself.*

KEY WORDS – *Neolithic; Greece; celts; production processes; production loci*

Procesi in prostori izdelave sekir v neolitski Grčiji: dokazi z najdišča Makri v Trakiji

IZVLEČEK – *Neolitske sekire so v grški arheologiji eden izmed najbolj proučevanih makrolitov – obdelanih kamnov – predvsem zaradi svoje estetske vrednosti, ne pa njihove pogostosti. Na voljo je različno obsežna in podrobna dokumentacija o približno 50 zbirkah. Te pa zaradi metodoloških pristranskosti v arheološkem raziskovanju niso enakomerno geografsko porazdeljene; večina prihaja iz Makedonije in Tesalije, medtem ko so druge regije redko ali sploh ne zastopane. Raziskave so pokazale povezave med vrstami uporabljenih surovin, načini njihovega pridobivanja, tehnikami izdelave, funkcijami orodij, načini njihove zavrženosti in razmerjem do standardnih velikosti. O dejanskih lokacijah izdelave teh sekir pa vemo zelo malo. V članku skušamo zapolniti obe vrzeli – tako v geografski kot tehnološki distribuciji – s poudarkom na severovzhodni Trakiji. Analiziramo neolitske sekire, odkrite na srednje- in pozno-neolitskem tell naselju Makri, s poudarkom na njihovih oblikah, petrografski sestavi in operacijski sekvenci izdelave. Ponovno ovrednotimo strukturo, ki so jo izkopavalci označili kot 'delavnico sekir', primerjamo najdbe z drugimi najdišči in podvomimo v koncept 'delavnice sekir'.*

KLJUČNE BESEDE – *neolitik; Grčija; sekire; procesi izdelave; prostori izdelave*

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In honour of Professor Nikos Efstratiou

Introduction

The field of macrolithics is notorious for its lack of standardized terminology. This applies to various functional categories, including the one discussed here: tools with a cutting edge on one end that operated in an active linear mode. For these artefacts we have chosen the term 'celts' over others – such as 'axes', 'adzes', and 'chisels' – that are commonly found in the literature. We consider such terms problematic as they imply an understanding of these tools' functions, which is not feasible without use-wear analysis.

Celts represent the first macrolithic type from Neolithic Greece to attract archaeological attention. For the better part of the 20th century, they were approached in the context of static classification systems constructed on the basis of morphological characteristics (*Tsountas 1908.309–322; Wace, Thompson 1912.23–24; Mylonas 1929.63–75*). It was only from the late 1960s, and especially since the early 2000s, that life was breathed upon these tools with a steady flow of studies exploring their raw materials, the dynamic processes of their production, their uses, practices of discard, and even symbolic dimensions (*e.g., Evans, Renfrew 1968.65–66; Oosterom 1968; Moundréa 1975.65–98; Christopoulou 1979; 1992; 2000; Moundréa-Agrafioti 1981.165–254; Winn, Shimabuku 1989.262–268; Séfériadès 1992; Sugaya 1992; 1993; Yeroussi 1999.39–64; Mould* et al. *2000.112–146; Melfos* et al. *2001.764–767; 2020.13–15; Alisøy 2002.561–562,566–572; Melfos, Stratouli 2002; Stratouli 2002.158–162; Dixon 2003a–b; Elster 2003.175–186; Strasser, Fassoulas 2003–2004; Stroulia 2003a; 2003b.572–575; 2010a.61–79; 2010b; 2018a; 2018b.212–218; 2022.324–332; Stratouli, Melfos 2008.382–385; Tsoraki 2008.45–47,62–69,76–78,84–91; 2011a–c; Lewis* et al. *2009; 2011; Chadou 2011.43–70; Chondrou 2011.57–74; 2018.84–145; 2022.250–253, 2024; Stroulia, Chondrou 2013; Bekiaris* et al. *2017; Bekiaris 2018.134–140,177–183,201–206,281–292; Almasidou 2019.63–83; Ninou 2022; Stergiou* et al. *2022*). The result has been a number of reports for approximately 50 sites, making celts the most studied of all Greek Neolithic macrolithic types.

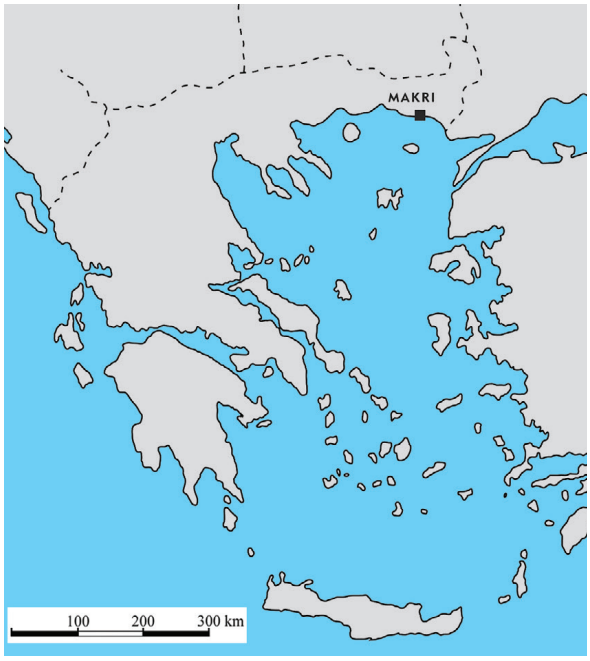

Fig. 1. Map of Greece with location of the site of Makri.

Despite this progress, serious imbalances exist. One has to do with the level of detail, with some reports being systematic, others rather superficial, and yet others consisting of no more than one or a couple of sentences. Another pertains to the geographic distribution of the studied assemblages. The majority derive from sites in the regions of Macedonia and Thessaly. Other areas are represented only minimally or not at all. Moreover, we know very little about the whereabouts of celt production. There is not much we can do here about the existing superficial studies, but we do attempt to address the other two imbalances.

Our focus is the assemblage from Makri, a Middle-Late Neolithic site in the northeastern region of Thrace where celts (as well as other macrolithic types) are essentially *terra incognita*. We discuss the technomorphological characteristics of the site's celts, their raw materials and production processes, but also carefully reexamine the evidence from a specific building interpreted by the excavators as a 'celt workshop' (*Efstratiou, Ntinou 2002.1*). In the end, we go one step further and question the usefulness of the celt workshop concept itself. Throughout the paper we adopt a comparative approach, constantly zooming in and out of the Makri assemblage as we try to assess, on the one hand, the local choices and, on the other, the trends and exceptions in Aegean Neolithic celt industries in general.

The site and the excavations

Makri is a coastal site near the homonymous village and about 10km west of the town of Alexandroupolis (Figs. 1–2). It consists of a tell located atop an abrupt

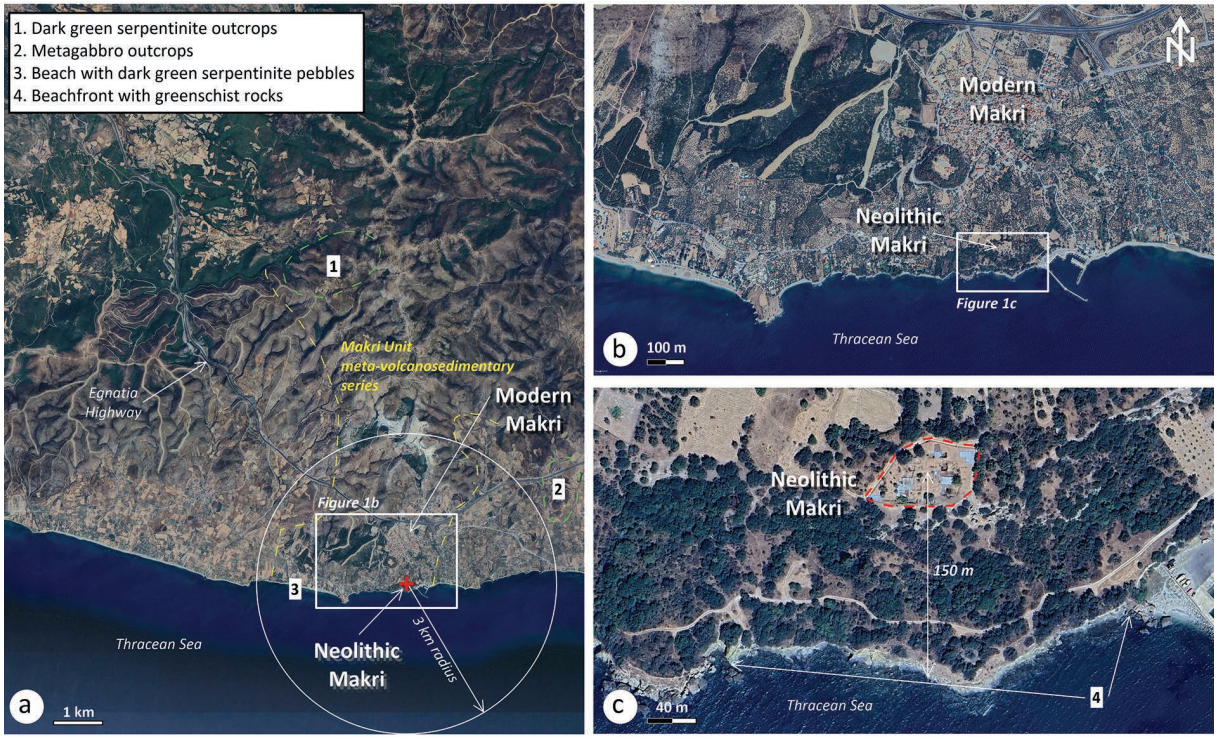

Fig. 2. Satellite images of the Marki area:* a *overview of the Makri region, showing the locations of dark green serpentinite outcrops, metagabbro outcrops, and beach deposits containing serpentinite. The area occupied by the meta-volcano-sedimentary series of the Makri Unit, mainly consisting of greenschist rocks, is outlined with yellow dashed lines.* b *close-up of the Makri region, indicating the Neolithic site's location in relation to the modern village of Makri.* c *close-up of the Neolithic site, located approximately 150m from a beachfront featuring greenschist rock formations.

travertine cliff edge overlooking the Thracian Sea and the island of Samothrace. The tell is 4m high and covers an area of 2000m². Systematic excavations by the local Ephorate of Antiquities in collaboration with Nikos Efstratiou of the Aristotle University of Thessaloniki were carried out from the late 1980s through the mid-2000s. They uncovered habitation layers dating to the Neolithic period, the Iron Age, as well as the Classical, Roman, and Byzantine eras (*Efstratiou, Kallintzi 1994.11–18; Efstratiou* et al. *1998.11–14; Karkanas, Efstratiou 2009. 955*).

Neolithic deposits were found on both the western and eastern parts of the tell (called areas A and B by the excavators) (Fig. 3). Only those on the latter part, however, were well-stratified, having largely escaped disturbances by later occupations. Over 20 trenches were dug there, making Makri the most extensively excavated Neolithic site in Thrace. Most trenches did not reach the bedrock. Dry-sieving was used for all trenches, with a fine mesh employed only for deep stratigraphic trench D8. Wet sieving was also used, but to a limited extent (*Efstratiou, Kallintzi 1994.11–18; Efstratiou* et al. *1998.11–14,24–25,47–51; Yiagoudi 2005.89,99*).

The excavations brought to light a settlement with well-preserved architectural features that, according to radiocarbon dating, spans the middle of the 6th millen-

Fig. 3. Site of Makri with marked areas A and B.

nium through the beginning of the 5th millennium BC. The stratigraphy includes two distinct depositional units separated by a thick destruction layer. They correspond to two different phases: an earlier and short-lived Makri I; a later and much longer Makri II. Identified only in one trench at the top of the mound, Makri I consists of a single habitation horizon and probably represents the remains of a small camp. Makri II, on the other hand, was identified throughout the mound and includes four habitation horizons (*Efstratiou, Kallintzi 1994.19–20; Efstratiou* et al. *1998.15–17,24–25,58; Karkanas, Efstratiou 2009.964*).

Fig. 4. View of 'complex area' at the top of the mound.

According to the excavators, the Makri II settlement presents a complex picture regarding the organization and use of space. It features three sectors with distinct characteristics, an arrangement that apparently persisted for hundreds of years. The first and central sector was designated as the 'top'. It was dominated by the so-called 'complex area', a communal space consisting of a large, possibly two-storey, post-framed wattle-and-daub structure. This structure had a fine plaster floor with half-sunken bins, a deep pit, and a well-constructed clay platform. Encircled by a post-framed wall, a section of the complex area appears to have been used for the communal storage of goods (Fig. 4). The second sector, known as the 'slope', was defined as a residential area and comprised rectangular post-framed houses with thermal features, platforms, and small storage or rubbish pits. The third sector, the so-called 'periphery', is the least excavated. It yielded a post-framed building of much larger size than those found elsewhere at the site. The character of this structure is unclear, although its contents appear typical of residential units (*Efstratiou* et al. *1998.25–26*)

The excavations yielded a plethora of artefacts, such as pottery, stone and bone tools, weaving-related implements, figurines, and ornaments. Among them are the celts and related material that make up the focus of this paper.

Numbers, provenience, and phasing

Makri yielded 230 celts and related specimens (*i.e.* unworked pieces of raw material and byproducts of manufacture). The vast majority (81%) derive from the stratified Neolithic deposits of the eastern part of the mound. Thirteen percent originate in the western part where Neolithic deposits were disturbed. The rest were retrieved from trial trenches at different spots around the site or collected on the surface. All items are treated here together regardless of provenience. Makri I is not represented in this assemblage. Most tools are securely assigned to Makri II, and this is the phase assumed for specimens found in disturbed deposits or on the surface of the site.

One hundred-seventy specimens consist of finished tools. This number includes celts whose edge was broken off or recycled to serve a non-linear function. Twenty-five (or possibly 26) are unfinished. In addition, the excavations yielded three unworked nodules of raw material that may have been intended for celts. We would not rule out the possibility that more such pieces were uncovered, but neither kept nor recorded by the excavation team (which lacked macrolithic experts). Finally, an examination of bags of chipped stone tools from deep stratigraphic trench D8 – undertaken by AS and TB for the purposes of this paper – yielded 31 flakes that presumably resulted from celt manufacture. Additional celt-related flakes probably exist in chipped stone bags that have yet to be checked.

Preservation and morphometry

Seventy-four of the finished tools (44%) are complete (or nearly so). A higher number, 96 (56%), are fragmentary.

The complete specimens range from 2.3 to 14.0cm in length ($\bar{x}$=6.5cm), from 1.2 to 4.5cm in width ($\bar{x}$=3.5cm), and from 0.4 to 3.5cm in thickness ($\bar{x}$=1.5cm).

The length/width and width/thickness ratios range from 1.3 to 4 ($\bar{x}$=1.9) and from 1.2 to 5.1 ($\bar{x}$=2.6), respectively.

Fourteen of the complete tools (19%) can be considered small, as they are no longer than 4.9cm and have an average width and thickness of 2.6cm and 1.0cm, respectively (Fig. 5). Fifty-eight (78%) can be considered as medium-sized as they are between 5.0cm and 9.9cm long, and average 3.6cm and 1.5cm in width and thickness, respectively (Fig. 6.a). Surpassing 10.0cm in length and with a mean width and thickness of 4.9cm and 2.5cm, respectively, the remaining two specimens (4%) count as large (Fig. 6.b). The data points to an overwhelming preference for medium-sized tools.

Nevertheless, a look at the fragmentary specimens, paints a more nuanced picture. Rough original length estimations have been feasible for 37 of them. Close to half (n=17) belong to large tools, a number over eight times higher than that of their complete counterparts.

Fig. 6. **a** ***faces, one side, and frontal edge view of medium-sized greenschist specimen;*** **b** ***faces and one side of large greenschist specimen.***

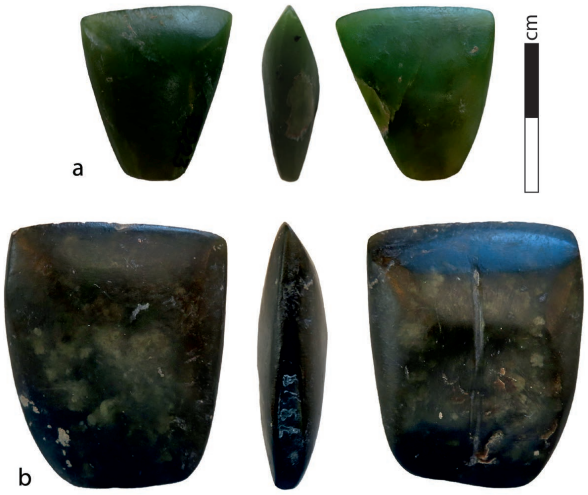

Fig. 5. **a** ***faces and one side of small serpentinite specimen;*** **b** ***faces and one side of small serpentinite specimen (traces of sawing on one face and side).***

It appears that: (1) large celts were fractured more frequently than smaller ones; (2) a more substantial percentage of celts were of large size than indicated by the complete specimens. A similar masking of the actual number of large celts by breakage has been noted at other Greek Neolithic sites such as Varemeni Goulon (*Stroulia 2018a.50–51*) and Platia Magoula Zarkou (*Stroulia 2022.324*).

A sizable quantity of large specimens at Makri should be expected. The site's construction techniques involved not only clay but also timber (*Efstratiou* et al. *1998.24–26,54*). Employed for post-framed buildings, the latter could not have been produced and processed without large celts.

The majority of small complete celts (n=12 or 80%) are trapezoidal. The rest have triangular or intermediate trapezoidal/triangular plans. Generally speaking, small specimens are not highly elongated but have flattish forms, as indicated by their average length/width and with/thickness ratios of 1.8 and 2.6, respectively. They have strongly or (more rarely) lightly asymmetrical profiles and sub-rectangular cross-sections. Their edges range from straight to (lightly or strongly) curved both in plan and frontally (Fig. 5).

Most medium-sized specimens (n=39 or 67%) are also trapezoidal. The rest have triangular or (more rarely) intermediate trapezoidal/triangular and narrow chisel-like forms. Medium-sized tools tend to be more elongated and flattish than their small counterparts, as indicated by their higher average length/width and width/thickness ratios: 2.0 and 2.9, respectively. For

the most part, they have asymmetrical profiles, while their cross-sections are sub-rectangular or (less often) subsquare, planoconvex, and ovate. Their edges are lightly curved in plan and frontally, with several nearly straight or strongly curved cases (Fig. 6.a).

Of the two large complete celts, one is triangular (Fig. 6.b), the other ovate. The forms represented among the 17 fragments that presumably belong to large tools (see above) are trapezoidal, rectangular, triangular, and (more rarely) narrow chisel-like or ovate. As far as we can tell, large specimens exhibit both the most elongated and the least flattish shapes. Asymmetrical profiles prevail in this group as well, but there is a more substantial percentage of symmetrical ones than in the other two. Most edges are curvilinear in plan and straight or lightly curvilinear frontally.

In terms of shape, the assemblage is generally dominated by thin, flattish, trapezoidal, modestly elongated tools with asymmetrical profiles and curved edges. Significantly, a strong emphasis on thin, flattish, trapezoidal forms is not known from other Aegean Neolithic celt assemblages.

Raw material types and procurement

The geology of the site's wider area comprises Late Triassic to Jurassic metamorphic rocks which are part of the Makri Unit of the Circum-Rhodope Belt. The rocks of the Makri Unit have been metamorphosed under greenschist facies conditions and are divided into: (1) a lower meta-sedimentary series consisting of marbles, dolomites, calcareous schists, and phyllites; (2) an upper meta-volcano-sedimentary series of greenschists and intrusive metadiabases and metagabbros (*Meinhold, Kostopoulos 2013.60*). The same series includes serpentinites. They outcrop north of the modern village of Makri (*Magganas 1988.234; Melfos* et al. *2001.765*) (Fig. 2.a).

Most recent lithologies include Paleogene plutonic to volcanic and sedimentary rocks, as well as Neogene travertine, alluvial, and coastal deposits (*Melfos* et al. *2001.765; 2002.651–652*). A 50m-thick sole of travertine mound appears along the coast south of the modern village of Makri, and this is where the Neolithic settlement was developed (*Melfos* et al. *2001.765*) (Fig. 2.c).

An earlier geoarchaeological project by Vasilios Melfos *et al.* (*2001.767–768*)[1] revealed that the Makri macrolithic industry employed most of the regional rock types (see also *Bekiaris 2007*). Macroscopic examination of the celt assemblage by VM and CS in the context of the current study identified three broad raw material types. Legacy thin sections of specimens representative of these lithologies[2] were studied under a ZEISS Axioskop 40 dual reflected-transmitted light polarizing microscope at the Department of Geology, Aristotle University of Thessaloniki.

Accounting for 64% (n=109) of the finished specimens, greenschist represents the dominant raw material (Figs. 6,7.a). It is followed by metagabbro (19%, n=33) (Fig. 7.b) and serpentinite (8%, n=13) (Figs. 5,7.c). Due to fire exposure or other factors, the lithologies of the remaining 9% of specimens have not been determined.

The term greenschist is highly descriptive, referring to a material of generally green colour with a proffered orientation of its mineral components resulting in schistosity. This is a fine- to medium-grained foliated metamorphic rock, predominantly incorporating the green-coloured minerals chlorite, actinolite, and epidote, and to a lesser extent albite, quartz, and calcite. Its formation is the result of regional metamorphism of mafic igneous (commonly basaltic) rocks under greenschist facies (T=300–450°C, P=1–4 kilobars) (*Bucher, Grapes 2011.33*).

In the geological literature, non-schistose greenschist is often referred to as 'greenstone' (or 'prasinite'), a term coined from the source areas of such rocks – mostly the 'greenstone belts', which include crustal-scale areas with high pressure (HP) metamorphic rocks mainly of Archaean age (*e.g., Leardi* et al. *1986.263; Bucher, Grapes 2011.33*). According to the Hoek-Brown classification model, greenschist is a strong rock (UCS = 65–85 MPa), while greenstone is very to extremely strong (UCS=120–280 MPa) (*Derbin* et al. *2019.15*).

In European archaeological literature, the term 'greenstone' often refers to rocks described as eclogite and jade, as well as omphacite schist, glaucophanite, and other HP-related metaophiolites (*D'Amico 2005.244*). For the most part, the 'greenstone' in question originated from the Alps and was used for the production of Neolithic 'axes'/'adzes' (*D'Amico 2005.236–244;*

1 This was one of the first archaeometric investigations of Greek Neolithic macrolithic assemblages.
2 The thin sections were produced in the context of the earlier project.

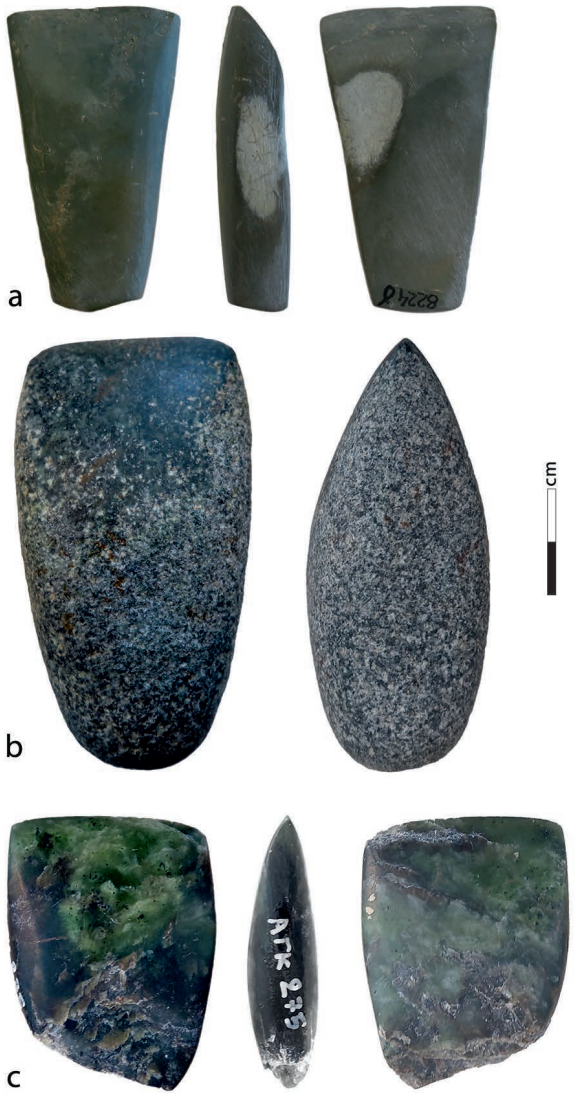

Fig. 7. Celts of the three main raw materials represented in the Makri assemblage:* a *faces and one side of medium-sized greenschist specimen;* b *one face and one side of medium-sized metagabbro specimen;* c *faces and one side of small serpentinite specimen.

Váczi et al. *2019.11–13; Giustetto* et al. *2020.158–162; Biró* et al. *2021.522)*.

Here the term greenschist is used following the narrow petrographic description (*Bucher, Grapes 2011.33*) for rocks formed under low-temperature and low-pressure metamorphic conditions, which show macroscopic and/or microscopic schistosity and originate from the meta-volcano-sedimentary series of the Makri Unit, Circum-Rhodope Belt (*Magganas 1988.282–304*) (Fig. 2.a). During the macroscopic examination of the Makri celts, distinctions between foliated and non-foliated materials were difficult to impossible, due to the implements' modified and abraded surfaces.

The greenschists used at Makri are light to dark green and compact. Common mineral parageneses include chlorite, epidote, and quartz, followed by various contents of actinolite, plagioclase, clinozoisite, titanite, calcite, and sericite (Fig. 8.a). Another characteristic paragenesis consists of prehnite, clinopyroxene, scapolite, and traces of quartz (*Melfos* et al. *2001.766*) (Fig. 8.b). The latter paragenesis is mainly associated with a greenschist variety showing amygdaloidal texture. On the basis of their minerals these greenschists have a Mohs hardness of 5.[3] Most of the studied samples retain a non-schistose texture and as a consequence have a conchoidal fracture (Fig. 8.a). By contrast, in some samples a strong orientation is observed developing schistosity (Fig. 8.b).

Provenience investigations on the basis of mineralogy and geochemistry point to local outcrops as the original source of the greenschists (*Melfos* et al. *2001.768*) (Fig. 2.a). However, these outcrops are supergene altered and were not exploited by the Neolithic inhabitants of Makri. As evidenced by excavated roughouts and unworked pieces, the used greenschists consisted of water-rolled blocks, with typically flattish, albeit not necessarily rectilinear, shapes and wavy surfaces. Such material is plentiful at the beach below the site. More specifically, the greenschist beach rocks show a blocky and disturbed rock mass with smooth and moderately weathered surfaces. These rock mass characteristics in combination with the rapid weathering of greenschist by coastal salt spray[4] produce abundant eroded material which is deposited directly in front of the coastal rocks (Fig. 2.c). The eroded debris is worn by sea waves and shaped into a significantly strong material.

Metagabbro, a metamorphosed variant of the primary igneous rock gabbro, to a large degree retains the initial textural and mineralogical characteristics (*Gill, Fitton 2022.93*). Metagabbro exhibits a wide range of uniaxial compressive strength, with values as high as 351 MPa, making it a potentially extremely strong material (*Hoek, Brown 1997.3; Segaetsho, Zvarivadza 2019.34*). On the basis of its minerals, it has a Mohs hardness ranging from 6 to 7.

3 The term 'strength' refers here to measurable mechanical properties of rocks, such as resistance to fracture or compression, which can be quantified through testing (*Hoek, Brown 1997.1*). 'Strength' is different from 'hardness', a term used in geology to describe the resistance of (mostly) minerals to surface wear or scratching. Such resistance is relatively assessed through the Mohs scale (*Gerberich* et al. *2015.2681*).

4 This is due to the effect of sea salt on chlorite (*Mottershead 1982.2*).

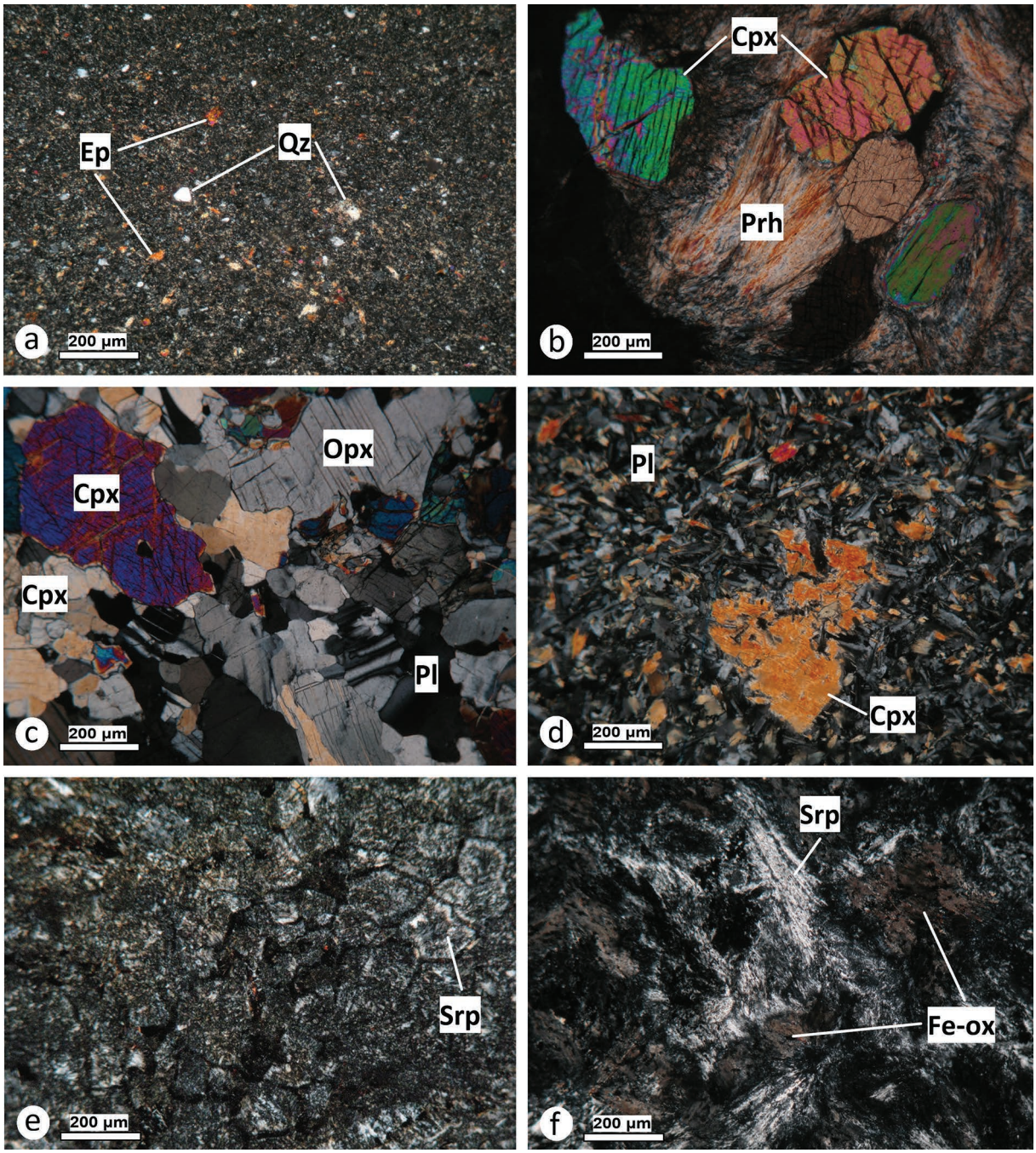

Fig. 8. Photomicrographs showing typical mineralogical paragenesis and textures (crossed-polarized light) of the raw materials used in the Makri celt assemblage:* a *very fine-grained quartz (Qz) and epidote (Ep) in greenschist specimen;* b *clinopyroxene (Cpx) and prehnite (Prh) in greenschist specimen showing amygdaloidal texture;* c *clinopyroxene (Cpx), orthopyroxene (Opx), and plagioclase (Pl) in metagabbro specimen;* d *lath-shaped plagioclase (Pl) and clinopyroxene (Cpx) developing typical diabasic texture in a metadiabase;* e *serpentine (Srp) showing the mesh-texture in a serpentinite specimen;* f *fibrous serpentine (Srp) and iron-oxides (Fe-ox) in a serpentinite specimen.

The metagabbros used at Makri have a phaneritic texture and are composed of plagioclase, clinopyroxene, biotite, minor quartz, titanite, and pyrite (Fig. 8.c). Some of the analysed samples include only euhedral lath-shaped plagioclase crystals and clinopyroxene, exhibit a typical diabasic texture, and are classified as metadiabase (or microgabbro) (Fig. 8.d). Alteration minerals include actinolite, chlorite, and sericite. On the basis of their minerals these metagabbros have a Mohs hardness of 5 to 6. Melfos *et al.* (*2001.768*) linked them to an outcrop roughly 3km to the east of the site, not far from the sea front. Water-rolled metagabbro

cobbles[5] are abundant in alluvial and torrential deposits in that area (*Maratos* et al. *1977*) and this is where they were presumably obtained in the Neolithic (Fig. 2.a-b).

Serpentinite is a metamorphic lithology produced after the hydrous alteration of ultramafic rocks, *e.g.,* peridotite (*Bucher, Grapes 2011.208–210*). It mainly comprises the serpentine group minerals (*i.e.* antigorite, lizardite, chrysotile) and magnetite (Fig. 8.e-f). Relict minerals, such as olivine and pyroxene, related to the ultramafic protoliths, may also occur (*Bucher, Grapes 2011.34*). Serpentinite is characterized by varying strength (UCS=65–200 MPa, *Derbin* et al. *2019.15*), and is classified as a strong to very strong rock (*Hoek, Brown 1997.3*). Composed predominantly of serpentine group minerals, serpentinite has a Mohs hardness of 4.

Approximately 7km north of the site, dark green serpentinite that includes antigorite, tremolite, talc, and magnetite occurs in contact with metadiabase (*Papadopoulos 1982*) (Fig. 2.a). Minor serpentinite outcrops are also found along fault zones in the meta-volcanosedimentary series of the Makri Unit mentioned above. According to Melfos *et al*. (*2001*), the serpentinite utilized in the Makri celt industry derives from the local outcrops. The flattish morphology of some of the serpentinite celts, coupled with preserved natural non-water-rolled surfaces, points to collection of pieces of raw material at the outcrops (Fig. 2.c). Other celts, however, have a more convex appearance, indicating procurement in the form of water-rolled pebbles at the beach (Fig. 5).

Whatever their type, the harvested raw materials were as close in size and shape as possible to the intended final products, or so is suggested by some of the roughouts (Fig. 9). Such a choice, coupled with the targeting of local sources, points to an efficient exploitation strategy aiming to reduce the time and energy invested in raw material procurement and manufacture.

From a comparative perspective, the following notes are in order:

❶ Local lithic sources were exploited in the context of the Makri celt industry as was the norm for Aegean Neolithic celt industries in general. For examples, see Dispilio (*Melfos, Stratouli 2002.179; Stratouli 2002. 161–162*), Varemeni Goulon (*Stroulia 2018a.51–52*), and Servia (*Mould* et al. *2000.112*).

❷ Secondary raw material sources were targeted for celts at Makri as was the rule for Greek Neolithic sites in general. For examples, see Varemeni Goulon (*Stroulia 2018a.51–52*), Franchthi Cave (*Stroulia 2003a.8; 2010.22*), and Alepotrypa Cave (*Stroulia 2018b.212*).

❸ To the best of our knowledge, the Makri celt industry is the only one in the Neolithic Aegean that routinely employed material of tabular, not round, morphology.

❹ Prevalent among Makri celts, greenschist is, with a couple of exceptions (*Warren* et al. *1968.239; Melfos, Stratouli 2002.179–181*), not known from other Greek assemblages. Rather than a prehistoric choice, this scarcity more likely reflects the small number of systematic archaeometric studies of celt assemblages.

❺ Gabbro and related lithologies were primarily used for celts at some sites such as Varemeni Goulon (*Stroulia 2018a.51*), while serpentinite was the main raw

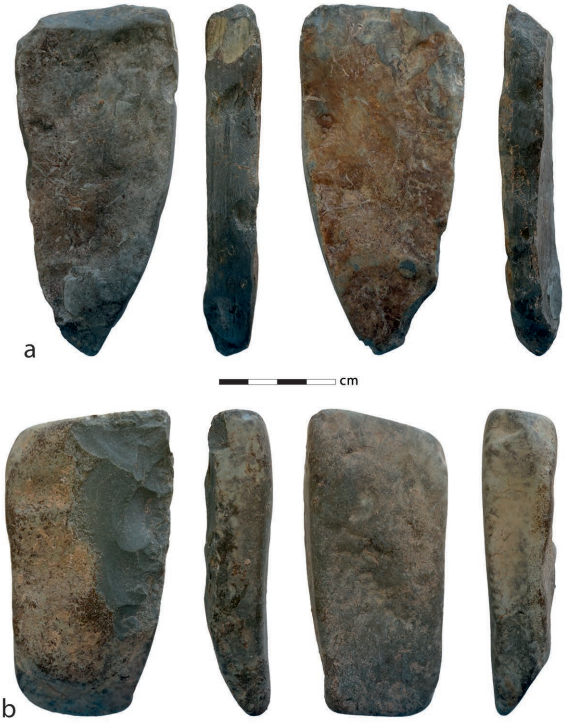

Fig. 9. **a** ***faces and sides of a greenschist celt roughout with minimal flaking;*** **b** ***faces and sides of a greenschist celt roughout with limited flaking.***

5 Following Katherine Wright (*1992.56*), the term 'cobble' is used here for a rock measuring between 6.5 and 25cm in maximum dimension, while 'pebble' is used for a rock measuring no more than 6.4cm.

material at others such as Dispilio (*Melfos, Stratouli 2002.179; Stratouli 2002.161–162*), Avgi (*Bekiaris* et al. *2017.418; Bekiaris 2018.178; Stratouli* et al. *2020.121; Stergiou* et al. *2022.8*), Kleitos (*Chondrou 2018.87–90; 2022.250*), Franchthi Cave (*Stroulia 2003a.5–7; 2010.66*), and Lerna (*Banks 2015.188*). Yet in the Makri assemblage, these lithologies are of secondary and tertiary importance, respectively.

❻ An efficient procurement of celt raw materials such as that noted at Makri has been documented at another northern Greek site, Varemeni Goulon (*Stroulia 2018a.52*).

Manufacturing techniques and processes

As is often the case with such tools, most traces of the earlier stages of the celt manufacturing sequence at Makri were obliterated by subsequent ones. However, sufficient evidence remains for a rough reconstruction. Four techniques were employed to convert rocks into tools. They are presented below:

❶ Direct percussion flaking. It represents the main reduction technique in this industry. Flaking would have been carried out with percussive tools. Globular quartz and gabbro hammers that appear suitable for such a task were recovered by the excavations (*Bekiaris 2007.53*). Antler hammers were apparently not used in this or other contexts, as there is no mention of such implements in the preliminary report on the site's osseous tool assemblage (*Efstratiou* et al. *1998.36–40*).

We have detected two flaking varieties:

(a) The first and most common consists of chipping. While a few exceptions subjected to extensive chipping do exist, roughouts or finished specimens with ghost scars indicate that only parts of the raw nodule were typically targeted. Sometimes one or both sides, or even the whole periphery, were chipped to determine the tool's plan. The faces, on the other hand, remained unaltered preserving the block's original thickness (Fig. 10.a). Other times the treatment of the raw material was exactly the opposite: the sides were left unmodified, preserving the block's plan, but one face or both were chipped to reduce its thickness (Fig. 10.b). An efficient strategy of partial flaking of raw materials of suitable shapes as the one adopted at Makri has been documented for the celt assemblage of Varemeni Goulon (*Stroulia 2018a.55*).

Makri is one of only a handful of Greek Neolithic sites with notable evidence of chipping in a celt-making context, with the others being Dispilio (*Bekiaris* et al. *2024; Bekiaris, Stratouli, in preparation*), Varemeni Goulon (*Stroulia 2018a.50–55*), Vrastero (*Chondrou 2024.275*), and Kremasti-Kilada (*Stroulia 2010b.65; Chondrou 2011.62*). More limited or sporadic use of this technique has been reported for a few other assemblages, such as Sesklo (*Moundrea-Agrafioti 1981.81*), Makriyalos (*Yeroussi 1999.61; Tsoraki 2008.64*), Kleitos (*Chondrou 2018.96; 2022.251*), Koroneia (*Almasidou 2019.63–64, 69*), Megalo Nisi Galanis (*Fotiadis* et al. *2019.30*), Mavropigi-Fillotsairi (*Ninou 2022.221, Tab. 11.7*), Servia (*Mould* et al. *2000.117; Stroulia 2018a.70*), Platia Magoula Zarkou (*Stroulia 2022.327*), Franchthi Cave (*Stroulia 2003a.9; 2010a.68*), Knossos (*Evans 1964.229*), and Saliagos (*Boleti 2009.221 cited in Chondrou 2018.127*).

(b) The second variety consists of detaching a large flake from a block to serve as a celt blank (see also *Antonović 2014.80*). It was identified through a couple of thin, flattish finished specimens with a convex-concave

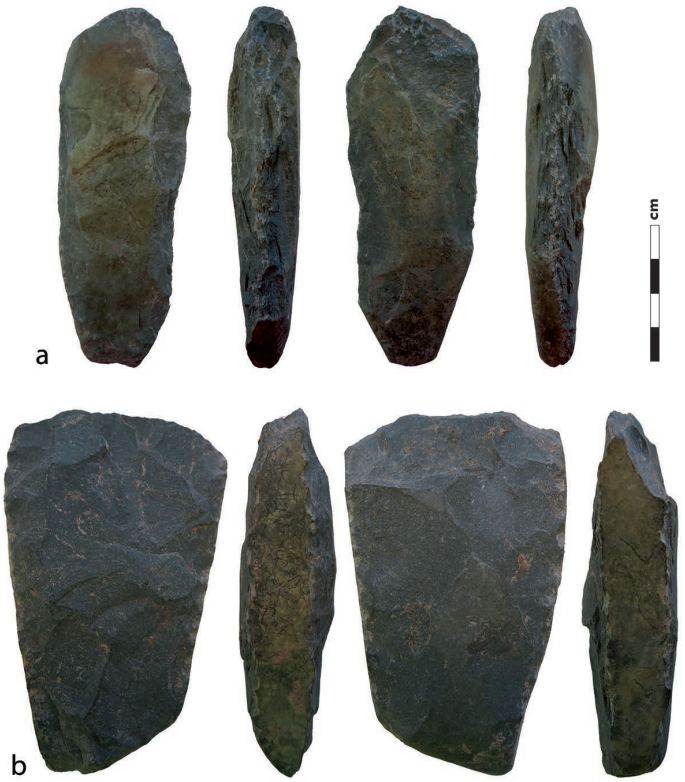

Fig. 10. **a** ***faces and sides of a greenschist celt roughout (chipped periphery);*** **b** ***faces and sides of a greenschist celt roughout (chipped faces).***

profile (Figs. 6.b,11). Actual flake blanks or cores (from which such flakes would have been removed) were not uncovered by the excavations. We assume that the use of flakes as celt blanks was rare at Makri, as it was in Neolithic Greece in general. The few examples we know of derive from Varemeni Goulon (*Stroulia 2018a.61–62*), Dispilio (*Bekiaris, Stratouli, in preparation*), Kleitos (*Chondrou 2018.94–96*), Kremasti-Kilada (*Chondrou 2011.66; Stroulia 2018a.62*), Servia (*Stroulia 2018a.62*), Knossos (*Evans 1964.186*), and Saliagos (*Boleti 2009.224 cited in Chondrou 2024.280*).

❷ Pecking. This reduction technique is slower and less risky than chipping, as only a tiny portion of raw material is crushed with each hammer stroke. It was used to give the raw material a shape as close as possible to that of the final product. The excavated globular hammers (*Bekiaris 2007.53*) could have been well suited for this technique, as they would also be for chipping. Pecking was identified in a limited number of specimens (Figs. 7.b,12). Exactly the opposite is the case with many other assemblages, in which this represents the most common reduction technique. For examples, see Stavroupoli (*Alisøy 2002.567*), Varemeni Goulon (*Stroulia 2018a.55*), and Lerna (*Banks 2015.188*).

❸ Sawing. This is represented by a single case: a small serpentinite specimen with remnants of one groove on one side and a second groove in the middle of one face. The first groove signifies division either of the raw material in the context of manufacture or of a larger celt in the context of redesigning. The second groove certainly represents a redesigning attempt (Fig. 5.b). In its almost complete lack of sawing traces, the Makri celt corpus deviates from the Greek Neolithic norm. Most assemblages carry such evidence – see, for example, Makriyalos (*Tsoraki 2008.60–62*), Avgi (*Bekiaris 2018.203,Tab. 6.29*), Servia (*Mould* et al. *2000.112–137*), Kremasti-Kilada (*Stroulia 2010b.65*), Sitagroi (*Elster 2003.183*), Kleitos (*Chondrou 2018.92–94; 2022.251*), Dispilio (*Stratouli 2002.161–162; Bekiaris* et al. *2024; Bekiaris, Stratouli, in preparation*), and Varemeni Goulon (*Stroulia 2018a.63–65*).

❹ Abrasion. This technique was universally applied as it was necessary for forming the linear edge on one of the celt's ends, *i.e.* the distinctive feature of this macrolithic type. However, with a handful of exceptions, abrasion was comprehensive as it targeted not only the distal part but also the rest of the body. Holistic as it may have been, abrasion typically was not thorough enough to entirely eliminate the natural waviness of the raw material or scars left over from the chipping stage (Fig. 13.a). This was a practical choice, as a complete erasure of surface anomalies would have increased the time and effort invested in manufacture, as well as reduced the tools' overall sizes (see also *Nami 1974.105; Chondrou 2018.99*).

Fig. 11. Faces and one side of a medium-sized greenschist celt made from a flake blank.

The surfaces of the Makri celts are smooth. According to ethnographic accounts and experimental work, such smoothness is produced through wet abrasion in the context of manufacture (*Vial 1940–1941.159; Blackwood 1950.15; Kozák 1972.20; Best 1974.72,99; Dickson 1981.41–44,153–156; Hampton 1999.93–97; Toth* et al. *1992.91; Pétrequin, Pétrequin 2020.124, 126,161*). Despite this, it is not uncommon for the smooth surfaces of the Makri celts to be crossed by clearly visible striations (Figs. 6.a,13,14.a). On the basis of our experiments, we consider the striations to be the product of a secondary (probably post-manufacturing)

Fig. 12. Faces and one side of a large metagabbro celt roughout with a pecked surface.

treatment that involved dry abrasion. It appears that this treatment was sometimes carried out with passive abrading tools, other times with active ones. In some, but not all, cases the secondary abrasion looks like it was meant to address localized damage. The use of hand-held abraders has been reported for several celts from the site of Kleitos (*Chondrou 2018.99*). It is also known ethnoarchaeologically (*Dickson 1981.156–157; Hampton 1999.93; Pétrequin, Pétrequin 2020.117, 132–133*).

One more intriguing aspect of the logistics of the Makri celt abrasion process is that the tools typically have a thin flattish appearance that is well expressed in a low average thickness and a high average width/thickness ratio. That said, one of the faces tends to be more or less flat, the other lightly convex (Fig. 7.a). This raises the possibility of abrasion on two different passive surfaces – one flat, the other somewhat concave. It is tempting to assume that the combination of a lightly convex face with a flat one aimed to determine the celt edge angle. This is not the case, however, since often the face flatness does not reach all the way to the edge. We propose two other hypotheses: (1) one face was made flat to facilitate a perfect match with a flat haft surface; (2) the lightly convex face-flat face configuration represents a stylistic choice with no functional significance.

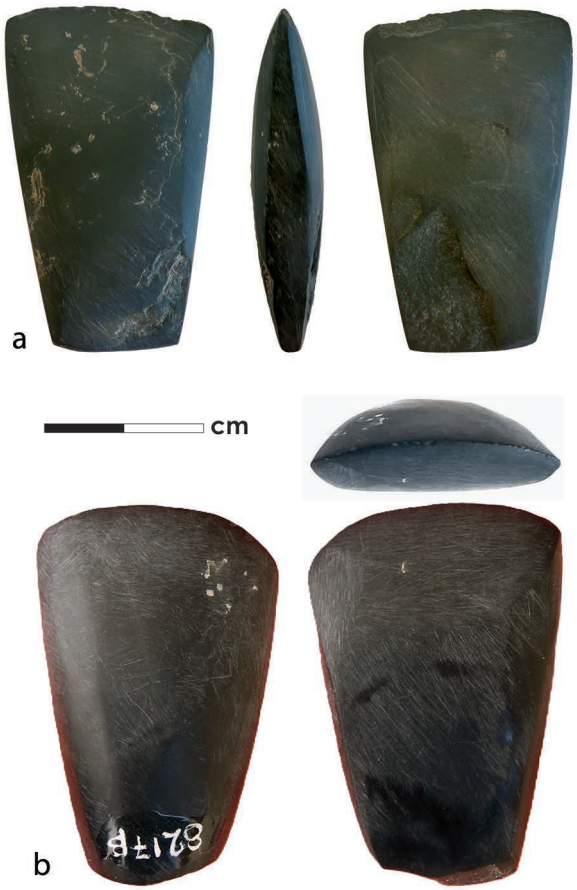

Fig. 13. **a** ***faces and one side of a small greenschist specimen (flaking scars not covered by abrasion, striated surface);*** **b** ***faces and frontal edge view of a small serpentinite celt (striated surface, dark clouds).***

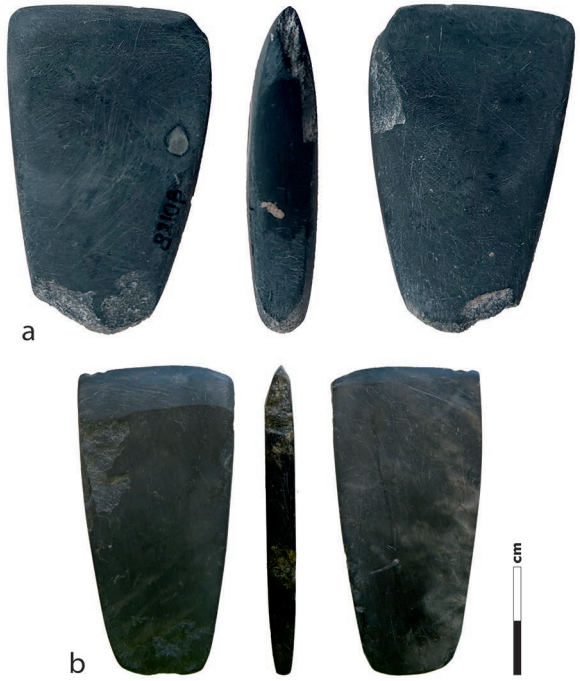

Fig. 14. **a** ***faces and one side of a medium-sized greenschist celt (striated surface, dark cloud, percussion traces on butt);*** **b** ***faces and one side of a resharpened medium-sized greenschist celt.***

Several abrading slabs were uncovered by the excavations (*Bekiaris 2007.41–45*). Whether, however, they were used for shaping celts, or other artefacts of stone, bone, wood, and shell instead, cannot be tested without use-wear analysis. We should not, on the other hand, assume that celt abrasion took place in the Makri village itself. This manufacturing stage involves water and most conveniently takes place near an aquatic source. Celt abrasion by a river, stream, or other steady water supply outside the settlement is common in ethnographic settings (see *Townsend 1969.200; Pétrequin, Pétrequin 1993.368; 2020.106,124,126,161; Hampton 1999.93–97,272–273; Stout 2002.700*).[6] We consider it plausible that the Makriotes carried it out

6 Celt abrasion inside the village with an artificial supply of water is also known ethnographically, see Elsdon Best (*1974.71–72*) and Orville W. Hampton (*1999.273*).

by the stream that until recently ran east of the tell (*Efstratiou, Kallintzi 1994.13*).

It appears that for a small number of specimens the *chaîne opératoire* consisted of a single stage of abrasion. In all other cases, abrasion represents the second and last stage of a production sequence that began with flaking or pecking.

These were not random choices. More specifically, serpentinite was treated nearly exclusively by abrasion (Fig. 5). This probably has to do with the relative softness of this lithology and the small size of the specimens made from it. With one possible exception, flaking is the only reduction technique for greenschist (Figs. 9.b,10). This is expected since greenschist is a fine-grained material with conchoidal fracture that lends itself better to knapping than pecking. Pecking, on the other hand, was exclusively applied on metagabbro (Figs. 7.b,12). This is not unexpected either, given that coarser macrocrystalline rocks are easier to peck than flake. The pattern is clear: manufacturing techniques were selected on the basis of the physical, metric, and mechanical qualities of each lithic type. The goal, again, was to maximize efficiency.

A differential treatment of different raw materials has been encountered at other Greek Neolithic industries such as those of Varemeni Goulon (*Stroulia 2018a.53*) and Platia Magoula Zarkou (*Stroulia 2022.327*). This is not surprising, as nothing but an intimate understanding of the available lithologies and their properties should be expected of Neolithic peoples.

Hafting, use, and curation

No celt hafting devices were recovered at Makri. They must have been fashioned out of wood, as were those uncovered at lakeside settlements of the Amindeon Basin in northern Greece (*Chrysostomou* et al. *2015. 30*) or others known ethnographically (*e.g., Sillitoe 1988.43–50; Toth* et al. *1992.92; Hampton 1999.72–88*).

There are various ways in which the haft could have been placed in relationship to the stone head and its edge: haft and stone head on the same plane, with the haft's long axis parallel to the edge; haft and stone head on the same plane, with the haft's long axis perpendicular to the edge; or haft and stone head on perpendicular planes. Without use-wear analysis it is impossible to specify the hafting mode. Nor should we assume that this remained stable throughout the tool's use life. Contemporary New Guinea groups, for example, haft their stone heads one way or another depending on what is needed at any one time, or in such a way that they can be rotated within their handles (*Malinowski 1934.191; Heider 1967.56; Sillitoe 1988.43–44*). Moreover, the hafting mode can change as the tools pass from one group to another in the context of exchange (*Pétrequin, Pétrequin 1993.371).*

Be that as it may, the surface of a few Makri celts bears distinct dark smooth clouds, some of which clearly interrupt striations attributed to abrasion (see above). With one exception, they are found in the mesial and proximal portions (Figs. 13.b,14.a). We suspect that these clouds are haft-related, possibly pertaining to the use of an adhesive substance or a certain friction between haft and stone head. This is a hypothesis, however, that cannot be tested without microscopic analysis.

Without such analysis it is also impossible to securely assess the functions of the Makri celts. Nevertheless, it is reasonable to assume that, with their medium size and thin flattish appearance, the majority were suitable for light duty tasks. The large, more massive specimens would have been capable of heavier tasks such as tree chopping. The fact that almost all of them are broken certainly supports this hypothesis.

Four strategies were employed to prolong celt lives: resharpening, redesigning, recycling, and reroughening.

Resharpening – in the form of one or more bevels next to the edge – was identified on 25 specimens (Fig.14.b). They represent roughly 20% of the tools retaining their distal portion. Bevels can be strong or light, and all but four specimens exhibit a single bevel on one face. The exceptions show a double bevel on one face, one bevel on each face, or a single bevel on one face and a double one on the other. No significant preference for flatter or more convex faces has been detected regarding resharpening.

Redesigning is represented with 15 cases (9% of finished tools). It comes in five versions. All but one involve chipping that cut an abraded surface and therefore cannot have been part of the manufacturing process. The first version consists of (usually bifacial) chipping of the butt and, with ten instances, is the most common (Fig. 15.a). We assume that this modification pertains to readjustment of the stone head to its haft or adjust-

ment to a new haft. Represented by two secure cases, the second version pertains to bifacial chipping of one of the tool sides. This type of chipping looks like it was meant to form a lateral edge. The edge, however, is sinuous and does not appear used (Fig. 15.b). The third version involves chipping of both sides, presumably to produce a narrower tool. The fourth consists of chipping both the butt and one side. We suspect that, like the first one, it is haft-related. The fifth and last version pertains to sawing for the purpose of division of a larger specimen (Fig. 5.b) (see above). Each of the last three versions is represented by a single specimen.

Only 19 recycled specimens were securely identified, making up 11% of finished tools. Three varieties were distinguished. Detected on 11 specimens, the first consists of abrasion that produced rounding or, more rarely, flattening of the edge or part thereof. The second, consisting of diffused percussion, involved only the butt, only the edge, or both (Fig. 14.a). There are seven such specimens, half of metagabbro, implying a certain preference for this hard and dense material regarding this kind of treatment. With a single example, the third variety combines abrasion and diffused percussion.

Fig. 15. **a** ***faces and one side of a medium-sized greenschist celt (chipped butt, reroughened side);*** **b** ***faces and sides of a large greenschist celt (one side chipped).***

The term reroughening refers here to attempts at replacing the smooth abraded surface of a side or face with a coarser one by means of pecking. Six cases of this were identified. We consider this strategy to be haft-related (Fig. 15.a).

Clearly, resharpening, redesigning, recycling, and reroughening were not routine practices in the context of the Makri celt industry. Apparently, there was no strong interest on the part of the users in extending their tools' lives. There are other sites where the above strategies were much more extensively applied, pointing to a more practical, flexible, and economizing attitude towards both raw materials and tools; see Makriyalos (*Tsoraki 2008.68*) and Dispilio (*Bekiaris* et al. *2024; Bekiaris, Stratouli, in preparation*).

Spatial distribution of finished celts

The three main sectors of the site yielded a total of 127 finished celts. The vast majority are divided between the top and the slope, with a higher percentage originating in the former than in the latter (52% *vs.* 39%). Only about a dozen (9%) derive from the periphery – not unexpected, since only three trenches were excavated there.

Fifty-two of the tools recovered from the three sectors are complete. No concentration has been detected. Excavated on floors or in the filling between floors, most can be assumed to come from interior spaces. Whether these represent use loci or, instead, contexts of storage, maintenance, or even discard we do not know at this point. Such distinctions will hopefully be clarified when the systematic study of the site's excavated spaces, features, and materials is completed and the relevant associations are drawn.

Seventy-five tools are fragmentary. There are no joining pieces, thus no celt breakage context has been identified. Intriguingly, 37 of the fragments consist of distal portions, only 19 are proximal. Why the number of proximal specimens is disproportionately low is unclear, but certainly this cannot be attributed to a tendency to redesign such pieces into smaller tools (see above). What is clear it that after breakage, a tool's distal and proximal parts were separated, followed different trajectories, and eventually ended their biographies in different spatial contexts. Some of these contexts were outside the excavated area and perhaps even outside thesettlement altogether. The discard processes for broken celts at the site were far from straightforward.

Significantly, apart from four fragments, celts are not represented in the so-called complex area – an indication that, for the most part, whatever activities took place there did not involve this tool type.

Spatial distribution of unfinished specimens and the whereabouts of celt production

With one possible exception excavated in the periphery, unfinished celts derive from the top and the slope. Four or possibly five derive from the top, while 19 originate in the slope. The distribution of unfinished specimens between the two areas is clearly uneven. Moreover, it contrasts with the distribution of finished specimens from the same areas, which is skewed in the opposite direction (see above).

While no particular concentration of roughouts has been detected at the top, a different picture is conveyed by the slope. We are referring here to the remains of a burnt rectangular post-framed building with successive lime plaster floors, a hearth, and a pit uncovered in trench D8 during the 2002 excavation season (Fig. 16). According to the excavators, this building represents a "*celt making workshop*" containing a "*complete sequence of [...] celt manufacture*" (*Efstratiou, Ntinou 2002.1–2*).[7] The discovery was described in a preliminary report, three excerpts of which are reproduced below:

"In this relatively limited space and almost together the following were found: an amount of raw material, that is, a piece of metamorphic material from the area (greenschist), a percussive tool from quartzite or some other granitoid material [...], an abrading slab from local sandstone [...], eight adzes in the process of manufacture (roughouts), seven tools made of greenschist (adzes and chisels) at various stages of manufacture (unfinished, finished, broken) [...] and finally a cylindrical clay object of unknown function with various incisions. From the whole floor a total of at least 20 adzes and chisels of various sizes were uncovered, but also debris from the flaking stage of the celt manufacturing process, as well as ten burnishers. Also, a large number of stone beads (at least 34) were found, something that possibly points to the use of this space for making other stone objects as well." (*Efstratiou, Ntinou 2002.2*)

"Also, very close to the post-framed structure an impressive rectangular platform-structure was located. Although of unknown use, it was for sure related to this space's function. [...] What is interesting is that exactly next to the platform was the dumping area of the workshop with plentiful ceramic and stone finds such as pots, burnishers, and a number of flakes." (*Efstratiou, Ntinou 2002.2*)

"Our first evaluation is that the workshop was not part of a usual domestic unit, but rather defined a specific space of specialized production at the community level, perhaps a portion of a larger workshop complex at Makri that included the production of other goods." (*Efstratiou, Ntinou 2002.1*)

This was a unique discovery for the Greek Neolithic, which has yielded a large number of finished celts, sometimes along with byproducts of manufacture, but no specific spot within a settlement where celt-making was carried out. This discovery was even more fascinating for raising questions about craft specialization and socioeconomic organization in the Neolithic Aegean.

We entirely agree with the four criteria used to identify this particular building as a workshop. These criteria

Fig. 16. Partial view of a structure interpreted as a celt workshop by the excavators.

7 The original is in Greek. All translations are ours.

refer to the presence of: (1) unworked raw material; (2) celts in different stages of manufacture; (3) tools used in the production process; (4) manufacturing waste. However, our re-examination of the evidence from this structure and the surrounding area for the purposes of this article has raised questions about the evidence itself. We summarize the results of this endeavour below, although, it should be noted that the systematic study of the stratigraphy of D8 and neighbouring trenches is still pending.

❶ The post-framed building is found not only in trench D8 but also trenches D1 and D2 (*Yiagoudi 2005.30–31*).

❷ It yielded five finished celts. All but one are complete.

❸ It also yielded nine roughouts with various degrees of flaking. Almost all are complete (Figs. 9–10).

❹ We have not located any unworked piece of greenschist, serpentinite, or metagabbro among the contents of this building. Nor did we find flakes that might represent celt manufacturing debris.

❺ The tool identified as a hammerstone, and therefore as a crucial component of the celt maker's tool kit, measures *c.* 18x8.5x5.5cm and weighs *c.* 1kg. It has a plano-convex section and its entire surface is pecked. It does not appear to have been used and can best be described as a roughout of an active grinding tool (a so-called handstone). On this basis, we would argue that no hammerstone that could have been involved in the flaking or pecking stage of celt manufacture has been uncovered in the so-called workshop.

❻ The abrading sandstone slab referred to by the excavators consists of a block measuring *c.* 14x13x11cm (Fig. 17). The work face is concave and crossed by five roughly parallel U-shaped grooves with pointed ends (two begin on opposite sides and join each other in the middle of the face). The grooves range from *c.* 2.5 to 10cm in length (the joining grooves have a total length of *c.* 13cm), from 0.3 to 0.6cm in maximum width, and from 0.2 to 0.6cm in maximum depth. An additional groove crosses the opposed face. It is tempting to see these grooves as the result of abrading celt sides, but their narrowness and steep pointed ends do not conform to the Makri celt side morphology. If not celt-related, these grooves appear to be compatible with abrading pointed bone or wooden tools. Indeed, at least five bone awls were recovered from the area of the 'workshop'. Our re-examination of the workshop's contents, on the other hand, revealed a schist slab measuring *c.* 22x19.5x1.5cm and carrying an enigmatic broken hole on one edge. We do not find the use of this slab in celt abrasion any more likely. Its raw material is not abrasive. Both faces are flattish and wavy with one showing scratches from an unidentified use. However, in a celt workshop one expects to find good quality abrading stones with extensive use-wear, since abrasion is a time-consuming stage. On these grounds, we would argue that no passive tool used in the abrading stage of celt manufacture was uncovered in the so-called workshop.

❼ The space interpreted as the workshop's dumping area yielded four fragmentary celts, four greenschist flakes, as well as one unworked piece of greenschist that, due to its large size and round shape, does not appear to have been collected for celt-making.

❽ According to the excavation journals, the so-called workshop and dumping area also yielded pottery, animal bones, carbonized grains, at least 15 burnishers, 15 bone tools, 30 blades and flakes (of flint and more rarely obsidian), 30 beads (almost all stone), and 40 complete unperforated shells intended for ornaments (on the last two categories, see also *Yiagoudi 2005. 100–101*).

As exciting as the celt workshop hypothesis may be, it does not appear convincing. Given the lack of celt production equipment, debitage, and unworked raw materials in the building in question, as well as the mini-

Fig. 17. Stone tool with face crossed by narrow grooves.

mal presence of relevant material in the surrounding space, it is hard to view this area as one where celt manufacture was undertaken on a routine basis.

If not a celt workshop, how can the roughout concentration in this building be accounted for? The most plausible alternative scenario is that the unfinished specimens entered the archaeological record when the building caught fire and as they waited to undergo the final abrading stage somewhere else. If so, these artefacts represent a case of temporary storage.

A hypothesis of temporary storage prior to (further) processing at other locations may be applicable to other materials found in the same area such as the grinding tool roughout and the numerous unperforated shells presumably intended for ornaments. The multiple excavated burnishers, probably involved in the pottery *chaîne opératoire*, may have also been stored there. If so, storage space is a more appropriate characterization for the building in question than workshop, although, we should emphasize, its domestic characteristics make a specialized function rather unlikely.

Given the hypothesis of the temporary storage of celt roughouts in a specific location at the settlement, it is tempting to go one step further and propose that roughing out took place not at the site but rather at the sources where the raw materials were obtained – mostly at the beach, the main supply of greenschist blocks. But things are slightly more complex, or so is suggested by the presence of 12 (mostly) greenschist roughouts, 27 greenschist flakes, and two unworked pieces of greenschist at the slope and to a much lesser degree at the top of the settlement. While not substantial, this material is sufficient to suggest that some greenschist blocks were taken to and knapped at the site.

If our understanding is correct, the Makri celt production sequence comprised:

❶ obtaining greenschist blocks at the beach;
❷ knapping most blocks at the beach and taking the resulting roughouts to the village; taking other blocks to the village for flaking;
❸ storing the roughouts at this or that spot in the village;
❹ taking the roughouts to a nearby water source – possibly the stream located outside the settlement – for the finishing abrading stage;
❺ attaching the stone heads to hafts at this or another location inside or outside the village.

Our discussion focused on greenschist since this is the main lithic type of the Makri celt industry. The *chaîne opératoire* must have been somewhat different for metagabbro since this was not sourced at the beach and not flaked. Likewise for serpentinite, which was sourced partly at the beach but underwent a single abrading stage.

In the previous paragraphs we deconstructed the hypothesis of a celt workshop at Makri. Does this automatically discredit the excavators' claim regarding celt craft specialization at the site? Not necessarily. A careful reading of ethnoarchaeological accounts on various celt-making New Guinea groups forces us to decouple celt manufacture specialization from workshops. These accounts do not include references to celt workshops even when (part-time) celt-making specialists are a definite part of the picture (*e.g., Toth* et al. *1992.88; Stout 2002.696–700; Pétrequin, Pétrequin 2020.141–161,169,234*). This is because celt craft specialization is not defined by the place where celt manufacture is carried out, but rather by the long apprenticeship it takes to become an expert, the complex technical skills, knowledge, and experience experts possess, the challenging characteristics of their finished products, and even the rituals they perform at different stages of the celt production sequence (*Stout 2002.696–711; Pétrequin, Pétrequin 2020.143,232*).

Any information on potential specialist-related rituals or apprenticeships at Makri is beyond our reach. The characteristics of the celt assemblage are, however, quite eloquent. There is nothing too complex or extraordinary in the tools' raw materials, forms, and sizes that would have required a high level of technical expertise. The raw materials were local and would have been easily acquired. Of the identified manufacturing techniques, flaking is the most technically demanding and requires some form of training. The ability to flake stone, however, was mastered by a large number of individuals at Makri, as suggested by the widespread distribution of lithic debitage all over the site (*Efstratiou* et al. *1998.43*). Moreover, more than ten excavation seasons yielded fewer than a couple of hundred specimens for a site that spanned several centuries. Assuming that finished tools did not leave the site in large numbers in the context, for example, of exchange, the celt output was not particularly large. The relatively simple technical know-how involved in celt-making coupled with an easy raw material acquisition method and a modest production scale argue against celt craft specialization at Makri.

That said, two notes are in order: (1) The assemblage displays a certain homogeneity as attested in the emphasis on greenschist, medium sizes, and flattish trapezoidal shapes. All aspects of this homogeneity, however, can be easily interpreted as culturally specific choices that were passed from generation to generation rather than evidence of craft specialization. (2) A non-specialized celt production does not rule out a specialization by gender in the making and/or use of these tools as is encountered ethnoarchaeologically. Among many New Guinea groups, for example, celts are exclusively or primarily associated with men (*Strathern 1970.327; Godelier, Garanger 1973.197; Pétrequin, Pétrequin 1993.363; 2020.43–49*).

Evidence of celt production in the Neolithic Aegean

Throughout this paper references were made to other sites placing the Makri celt assemblage in its Greek Neolithic context in terms of technomorphological characteristics, raw materials, manufacturing processes, and curation strategies. In this section, we adopt a similar comparative approach regarding evidence of celt production.

Makri is one of seven sites with significant amounts of celt manufacturing debris. The other six are:

❶ Dispilio (Kastoria region, west Macedonia). This lakeside site was targeted by a multi-year systematic excavation. Among the enormous quantities of finds are approximately 700 finished celts and 300 specimens consisting of roughouts and other byproducts of manufacture. The raw material consists for the most part of serpentinite. This was obtained from a nearby outcrop, making this a rare case of primary source exploitation for celt raw material known from Neolithic Greece. The harvested nodules were converted into tools through sawing, flaking, and abrasion (*Melfos, Stratouli 2002.176,179; Stratouli 2002.161–162; Bekiaris* et al. *2024; Bekiaris, Stratouli, in preparation*).

❷ Varemeni Goulon (Kozani region, west Macedonia). The celt assemblage of this riverside site was retrieved through unsystematic surface collection by non-archaeologists and (to a lesser extent) salvage excavation. It comprises approximately 460 finished tools, over 850 unfinished specimens, and hundreds of byproducts of manufacture. The raw materials were obtained by the river. Six manufacturing techniques were identified in this industry: flaking, pecking, sawing, splitting, abrasion, and drilling. Over 100 hammerstones were retrieved from the site, but almost no abrading tools (*Stroulia 2018a*).

❸ Kremasti Kilada (Kozani region, west Macedonia). The celt assemblage comprises over 300 finished specimens, 150 roughouts, and 150 flakes, as well as pieces of raw materials and relevant production refuse. All were retrieved by salvage excavation in secondary contexts: pits and (to a lesser extent) ditches located near an unexcavated mound that presumably represents a residential area. The raw materials were procured at both local and extra-local sources. Manufacture involved flaking, pecking, sawing, splitting, abrasion, and drilling (*Stroulia 2010b.64–65, 2018a.62; Chondrou 2011.57–74; Stroulia, personal observations*).

❹ Megalo Nisi Galanis (Kozani region, west Macedonia). The site was investigated through (limited scale) systematic excavation and surface survey. With only 31 securely identified specimens, the celt assemblage is really small. However, five (16%) consist of roughouts. Roughly 15 flakes and other byproducts of celt manufacture were uncovered as well. The main lithologies – serpentinite and gabbro – were collected at local and regional sources. Pecking, flaking, sawing, and abrasion are the identified manufacturing techniques (*Stroulia 2003b.572–575; Fotiadis* et al. *2019.30; Stroulia, personal observations*).

❺ Vrastero (Grevena region, west Macedonia). Recently investigated through surface survey and small-scale excavation, the site yielded hundreds of celt roughouts and relevant byproducts of manufacture, with a much smaller number of finished products. Local ophiolithic materials were employed. Flaking was the main reduction technique, but pecking was also employed. Apparently, abrasion was not carried out on-site (*Chondrou 2024.275; Chondrou* et al. *2024*).

❻ Sesklo (Volos region, Thessaly). The celt assemblage has not been published systematically, thus its size remains unknown. Be that as it may, a report mentions a concentration of five pecked roughouts and seven finished celts in one area, with an unspecified number of additional unfinished tools excavated around the site (*Tsountas 1908.316*). The manufacturing techniques consist of pecking, sawing, flaking, and abrasion (*Moundréa-Agrafioti 1981.180–184*).

Comparisons among the above sites are not easy given substantial differences in methods of recovery, extent

and dating of investigated areas, amounts of recovered material, proximity to lithic sources, *chaînes opératoires*, thoroughness of reporting, *etc.* These caveats notwithstanding, the large scale of celt production at Dispilio, Varemeni Goulon, and Vrastero is clear. In fact, at these sites the output appears to have surpassed what would be sufficient to cover the needs of the community. Export to other settlements has been proposed in all cases (*Chondrou 2018.129–130,418; 2022.251–252; Stroulia 2018a.69–70; Bekiaris* et al. *2024; Chondrou* et al. *2024; Bekiaris, Stratouli, in preparation*).[8] Intriguingly, all three sites are located in west Macedonia. Whether this concentration is real, or an artefact of the extra attention paid to this part of Greece by macrolithic experts for the last two decades, we cannot tell.

The substantial celt production refuse uncovered at Makri and the above sites is of course fascinating. What is intriguing is how few of these sites there are. Elsewhere, securely identified celt manufacturing debris are rather limited – see Makriyalos (*Tsoraki 2008.76–78, Figs. 4.4–4.5, Tabs. 4.51–4.53*), Kleitos (*Chondrou 2018.103–104,126*), Franchthi Cave (*Stroulia 2003a.4; 2010a.65*), Nea Nikomedeia (*Rodden 1962.279*), and Servia (*Mould* et al. *2000.112–146; Stroulia 2018a.70; Stroulia, personal observations*). At yet other sites, the evidence is practically non-existent; see Avgi (*Bekiaris* et al. *2017.425–426*), Dikili Tash (*Séfériadès 1992.84,86*), Platia Magoula Zarkou (*Stroulia 2022.327*), and Alepotrypa Cave (*Stroulia 2018b.215*).

The scarcity or complete absence of celt production waste from the majority of Aegean Neolithic sites could be attributed to archaeological biases, since most were only partially excavated. It could also be explained through an import of finished products from elsewhere. Finally, there is a third (and perhaps more plausible) hypothesis: the bulk of celt production took place locally, but outside the settlement. In fact, we consider this last scenario as the most satisfactory for Kleitos. This large and fully excavated site yielded around 900 finished specimens – only a small fraction of which are suspected to be imports – but extremely limited quantities of unfinished specimens and manufacturing debris (*Chondrou 2018.106,126,129–130; 2022.251–252*).

Epilogue (beyond celt workshops)

In this paper, we approached the Makri celt industry at two levels. First, we discussed raw material types and procurement methods, technomorphological characteristics, production processes, and curation. Comparisons with other Aegean Neolithic sites revealed that: the Makri celt assemblage is unusual in its pronounced use of water-rolled blocks of greenschist and emphasis on thin, flattish, medium-size, trapezoidal forms; this is one of a small number of assemblages where flaking plays an important role in the manufacturing process; celt curation was not as widespread a practice as it was at some other sites. Secondly, we reviewed the evidence from a specific Makri building that yielded a concentration of celt roughouts, deconstructed the interpretation of this structure as a celt-making workshop, and briefly presented the few other sites with significant evidence of celt production. In this last section, we go one step further to deconstruct the celt workshop concept itself.

We argued above that three of the four criteria used by the excavators to identify the aforementioned Makri structure as a workshop – unworked celt raw material, tools used in the celt production process, and celt manufacturing debris – were not met. We concluded that there was not enough evidence to support this interpretation, and thus it should be abandoned.

However, a reality check from the realm of ethnoarchaeology suggests that the rationale used by the excavators to support the identification of the above Makri structure as a celt workshop, the same rationale that we used to debunk this identification, might have been flawed – and thus we and the excavators were perhaps both wrong. Let us explain: depending on the case, ethnographic accounts of celt-making may or may not make references to celt specialists and craft specialization, but almost never mention workshops. This, we believe, is the reason why – celt manufacture represents a complex process, which involves acquisition of raw material, testing the raw material, flaking and/or pecking and/or sawing, abrasion with the help of water, and hafting that involves wooden shafts and binding material, all steps taking place at this or that location. An example from the Langda village of Irian Jaya, New Guinea, aptly illustrates this point. The Langda live on a plateau. The celt manufacturing sequence

8 For a network of Vinča communities engaged in circulation of celts in different stages of manufacture, see Selena Vitezović and Dragana Antonović (*2020.45–46*).

begins at the bottom of a river valley where suitable raw material is obtained, is tested, and receives an initial flaking. Knapping continues at the field huts where the celt makers spend a couple of nights on their way back to the plateau. When back on the plateau, they complete the process of flaking, carry out abrasion with the help of water, usually outside the compounds, and haft the stone heads wherever the necessary hafting materials are available (*Toth* et al. *1992.89–92; Hampton 1999.257–273; Stout 2002. 696–700; Pétrequin, Pétrequin 2020.235–237*). What is conveyed by this picture is not the presence of a workshop but rather a spatial 'segmentation of the *chaîne operatoire*' (*Pétrequin, Pétrequin 2020.235*).

On this basis, would it perhaps be wiser to stop thinking in terms of workshops where celt making took place in prehistory and relevant evidence was deposited? Would it perhaps be more appropriate to start looking for what we would call celt production loci, in which different steps of the manufacturing sequence were carried out? The production loci concept would better fit the picture we have from Makri, where different celt-making stages appear to have taken place at various locations. It would also be more suitable for Dispilio, where sawing was used to detach blocks of raw material at the source, while sawing for the purpose of division along with other techniques were applied at the settlement (*Stratouli 2002.161–162; Bekiaris* et al. *2024; Bekiaris, Stratouli, in preparation*), as well as Vrastero and Varemeni Goulon where flaking and pecking were carried out on-site but abrasion apparently was not (*Stroulia 2018a.53; Chondrou* et al. *2024*). Beyond Greece but still in the neighbourhood, 'production locus' appears to be a more appropriate designation for an area called 'workshop of an axe-maker', at the Serbian site of Divostin, from which a large volume of chips from flaking celt raw material but no abrading tools were reported (*Prinz 1988.258–259*); or the so-called 'axe-workshop' at Selevac, also in Serbia, which yielded celt blanks and debitage, but, again, no abrading implements (*Voytek 1985.262*).

An archaeological approach based on the production loci concept better accommodates the picture offered by ethnoarchaeology and helps avoid awkward interpretations of areas with only partial evidence of the celt manufacturing sequence as workshops. As such, it better serves our goal of drawing ever more accurate and realistic portrayals of prehistoric realities.

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Obsidian treatment technology in the Lengyel culture. Case study on the settlement of Kiarov-Veľké ortovisko site (South Slovakia)

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ABSTRACT – *The article examines the treatment technology of the obsidian chipped stone industry, which, like the other findings, is mostly obtained from the major feature B15. The remains of an oven with a dome-shaped vault were also discovered inside it. Obsidian has an extremely high ratio among raw materials used in tool manufacturing at the monocultural site, accounting for 62% of the assemblage. All phases of its processing are present, allowing the reconstruction of technology. Obsidian is commonly used in the Lengyel culture sites in south and southwest Slovakia, but it is usually found in smaller quantities because it is a raw material obtained from a considerable distance. Until now, the more abundant assemblages have received insufficient evaluation in Slovakia. Kiarov is distinguished by the presence of miniature cores, which were utilized primarily to produce tiny bladelets, likely used as parts of more complex tools. In addition to obsidian, Tevel-type flint, limnosilicite, and silicite from the Kraków-Częstochowa Jurassic were used in the manufacture of tools. These raw materials yielded larger blades. The Kiarov-Veľké ortovisko site demonstrates the different usage of several raw materials.*

KEY WORDS – *Slovakia; Kiarov Veľké ortovisko; Lengyel culture; chipped stone industry; obsidian; technology*

Tehnologija obdelave obsidiana v Lengyelski kulturi. Študijski primer na najdišču Kiarov-Veľké ortovisko (južna Slovaška)

IZVLEČEK – *V članku preučujemo tehnologijo obdelave obsidiana, ki je bil tako kot večina ostalih najdb odkrit v strukturi B15. V njej so odkrili tudi ostanke peči s kupolastim obokom. Obsidian predstavlja kar 62% zbira. Vidne so vse faze njegove obdelave, zato je mogoče rekonstruirati tehnologijo izdelave orodij. Obsidian so na najdiščih Lengyelske kulture na južnem in jugozahodnem Slovaškem pogosto uporabljali, vendar ga običajno najdemo le v majhnih količinah, saj je kot surovina prihajal z oddaljenih območij. Večji zbiri obsidiana na Slovaškem do sedaj še niso bili zadovoljivo ovrednoteni. Za Kiarov so značilna miniaturna jedra, ki so jih uporabljali predvsem za izdelavo drobnih rezil, verjetno kot dele kompleksnih orodij. Pri njihovi izdelavi so poleg obsidiana uporabljali kremen tipa Tevel, limnosilicit in silicit z gorovja krakovsko-čenstohovske Jure. Iz teh surovin so izdelovali večja rezila. Najdišče Kiarov-Veľké ortovisko tako dokazuje različno uporabo več surovin hkrati.*

KLJUČNE BESEDE – *Slovaška; Kiarov-Veľké ortovisko; Lengyelska kultura; odbitkovna kamnita industrija; obsidian; tehnologija*

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Introduction

The Lengyel culture settlement and subsistence in central eastern Europe developed around 4900/4800 BC, in the Late Neolithic (*Manning* et al. *2014.1077; Regenye* et al. *2020.49–54*). Its primary territory was in Transdanubia and southwestern Slovakia (*Pavúk 2007; Barna 2017*). The culture is named after the eponymous site at Lengyel–Sánc in Hungary excavated in the 1880s (*Wosinszky 1889–91*). The Classic Lengyel culture phase is characterized by a characteristic material expression and maximum territorial expansion (secondary settlement territory) extending to Austria (Moravian–Eastern-Austrian group) and Moravia (Moravian Painted Pottery culture) in the west and to the periphery of eastern Slovakia in the east (*e.g., Pavúk 1981.257–259; Ruttkay 1995; Čižmář* et al. *2004.209; Stadler* et al. *2006; Stadler, Ruttkay 2007*). The end of the Classic Lengyel culture falls in the interval 4450–4300 BC (*Diaconescu 2014.30,39,Fig. 26,Tab. 1*).

The Classic Lengyel culture in Slovakia is well known for its decorated ceramic pottery featuring painted or incised designs, settlements sometimes with roundels, large two-room houses, burials with bodies in a flexed position on their sides, or occasional cremation in flat cemeteries or within settlements. The amount of research on the culture in Slovakia has increased since its initial discoveries in the 1930s. Many significant scholars, including Anton Točík and Ján Lichardus (*1966*), Jozef Vladár (*Lichardus, Vladár 2003*), Viera Němejcová-Pavúková (*1995; 1997*), and the still-active Juraj Pavúk (*1981; 2007; 2023*), are linked to the study of the Lengyel culture in Slovakia. The study of the chipped stone industry is an important aspect in understanding this culture, as it plays a significant role in answering issues pertaining to the development of specialized craft activities and long-distance communication. Of the sites that have relevant chipped stone industry, only a few have had comprehensive material analyses, mostly in the previous century (*e.g., Kaczanowska 1985*; *Cheben 1986; 1993*; *Kaczanowska, Kozłowski 1991; Březinová* et al. *1994.33–45; 2002; Hovorka, Illášová 1999; 2002; Kuzma* et al. *1999; Cheben, Cheben 2010; Kuzma, Cheben 2012*). However, the published research focuses more on the base of raw materials than on the material's technical and typological aspects. Recent studies are gradually shedding light on regional differences in the methods used to acquire raw materials and their production procedures, and we are interested in adding our own contribution to this growing collection of expertise.

Introduction of the Kiarov-Veľké ortovisko site and the aim of the study

An archaeological excavation was carried out along the linear structure of the high-pressure gas pipeline DN 800 Slovak Republic – Hungary in a total length of 18.8km (in the territory of Slovakia) in the central Ipeľ river valley in 2013. The structure crossed cadastral areas of nine villages (Veľké Zlievce, Malé Zlievce, Glabušovce, Zombor, Olováry, Kiarov, Želovce, Záhorce, Slovenské Ďarmoty) in the district of Veľký Krtíš. The excavation was executed by the Institute of Archaeology of SAS in Nitra, its branch in Zvolen, and led by Jan Beljak (*Beljak Pažinová, Beljak 2014*). Within the construction, four prehistoric sites (Fig. 1.A) with settlement relics of the Lengyel culture were identified in the northern and northwestern parts of the Kiarov cadastral area. The site of Veľké ortovisko with 15 features in total (Fig. 1.B) belongs to the Classic Lengyel culture phase. At the site, an area of 50×25m was investigated; the subsoil consisted of yellow loess (clayey). The features were situated on a rather steep convex slope with an eastern exposition, with the altitude varying between 185.7 and 195.2m. Four features did not contain any archaeological discoveries. As for the number of finds (around 12 000), the Kiarov-Veľké ortovisko site belongs to the richest Classic Lengyel culture settlements in central Slovakia.

The article primarily deals with the complex analysis of a selected type of chipped stone industry – obsidian (388 items; Tab. 1) from the Classic Lengyel culture site of Kiarov-Veľké ortovisko. The chipped stone industry made of other raw materials is partly included to create a complex picture of the assemblage and emphasize technological differences. In general, chipped stone industry (605 items) was found in the fill of ten features on the site. Features B11 (61 items) and B7 (37 items) can be considered features with high numbers of chipped stone industry. Sixteen specimens were found in feature B10, nine come from feature B6, and seven are from B5. Two finds of chipped stone industry were discovered in feature B12; the fill of features B2, B4 and B9 contained one exemplar each. A small number (20 items) from the analysed finds does not come directly from the fill of the features; they were detected as stray finds at the site. The obsidian stray finds (11 items) were also included in the analysis.

Feature B15 (Fig. 2) is exceptional in terms of size, depth, and number of finds. It contained up to 470 specimens of the chipped stone industry (including some

300 fragments of obsidian). The feature itself (length x width x depth: 6.2×5.0×1.9m) was a rather deep pit with an irregular oval ground plan and walls narrowing towards the irregular bottom with several depressions. During the excavation, the pit was divided into three parts and examined in stages. On the northern and eastern sides of the feature, the wall went slightly below the edge of the mouth; on the western side, the wall was convexly narrowing towards the bottom; on the southern side, the wall of the pit was rugged and almost perpendicular. The feature bottom was strongly rugged; in the upper third, there was a large (approx. 2.6×1.8m) shallow depression; in the centre of the feature, there was a small depression with a washbasin-shaped bottom – a stake hole? The fill contained a great quantity of daub (more than 800 fragments of max. 10×10cm), which included imprints of construction elements (almost on a fifth of them), mainly wattle. Fragments of daub with a rounded surface as well as narrow pieces with a smoothed surface on one side were identified as the remains of a dome-shaped oven covered with earthen plaster (*Jančiová 2016.37, Tabs.*

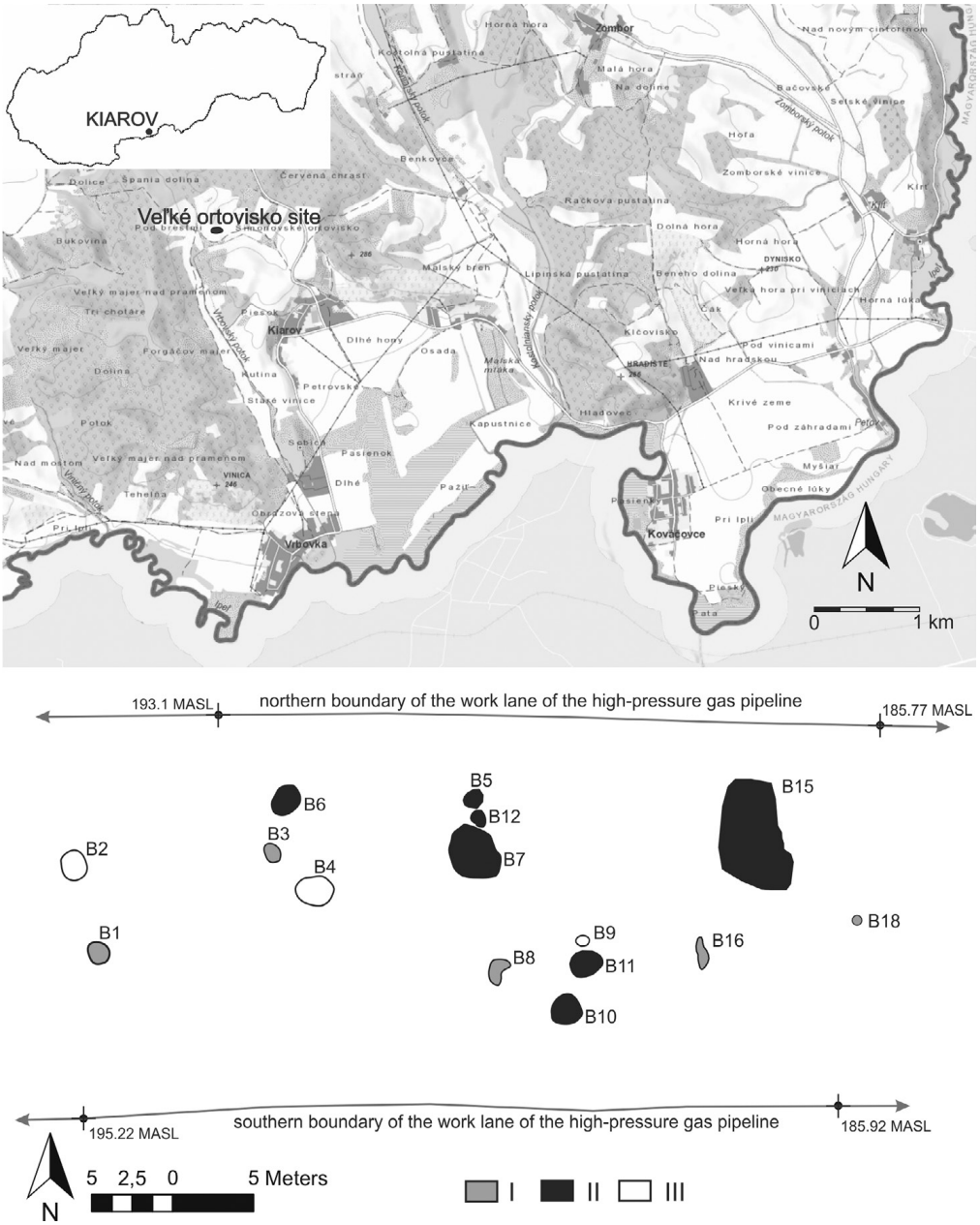

Fig. 1. Map of Slovakia showing the location of Kiarov-Veľké ortovisko site (inset) and the distribution of features on the site.* I *features (B1, B3, B8, B16, B18) without any chipped stone finds;* II *features (B5, B6, B7, B10, B11, B12, B15) with obsidian fragments in the fill;* III *features (B2, B4, B9) with chipped stone industry except obsidian.

No.	Feature No.	Flakes	Blades	Retouched blades	Cores	Debris	Total
1	B5	0	4	0	0	0	4
2	B6	3	1	0	1	0	5
3	B7	4	15	1	1	0	21
4	B10	5	4	1	0	0	10
5	B11	14	10	4	4	3	35
6	B12	0	1	0	0	1	2
7	B15	91	136	15	29	29	300
8	stray finds	4	2	3	2	0	11
	Total	**121**	**173**	**24**	**37**	**33**	**388**

Tab. 1. Kiarov-Veľké ortovisko site. Representation of technological groups of the chipped obsidian industry in individual features.

5, 7). A heavy black/sooty clay–loam–humus layer mixed with charcoals and daub was detected at several spots within the fill of the feature. Feature B15 represented the sunken part of an unknown structure with a dome-shaped oven. However, its exact function remains unknown.

Investigation of Neolithic assemblages with obsidian industry in Slovakia

Obsidian as a raw material for chipped stone industry manufacture occurs at Neolithic settlements quite frequently. As a local raw material, it was primarily important for eastern Slovakia. The Eastern Linear Pottery culture used obsidian at the very beginning of its origin. Use of this raw material continues intensely in the Bükk culture and the Csöszhalom-Oborín group; it later occurs in the Tiszapolgár culture (*Kaminská 2018.204–205*). Thanks to its properties, obsidian was also extensively imported (*Burgert* et al. *2016; 2017; Wilczyński 2016*). In western and central Slovakia, other raw materials dominate in Neolithic assemblages; nevertheless, it is an important element at many settlements (*Šiška 1989.77*). In the early stage of the Linear Pottery culture, its occurrence is sporadic, although it becomes more common mainly in the Želiezovce group environment (*Cheben 2020.202; Cheben, Cheben 2021*). The Lengyel culture mostly processed obsidian in its early years, and later its occurrence became rarer (*Kaminská 2021.244*).

A review of the intensity of obsidian use in Slovakia from the Palaeolithic to the Bronze Age is provided by Ľubomíra Kaminská (*2018; 2021*). Nevertheless, a unifying view of the technological procedures used in working with this raw material and records of changes in time or various geographical territories are absent. Obsidian itself is a very specific raw material of high brittleness and sharpness. It can be supposed that its importance and status at some Neolithic settlements was special, and the method of its processing was different from that used with other raw materials. Naturally, this is influenced by the distance and access to its sources in the Zemplínske vrchy hills and the adjacent Tokajské vrchy hills. The best-quality obsidian is located on the Slovak side (*Furholt 2024.11*), and was most used by the prehistoric communities in the eastern part of central Europe (*Werra* et al. *2021*).

The technology of the manufacture of chipped stone industry from the Late Stone Age has not been evaluated in detail in Slovakia. The region of central Europe

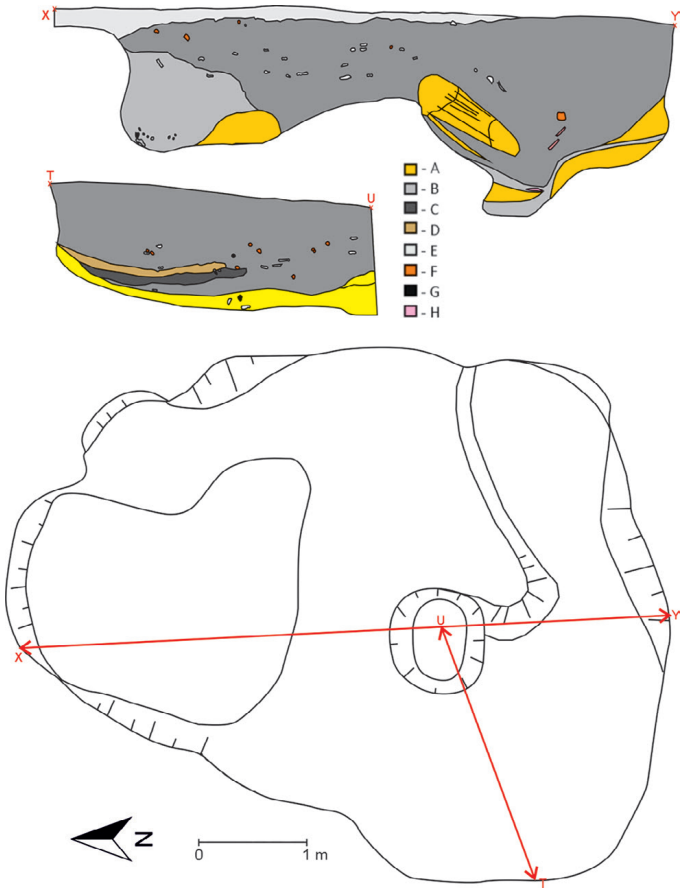

Fig. 2. Kiarov-Veľké ortovisko site. Profiles and ground plan of feature B15. Feature fill:* A *mixed lighter brown-yellow layer,* B *clay-humus layer mixed with charcoals and daub,* C *layer mixed with charcoals,* D *lighter layer,* E *rock,* F *daub,* G *charcoal,* H *pottery.

is dealt with in an earlier work by Małgorzata Kaczanowska (*1985*), who evaluates the characteristics of the industry and distribution of raw materials in the environment of the Western and Eastern Linear Pottery cultures, as well as the Lengyel and Polgár territory. Older works include the evaluation of the chipped stone industry of the Eastern Linear Pottery culture by Małgorzata Kaczanowska and Janusz K. Kozłowski (*1997*; *2008*). Among more recent studies, the still unpublished manuscript of a dissertation by Michal Cheben (*2020*) is important, as it deals in detail with assemblages of the Linear Pottery culture in southwestern Slovakia.

There are also a number of separately evaluated eastern Slovakia sites that contained obsidian industry, *e.g.,* Šarišské Michaľany (*Kaczanowska* et al. *1993*) and Moravany (*Kaczanowska* et al. *2003; 2015*). Zemplínske Kopčany, Čečejovce and Prešov-Šarišské lúky were processed in an older study by Kozłowski (*1989*). As for the turn of the Neolithic and Eneolithic in Východoslovenská nížina lowlands, the study of the Csöszhalom-Oborín group settlement in Hrčeľ-Nad baňou is relevant (*Kaminská 1987; Kaminská, Pelisiak 1991*).

A more detailed technological analysis and reconstruction of procedures in the treatment of obsidian was published for the Bükk culture settlement in Humenné in eastern Slovakia (*Kaczanowska, Kozłowski 2002*). It is a culturally homogenous and rich assemblage that contains all the necessary categories, and it is almost totally dominated by obsidian. In terms of the Bükk culture, the findings from the Kašov-Čepegov site in Východoslovenská nížina lowland were evaluated in detail. The site became known thanks to an assemblage of large obsidian cores and regular blades, which were supposed to document the existence of a workshop feature (*Bánesz 1991*). A new analysis focused on the possible existence of a workshop and production technology at the site does not consider the finds different from the inventory of Bükk culture settlements (*Allard* et al. *2017*). Technological differences between artefacts made of different raw materials were monitored at the Tiszadob culture settlement at the Košice, Galgovec site (*Kaminská* et al. *2016*). Regardless of several observed differences, the procedure of obsidian chipping was evaluated as rather similar (*Kaminská 2020*).

We have less information on the processing of obsidian in western and central Slovakia in the Neolithic. The register of sites with discovered obsidian was published in the 1990s by Stanislav Šiška (*1998*). Additionally, there is a lack of research on the Lengyel culture's obsidian-related assemblages. For example, the changes in knapping that have occurred since the Lengyel culture have not been evaluated so far. Most of the known sites (Fig. 3) are separately processed, such as Bučany (*Cheben 1986*), Golianovo (*Březinová* et al. *2002; Kuzma, Cheben 2012*), Nitriansky Hrádok (*Hovorka, Illášová 1999; 2001*), Bánovce nad Bebravou (*Březinová* et al. *1994*), Horné Otrokovce (*Kuzma* et al. *1999*), and Žlkovce (*Hovorka, Illášová 2002*). However, rather than concentrating on manufacturing methods, the researchers primarily carried out raw material assessments. The evaluation conducted on Svodín (*Kaczanowska, Kozłowski 1991*) in southwest Slovakia is one of the earliest studies on the Lengyel chipped stone industry. Though images show the use of this raw material, primarily to produce tiny cores and bladelets, the assembly is evaluated as a whole, and the obsidian blades or cores are not mentioned individually.

The most recent studies of the processing of obsidian were carried out at the Nitra-Selenec site (*Nemergut* et al. *2022; Beljak Pažinová* et al. *2024)*. The settlement belongs to the beginning of the Aeneolithic (Ludanice group of the Lengyel culture). Although only a few artefacts made of obsidian come from the site, they demonstrate the unique phenomenon of grinding this raw material. Traceological analysis at the Selenec I site identified grinding marks on one miniature core and a fragment of one of the three retouched blades (*Nemergut* et al. *2022.197)*. No comparable discovery from Slovakia or the surrounding area is known to exist.

The information presented above makes it clear that obsidian was found at several Neolithic sites throughout Slovakia. Separate technological characteristics for obsidian artefacts, reconstruction of production procedures, or differences in comparison with other raw materials occur only rarely and for individual sites. It would be crucial, therefore, to include the entire collection in a sophisticated study that offers a cohesive perspective and potential site comparison. It is sometimes difficult to provide a more thorough description of production processes, particularly if there is insufficient obsidian present at the specific site or if categories like cores, *etc.*, are missing. Another reason might be that relevant artefacts do not vary from the rest of the chipped stone industry, and thus such an approach is considered unnecessary. Nevertheless, the issue of how obsidian has changed throughout time and among cultures might affect more than just Slovakia.

Analysis of the chipped stone industry from the Kiarov-Veľké ortovisko site

Raw materials at the site

The assemblage of chipped stone industry from the site contains 625 artefacts in total. The site is characterized by extensive use of obsidian as a raw material for chipping, although obsidian tools are not very frequent. Sixty-two percent of all artefacts are made of obsidian (388 items; Tabs. 1 and 2; Table 2 can be found at https:// doi.org/10.4312/dp.52.6). Miniature nodules, mostly globular, were preferred. Size is documented by individual finds, such as cores on which the cortex is often preserved, and it is clear in many cases that the dimensions of the original piece of raw material were not very different. Some decortication flakes document the presence of larger specimens, but their diameter was a maximum of 4cm. As such, local production used whole imported nodules. All the artefacts are made of transparent material without phenocrysts or striations, and seem very consistent.

Other raw materials used for manufacturing tools at the site – apart from obsidian – included mainly Tevel-type flint from Hungary (*Biró 2003*) and limnosilicite. As for the first, it represents 13% of artefacts (81 items), and the second 12% (73 items). The next most frequent raw material is silicite of the Kraków-Częstochowa Jurassic from the territory of southern Poland, and 8% (49 items) of the assemblage are made of it. Jasper occurs in 23 items, which represents 4%. Unspecified chert is rare (four specimens), and one artefact was made of sandstone.

Composition of the obsidian assemblage

The excavation in 2013 obtained 388 items of chipped obsidian industry in total (Fig. 4; Tabs. 1 and 2). In terms of technology, the site is dominated by blades (197 items). They constitute more than half of the assemblage, 51% in particular. They can be divided into unworked (173 items, 88%) and worked blades (24 items, 12%). As for frequency of occurrence, they are followed by flakes (31%), which means 121 items altogether. Only a few individuals among the flakes were used as tools – seven items (6%). There are thus 8% of blade and flake tools in the assemblage. Due to the fragmentary state, 9% of the assemblage was classified as waste. The smallest technological group contains cores. Their total number is 37, which is 10%.

Cores

Among all cores, obsidian cores (Figs. 5 and 6) are a dominant component at the site, and they demonstrate a rather uniform method of exploitation. In the assemblage in question, they are represented by 37 items, and among all cores of the chipped stone industry they constitute 63% of the total. There are all stages of manipulation with obsidian nodules at the site – from unused or just tested pieces of raw material, individuals in the phase of exploitation, flakes made by attempts to repair the flaking surface to residual items. They are miniature forms that can be classified as more or less prismatic shapes (20 items) or less frequently as conical shapes (six items). Some cannot be classified by their shapes due to their fragmentary state or the stage of debitage on individual items. One item was debited from a thick flake. The cores are mostly exploited, or they can be classified in the advanced stage; sometimes the initial stage occurs (three items). It is noteworthy that some cores in the advanced stage still provide enough space for further debitage. Despite this fact, they were abandoned. One core is a nodule with traces of several percussions, after which debitage did not continue. Some cores have been preserved as fragments. The total removal of the cortex is documented in only four items. Seven items have preserved cortex on one side; four have cortex on both sides. Six cores are covered with cortex only on the back site. There

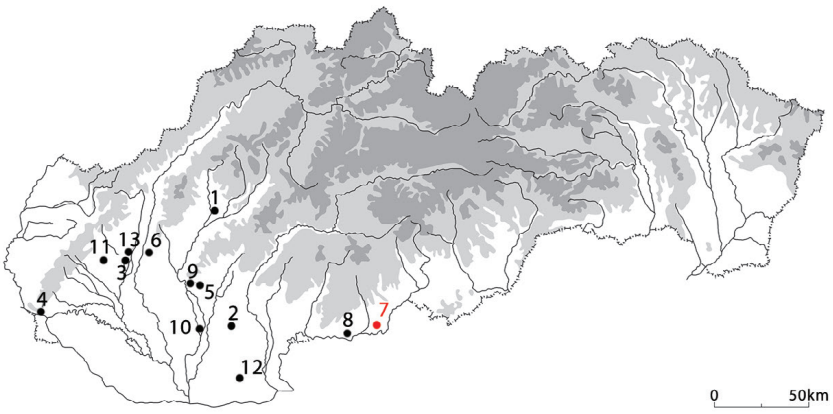

Fig. 3. Map showing the location of Lengyel culture sites in Slovakia mentioned in the article with analysed chipped stone industry. **1** ***Bánovce nad Bebravou;*** **2** ***Bardoňovo;*** **3** ***Bučany;*** **4** ***Bratislava-Mlynská dolina;*** **5** ***Golianovo;*** **6** ***Horné Otrokovce;*** **7** ***Kiarov (Veľké ortovisko site);*** **8** ***Koláre;*** **9** ***Nitra-Selenec;*** **10** ***Nitriansky Hrádok;*** **11** ***Ružindol-Borová*** **12** ***Svodín;*** **13** ***Žlkovce.***

are also items with cortex on one side and on the back site, and, finally, there are cases with cortex on both sides and on the back site.

The miniature cores in question were primarily used for obtaining bladelets, which is documented by the flaking surface on as many as 32 items of cores. On eight of them, negatives can be attributed to blades with their sizes (width exceeding 8mm). Before bladelet production itself, larger specimens were obtained and used, although they are still small blanks in comparison with other raw materials at the settlement. As for the number of platforms, it can be stated that the creation of a single platform was common on obsidian cores (29 items). A change in orientation during debitage can be observed in four items. It happened if the original debitage surface had been damaged. However, usually only a single platform remained. The method of core exploitation partly depended on the shape of the nodule itself and various natural cuts on its surface. Some cores were flaked on one side, especially prismatic nodules, but flaking on one or more sides creating a single rounded surface is a frequent phenomenon as well. Cores are not exploited on the back site, although some exceptions have been documented. Flaking surfaces are straight or slightly convex.

As suggested by the above-mentioned analysis of cortex presence, most back sides were made of cortex or modified by flakes, such as for a better grip. Creating a crest by flaking to prepare a debitage surface did not happen at all or very rarely. Before obtaining bladelets, the platform was faceted. Such a process is visible on most cores. Such modification was necessary for the debitage of cores, as exploitation by pressure or using a punch required a less slippery surface of the platform. In three specimens, faceting is not confirmed, and the platform is made from several large negatives. Creating a platform through a single large flake without any other modification occurs in the assemblage of obsidian cores only twice.

From the phases of reparation, a technological procedure is documented, when the upper part was completely removed, and the core became shorter. The aim was to obtain a new rejuvenated platform and the proper angle of the debitage surface. There is also an example where the distal part of the core was removed with a blade. Such a fault might

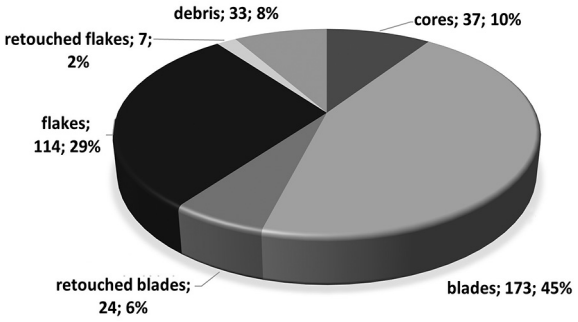

Fig. 4. Kiarov-Veľké ortovisko site. Technological composition of the analysed obsidian assemblage (created L. Popovičová).

occur on obsidian more frequently than on other raw materials. Nevertheless, intention cannot be denied. Another common feature of miniature cores is the unmodified edge between the platform and the flaking surface. This feature can sometimes be difficult to identify, but when it is identifiable (20 items), as many as 18 items do not show any traces of modification.

Metrical data for cores were gathered exclusively from relevant items, and they are orientation data. The average of measured lengths is 20.3mm (max. 26.3mm, min. 13.7mm), the average of the widths is 17.3mm (max. 31.3mm, min. 11.3mm), and the average value for thickness is 13.3mm (max. 20.9mm, min. 8.1mm).

Blades

The technological group of blades from Kiarov consists of products obtained from miniature obsidian cores

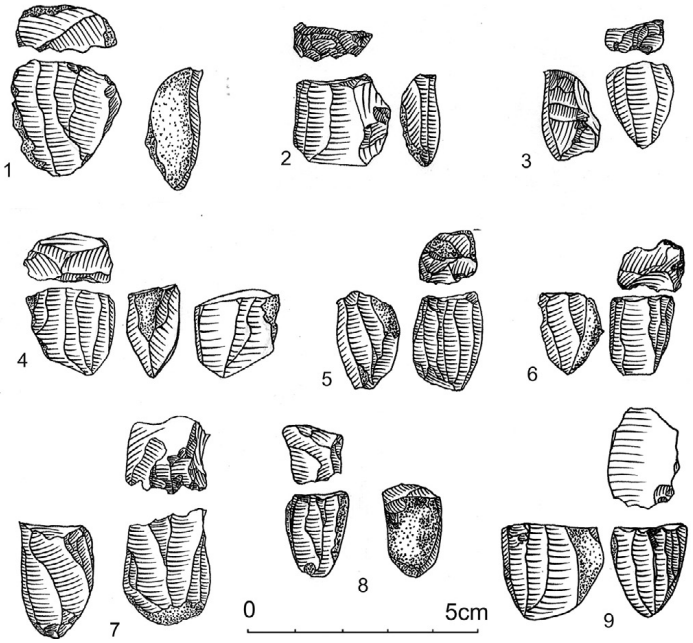

Fig. 5. Kiarov-Veľké ortovisko site. Miniature obsidian cores (drawing L. Popovičová).

(Figs. 5 and 6) as well as from cores from other raw materials (Fig. 7). The peculiarity of the work with obsidian causes considerable differences among them. Thus, the production of small blanks distinctly dominated at the site. It is documented by the character of the group of blades as well as by considerable representation of the above-described miniature cores. Bladeletsare rather frequent in the assemblage. In total, there are 95 items, and almost all of them are made of obsidian. Only three specimens are exceptions. Among the exclusively obsidian blades, bladelets constitute almost a half, *i.e.* 46% (84 items). Another half metrically belongs to the category of blades with a maximum width of 1.7cm.

The blades are rather well preserved, with 45% completely preserved. Other items are in different states of fragmentation, and none of the parts is represented more than others. As for the presence of the original cortex, individuals without cortex prevail among obsidian blades (57%). Thus, we can say that the cortex occurs quite often, which is associated with the raw material. Leaving cortex on cores is more frequent at debitage from obsidian, which is caused by the size of imported nodules. If the cortex occurs, it is mostly on the edge of the blade (22%), and less frequently on the distal part. Preparation exemplars are also present. They are probably the remains of the initial creation of the flaking surface. Crest blades are not present in the assemblage of obsidian. The negatives of the blades align with the unidirectional nature of the strike. Faceted butts prevail. Evidence of such modification can be observed in 82 items, which represent 68% of identifiable individuals. They are followed by the plain type, which represents 18% of the assemblage. Dihedral, linear, punctiform and cortex butts have been identified in small numbers. Another typical feature of obsidian blades/bladelets is that the edge between the platform and debitage surface was not significantly modified before debitage. Specimens were created slightly bent in the profile with parallel, slightly irregular or less frequently convergent edges. The bulbus is almost always indistinct, and micro-negatives occur on it in approximately half of the items.

The average length of obsidian blades is 25.37mm (max. 41.07mm, min. 15.5mm), the width is 8.97mm on average (max. 21.94mm, min. 3.3mm), the average thickness is 2.92mm (max. 10.85mm, min. 0.75mm). The division of all completely preserved blades into size groups reveals that individuals with lengths less than 30mm are almost entirely obsidian.

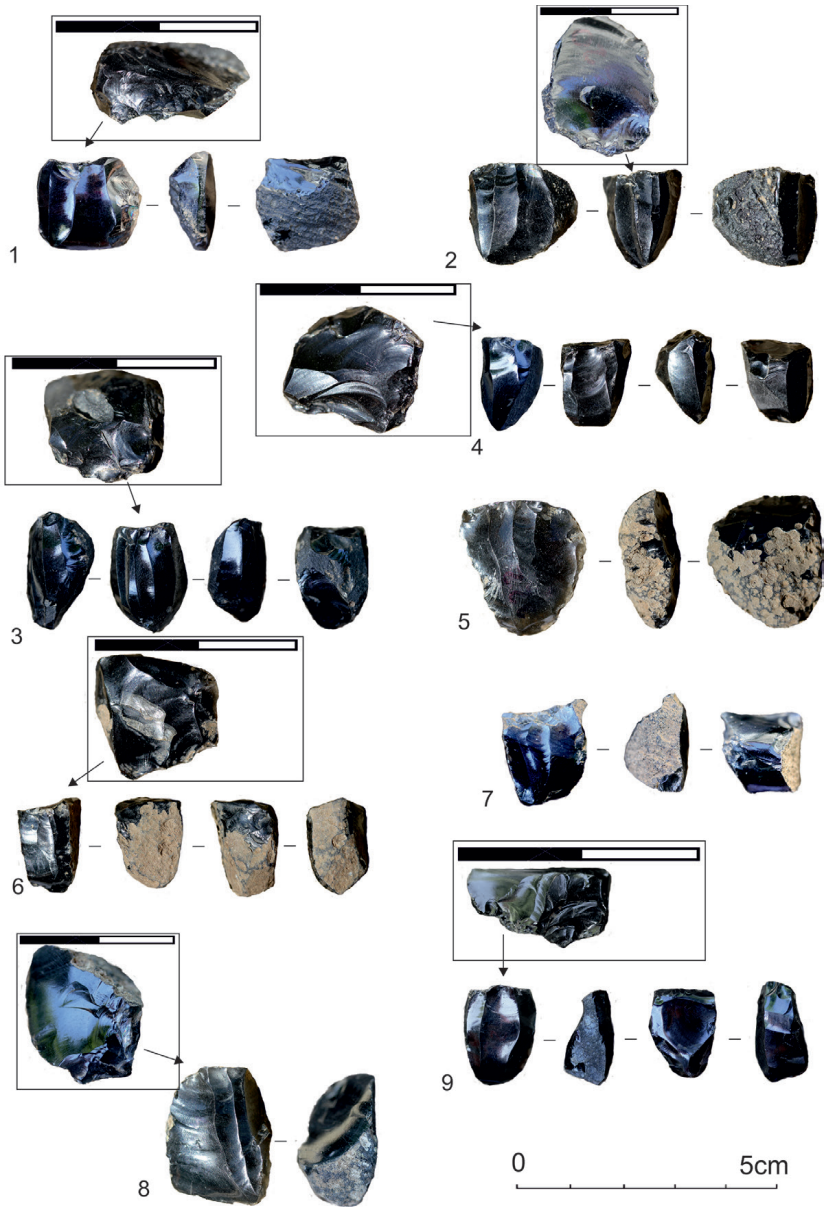

Fig. 6. Kiarov-Veľké ortovisko site. Miniature obsidian cores (photo L. Popovičová).

Flakes

The technological group of flakes includes 121 items. They are manufacturing byproducts that are partially used for various other purposes. At least 33 (27%) may be identified as flakes formed during the preparation of raw material. Decortication flakes are often large, which documents the original size of some nodules. They are often pieces that created a core platform. One of the flakes is a tablet. Cortex covering the whole dorsal surface occurs on ten items (9%); 75%–50% of the dorsal surface is covered on 29 items (24%). More items – 38 in total – have the original cortex on up to 25% of the dorsal surface (31%). Finally, 44 obsidian flakes do not have any original cortex, and these account for 36% of the assemblage in question. Negatives of previous flakes on the dorsal surface are either transversal or parallel. Cortex butts are the dominant type (30%), followed by plain types (29%) and then faceted butts (22%). The occurrence of faceted butts is much rarer than in blades. Apart from the abovementioned types, the punctiform, dihedral, and uniquely linear types have been recognized. The bulbs of the analysed flakes are usually indistinct. Distinct bulbs are represented by 30% of items.

The average length of flakes is 17.8mm (median 16.91), while the longest one is 36.21mm and the shortest specimen is only 7.02mm long. The average of the measured widths is 15.3mm (median 14.28), with a max. value of 43.36mm and a min. value of 6.04mm. As for the thickness, the average is 4.1mm (median 3.64) with the max. value of 11.31mm and min. value of 0.7mm.

Flakes show a distinct dependence on the raw material. Obsidian accounts for 83% of shorter flakes, measuring less than 20mm. Obsidian flakes are concentrated in the categories with the smallest width, as they represent 82% of flakes less than 20mm wide.

Typology

Among the obsidian blades, retouch can be observed on 24 (12%) items. Obsidian tools include a miniature end-scraper (Fig. 8.23), three transversally truncated blades, a notched blade, a blade with a retouched distal part, four laterally retouched blades, and a blade with a bilateral use-wear retouch. Regarding bladelet tools, there are three transversally truncated (Fig. 8.18,21), three obliquely truncated bladelets (Fig. 8.17,20,22), three notched bladelets (Fig. 8.16), and four bladelets exhibiting lateral retouch (Fig. 8.15).

Flake tools occur in smaller numbers. Their total number is seven, which means 6% of the group of flakes. An end-scraper can be distinguished (Fig. 8.19) as well as three flakes with lateral retouch, two flakes with local lateral retouch, a flake with lateral use-wear retouch, and one specimen with retouch in the proximal part.

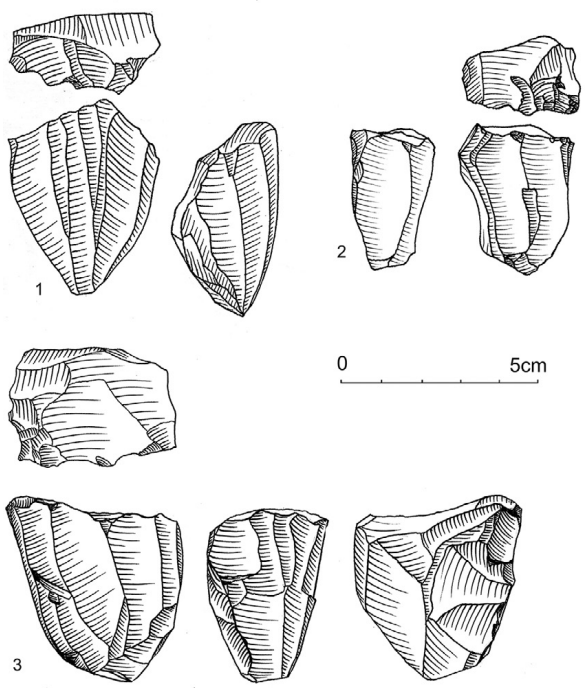

Fig. 7. Kiarov-Veľké ortovisko site. Cores made of other raw materials (drawing L. Popovičová).

Evaluation

The importance of the chipped stone industry finds from Kiarov lies in their number and the fact that most of them (77%) come from a single feature B15. The artefacts can also be undoubtedly associated with a specific stage of the classical Lengyel culture – phase Lengyel I. As all the necessary categories – from unused nodules or pre-cores to exploited cores, desired blanks, or tools – are represented, the method of use of obsidian at the site can be observed. Furthermore, the entire process of working with this raw material happened at the settlement itself. Although whole nodules were imported, they were small and most likely no more than 4cm long. Limnosilicite or silicite of the Kraków-Częstochowa Jurassic and Tevel-type flint were other more common raw materials found at the site. However, artefacts made of these were made from larger nodules.

Obsidian cores represent 63% of all obtained cores, and a rather uniform method of their exploitation can be observed. They are miniature forms from which bladelets were systematically produced. The debitage method is associated with the shapes and sizes of the nodules. A single platform was usually made through

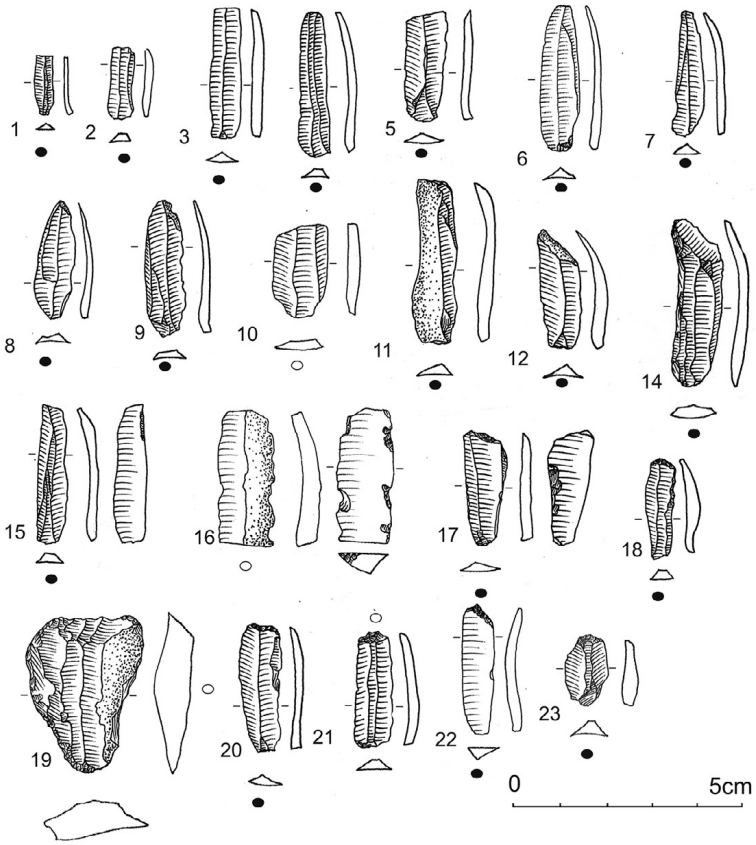

Fig. 8. Kiarov-Veľké ortovisko site. Obsidian blades and blade tools (drawing L. Popovičová).

a large flake, and the platform was carefully modified by faceting. Change of orientation or other reparation methods were limited due to the character of the nodules. During exploitation, a continuous debitage surface occurs by connecting the frontal surface with one or both sides. The back side remained covered with cortex or there was no debitage. Small, thin, and slightly bent blades or bladelets with parallel sides were made from these cores. In the whole group of blades, 64% (197 artefacts) are made of obsidian. Nevertheless, large and long blades were also made at the settlement in Kiarov, especially from the Tevel-type flint. Faceted butts were typical for obsidian blades. Among blades from other raw materials, the plain type prevails, and in rare cases such platform modification also occurred.

Even though obsidian was an imported raw material for society at the time, they did not make the best use of the nodules. Cores were occasionally abandoned in the advanced stages while there was still enough material for bladelet debitage or surface repair.

Unlike obsidian cores, the remaining cores (Fig. 7) at the settlement in the Kiarov-Veľké ortovisko site document mostly, but not only, the debitage of blades. Bladelets were made from these raw materials as well, but separate cores were not prepared. Most of them were probably products of naturally reduced exemplars. They are mostly larger cores. Among the differences in the form of exploitation, we can mention creating a crest on cores, including a secondary one, more moderate faceting of platforms, or various changes of orientation during debitage.

There is no evidence at the site suggesting the exact use of obsidian bladelets. Most tools are made of other raw materials. However, microbladelets of obsidian were not independent tools, and were used as their parts. Their size was standardized, and it is obvious that a large amount had to be made. Some obsidian blades or flakes were retouched, but this raw material was primarily used for bladelets; for other tools, less brittle and more easily available raw materials were used. There is thus a difference in terms of the material used. Among blades made of other raw materials, tools constitute 45% (50 items). End-scrapers are represented (Fig. 9.9,10,11,13), as well as a trapezoidal microliths (Fig. 9.14), borers (Fig. 9.12), obliquely truncated blades, and blades with lateral retouch (Fig. 9.2) or notches.

Discussion

It is hardly unexpected that obsidian, a sought-after raw material for long-distance trade, has been found in Lengyel chipped stone industry assemblages in Slovakia. However, there are often fewer obsidian artefacts, and other, more locally sourced raw materials predominate in particular communities. It is thus more notable at settlements further away from the primary raw material source, since the quantity of obsidian reduces linearly with increasing distance from the source. For instance, the level of occurrence of obsidian at classical Lengyel sites in western Slovakia is as follows: Svodín 8%, Bardoňovo 18.5%, Ružindol-Borová 6.6%, Bučany 41.3%, Bratislava-Mlynská dolina 20%, Golianovo 15% (*Cheben 1986; 1993.442–443,Abb. 1; Farkaš 1986; Březinová* et al. *1994.33*). The assemblage from the village of Koláre located in southern Slovakia, approx. 12.5km from the analysed site in Kiarov-Veľké ortovis-

ko, is particularly interesting. The high percentage of obsidian occurrence in Koláre (80.5%) is associated with local workshops (*Kaczanowska 1985.139*) where this raw material was processed. A rescue excavation was executed there by Jan Lichardus in 1962 (*Točík, Lichardus 1966.77–78*) and by Juraj Pavúk in 1972 (*Pavúk 1981.256*). Pottery material was classified to the classical Lengyel I stage (*Urminský 1999*). Several settlement pits rich in finds were detected over the area. The large (min. 5.6×5.0m) sunken feature 1/72 containing many obsidian flakes stood out (*Kaczanowska 1985*). Therefore, it was interpreted as a potential workshop for processing obsidian, where semi-finished products were made/modified for further use in tools (*e.g.*, sickles, knives, *etc*.). Nevertheless, the assemblage has not been evaluated independently in terms of technological procedures related to working with this raw material. Like in Kiarov, obsidian cores occur in miniature forms and are mostly used to produce bladelets.

Approx 50km south of Kiarov, in the territory of Hungary, a similarly dated settlement of the Lengyel culture, Aszód-Papi földek, is located (*Kalicz 1985*). Its development is associated with intense trade. Besides other reasons, it is famous for its high share of obsidian among the finds of the chipped stone industry (approx. 23%), and the site is considered a place specializing in the distribution of this raw material (*Kalicz 1985.69–70*).

The study of the origin of the lithic raw material and further modelling of distribution networks between Lengyel sites has been applied in Hungary for a long time (*Biró 1995*; *1998*; *2018*). Besides Aszód (Lengyel I), the following sites are considered principal distribution centres in the North Hungarian Mountains (Hun. Északi-középhegység) from the Zemplínske vrchy hills through the Cerová vrchovina hills to the Novohradské vrchy hills, *i.e*., in the wide territory of the Ipeľ river basin: Csesztve-Stalák (Lengyel III), Gönc-Gátdomb (Lengyel I), Szécsény-Ültetés (Pre-Lengyel), and Karancsság-Alsó-rétek (Lengyel I) (*Kalicz 1985.70; Biró 1987.154,158–159; 1998.45,50–51,57; Dobosi, Tárnoki 1987.10–13; Fábián 2005.15; Szilágyi 2009.32–33*). Kiarov is less than 11km from the site of Szécsény-Ültetés. Reconstruction of such networks and the role of some sites in the Lengyel culture period is limited by the state of research and, with obsidian particularly, by the stage of processing of the chipped stone industry – for the territory of Hungary as well as Slovakia. Sites with considerable shares of obsidian, such as Aszód and Koláre, which are also near Kiarov, have not been analysed or published to allow their mutual comparison.

The site of Kiarov-Veľké ortovisko clearly shows how the use of obsidian in the Lengyel culture is different from methods used with other raw materials, such as limnosilicite, silicite of the Kraków-Częstochowa Jurassic, or Tevel-type flint. Obsidian cores at the site are carefully prepared, and the aim is to obtain bladelets systematically, probably by the pressure method, which was not used with cores from other raw materials. Obsidian bladelets at the site of Kiarov are in obvious contrast with other finds, which are considerably larger and used differently. The fact that the whole process of obsidian processing took place right at the site is also important. There, only nodules – probably not ex-

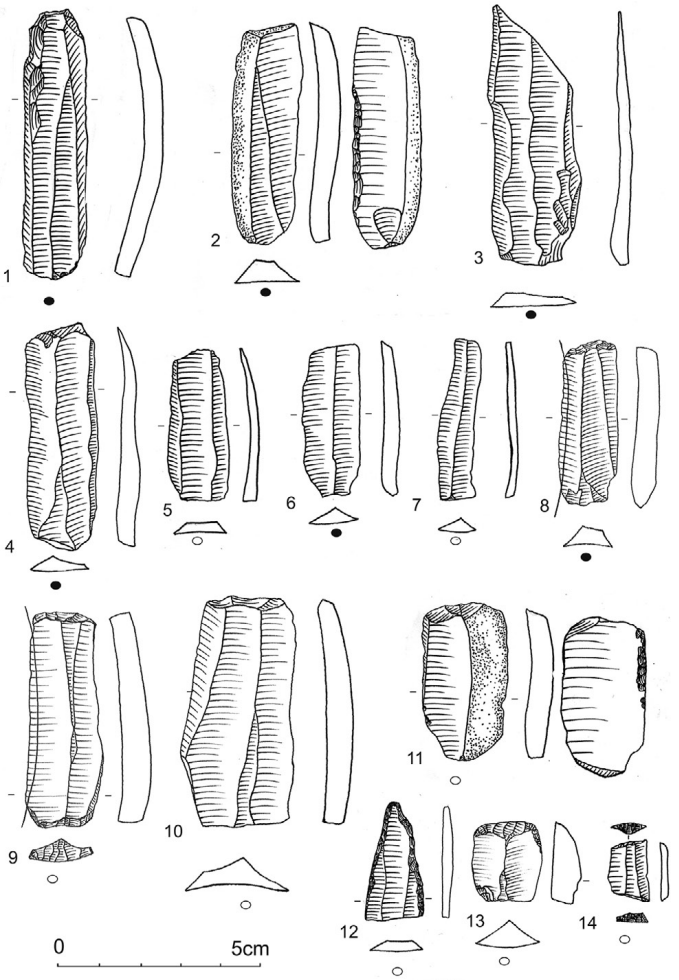

Fig. 9 Kiarov-Veľké ortovisko site. Blades and blade tools made of other raw materials.* 1,2,8,9,10,11 *Tevel-type flint,* 3,4,12,13 *silicite of the Kraków-Częstochowa Jurassic,* 5,6,7 *limnosilicite,* 14 *jasper (drawing L. Popovičová).

ceeding the size of 4cm – were distributed. This was a sophisticated and reliable distribution network providing desired raw materials to consumers at regular intervals.

Miniature obsidian cores are not typical for the region of the Ipeľ river basin alone, as small examples also occur at the Lengyel I site in Svodín in southwest Slovakia (*Kaczanowska, Kozłowski 1991.Tabs. 4 and 5*). Their shape is often pyramidal or prismatic, and they were used for debitage of bladelets, with all of them made of obsidian. Miniature cores made exclusively of obsidian are also present in the assemblage of chipped stone industry from Golianovo (Lengyel I), also located in southwest Slovakia. Cores from other raw materials were larger at the site as well (*Kuzma, Cheben 2012*). Nevertheless, sites of the Lengyel culture document the occurrence of large nodules and the use of obsidian for common tools, not only for miniature bladelets. The site of Kiarov-Veľké ortovisko itself is evidence of this, as it contains, for example, obliquely truncated or laterally retouched blades. Unworked blades are up to 41mm long, which, together with preparation flakes, reflects the sizes of some nodules and products.

A specific approach to obsidian is documented by the site of Nitra-Selenec (Lengyel IV-Ludanice group), where miniature cores were also discovered. One of these cores was modified by grinding after the exploitation of bladelets. It is not clear why this happened at the site, and similar findings for interpretation are absent. It may be a form of core reparation (*Nemergut* et al. *2022*).

The assemblage of obsidian artefacts (585 items) containing many miniature cores was analysed from the site of Targowisko 11 in southern Poland (*Wilczyński 2010*). The settlement belongs to the Malice culture (*Kadrow 2023.Tab. 1.3*), and thus it corresponds chronologically with the classical Lengyel culture. Finds allowed a rather exact reconstruction of methods used for processing the raw material at the site. Whole nodules, cores in the process of exploitation, as well as residual forms were identified. Cores as well as blades or bladelets obtained from them are very close to Kiarov-chronologically and with their sizes. Nodules of similar sizes were used at both sites. However, findings suggesting the further use of bladelets are absent in Targowisko too. The situation is similar to Kiarov's, as retouched artefacts mostly come from other raw materials. Among hundreds of them, there were only two obsidian tools. Certain traces of use occur on the edges of some bladelets, but the exact working activity is unknown.

Thus, the processing of obsidian and exploitation of bladelets from miniature cores is not a rare phenomenon in the late stage of the Neolithic. Nevertheless, a complex evaluation and detailed examination are absent at present.

Conclusion

The presented assemblage of chipped stone industry from obsidian was obtained during the rescue excavation by the Institute of Archaeology of SAS along the construction route of the high-pressure gas pipeline DN 800 Slovakia-Hungary in the northern part of the cadastral area of Kiarov, a village in southern Slovakia in the region of the Ipeľ river basin. The excavation carried out in spring 2023 at the site of Kiarov-Veľké ortovisko uncovered 15 settlement features (four of them without finds) dated to the first stage of the clasical Lengyel culture (Lengyel I) based on pottery fragments. The chipped stone industry (625 artefacts) occurred in ten features and as stray finds; in terms of raw material, obsidian prevailed (388 items; Tabs. 1 and 2). Obsidian fragments were found in the fill of seven features. The largest and deepest feature B15 contained the most fragments (*c.* 300). A considerable amount of daub also came from the feature B15, and analysis showed the remains of a dome-shaped oven covered with earthen plaster.

In terms of technology, obsidian blades are predominant on the site. They are divided into unworked (173 items from seven features) and worked exemplars (24 retouched blades from four features). There are also flakes (121 items from five features), only seven of which were used as tools. Tools (31) were found in the fill of four features (B7, B10, B11 and B15). Debris at the site was represented by 33 items from three features. Cores of miniature forms (37 items) were found in four features.

The fact that Kiarov contained all the evidence of manipulation with obsidian nodules – from unused or only tested raw material pieces to individuals in the stage of exploitation and flakes formed during the reparation of debitage surfaces to residual specimens – was significant for the technological analysis of obsidian processing.

Typical obsidian artefacts in the Lengyel culture are miniature cores and bladelets debited from them. The

importance of such production and the exact function of the miniature bladelets could not be fully explained. If a culture used obsidian, it was often in the form of the processing of miniature nodules and debitage of bladelets. In comparison with other raw materials in assemblages, the use is different. In the early period, *i.e.*, in the Late Linear Pottery culture and the Želiezovce group, such a difference was not manifested. In eastern Slovakia, obsidian was probably processed identically with other raw materials – either in the Linear Pottery culture or in later periods.

The assemblage of the obsidian chipped industry from Kiarov-Veľké ortovisko can be, based on the analysis, defined as technologically uniform. Similarities are shared in a wider territory, not only within the Lengyel culture, as suggested by the example from Targowisko 11 in Poland. This phenomenon can be seen as the development of a specific activity that was carried out in the same or very similar way. To some extent, the processing of obsidian at some settlements of the Late Neolithic can be defined as specialized.

The results of the analysis are consistent with the traditional Lengyel culture's known production. On several Lengyel culture sites, the previously documented varieties of obsidian industry with unique bladelets and tiny cores were verified. We can, however, consider the Kiarov-Veľké ortovisko site in southern Slovakia to be an extension of the information we have because the raw material was processed at the settlement and the manipulation technique using obsidian, one of the most significant stone raw materials of prehistoric times in central Europe, was observed.

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The emergence of the Neolithic in Dobrudja (Romania) reflected by the osseous industry

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ABSTRACT – *On the Lower Danube River basin, the oldest Neolithic assemblages appear around 6200 BC. However, the evolution of the Neolithic seems to have occurred later in the Dobrudja region between the Danube River and Black Sea. The archaeological evidence from the Dobrudja has shed light on subject long debated by specialists. At the current stage of knowledge, the oldest Neolithic archaeological finds belong to the Hamangia culture (*c. *5300–4600 cal BC), although some recent discoveries come from the Prehamangia culture and seem to precede the previously analysed Neolithic settlements, being dated to beyond 5700–5400 cal BC. The archaeozoological study presented in this contribution confirms the pastoral character of the Prehamangia and Hamangia economies, as indicated by the high percentage of domestic animals, especially cattle and caprines. The osseous industry that has been recovered reflects the economic type of these communities, which was clearly oriented towards the exploitation of* Ovis aries/Capra hircus *and* Bos taurus *bones. Technologically processed bones were recovered from accumulations of household waste deposited after the slaughter and consumption of these animals. Antler or tooth working is sporadically attested.* Unio *sp. shells were used as tools in domestic activities, as well as tortoise carapace. There are also worked pieces from exotic raw materials (*e.g., Spondylus *sp.) that illustrate the existence of wider regional intercommunity and exchange networks. The functions of the bone tools recovered are correlated with the specific economies of these communities, being used in domestic activities for the processing of ceramics, vegetable fibres or wood. The archaeological assemblage from the Hamangia settlement of Cheia was chosen as a case study. Comparisons will be made with the Prehamangia assemblage of Palazu Mare –* Malul Mare *and the Hamangia assemblage of Techirghiol –* Dealul Paloda-Minerva *in order to identify technological trends and innovations across both chrono-cultural stages.*

KEY WORDS – *Neolithic; Dobrudja; osseous industry; cultural traditions; technological and typological innovations*

Začetek neolitika v Dobrudži (Romunija), razmislek s pomočjo analize koščene industrije

IZVLEČEK – *Najstarejši znani neolitski kompleksi v porečju Spodnje Donave datirajo v obdobje okoli 6200 pr. n. št. V regiji Dobrudža, med reko Donavo in Črnim morjem, pa se zdi, da se je proces neolitizacije začel nekoliko pozneje. Na to časovno zamaknjenost opozarjajo arheološki podatki, ki so bili predmet dolgotrajnih razprav. Trenutna interpretacija kaže, da najstarejše zanesljivo datirane neolitske najdbe na tem območju pripadajo kulturi Hamangia (pribl. 5300–4600 pr. n. št., kalibrirano), čeprav nekatere nove najdbe kažejo na obstoj predhodne kulture pre-Hamangia, ki je datirana v čas pred 5700–5400 pr. n. št., kalibrirano. Naša arheozoološka študija potrjuje obstoj pašnega gospodarstva v obeh kulturah pre-Hamangia in Hamangia. Visok delež ostankov udomačenih živali, predvsem goveda (*Bos taurus*) in*

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*malih prežvekovalcev (*Ovis aries/Capra hircus*), potrjuje intenzivno živinorejo kot osrednji gospodarski temelj obeh kultur. Koščena industrija, ki temelji predvsem na uporabi kosti omenjenih vrst, potrjuje razširjeno rabo živalskih ostankov v vsakdanjih dejavnostih. Obdelane kosti so bile odkrite v gospodinjskih odpadkih, medtem ko so obdelani rogovi in zobje redko zastopani, kar kaže na selektivno rabo surovin. Prav tako so bile kot funkcionalna orodja uporabljene školjke vrste* Unio *ter oklepi želv, najverjetneje za potrebe domačih opravil. Izdelki iz eksotičnih surovin (npr.* Spondylus sp.*) nakazujejo na široka družbena omrežja in izmenjavo. Funkcionalnost koščenih orodij je bila povezana z vsakdanjimi dejavnostmi obeh skupnosti; uporabljali so jih pri izdelavi keramike ter obdelavi rastlinskih vlaken in lesa. Za študijski primer smo izbrali artefaktni zbir kulture Hamangia z najdišča Cheia. S primerjalnimi analizami kostnih zbirov kulture pre-Hamangia na najdišču Palazu Mare –* Malul Mare *ter kulture Hamangia z najdišča Techirghiol –* Dealul Paloda-Minerva *bomo prepoznali tehnološke trende in inovacije v obeh kronološko-kulturnih fazah.*

KLJUČNE BESEDE – *neolitik; Dobrudža; koščena industrija; kulturne tradicije; tehnološke in tipološke inovacije*

Introduction

Until recently, the oldest Neolithic archaeological finds from Dobrudja (Romania) were considered to belong to the Hamangia culture (*c.* 5300–4600 cal BC). However, some recent archaeological research carried out at the Palazu Mare – *Malul Mare* (*Voinea* et al. *2023*) (Fig. 1) seems to push the oldest Neolithic settlements beyond 5700–5400 cal BC. The site of Palazu Mare (Malul Mare) is located on the northeastern edge of the old Palazu Mare village, currently part of the city of Constanța. A preventive archaeological investigation led to the discovery of Neolithic occupations at Palazu Mare, which now contribute essential information for understanding the Neo-Chalcolithic in the West Pontic area. The whole site totals an area of over 2800m^2, and within this 146 archaeological complexes have been uncovered and culturally classified to the Neo-Chalcolithic, Hellenistic (first half of the 2nd century BC) and Early Roman (2nd century AD) times. Two radiocarbon dates from the SL1 dwelling structure (5739–5626 cal BC and 5347–5332 cal BC (*Voinea* et al. *2023.Figs. 2–3*) have supported the new definition of the Prehamangia culture and the finding of occupations in the Dobrudja older than the Hamangia habitation.

For the Hamangia culture, the most representative settlement in the Dobrudja is that from Cheia (Constanța county), which is located in the Casimcea Valley, in the centre of the karstic area of the Dobrudja. The complex stratigraphy, consisting of sedimentary deposits which exceed three metres, suggests significant dynamics of communities with consecutive returns to the site, all dating to the Hamangia III phase. The four stratigraphic sequences have revealed a pattern of periodic occupation with permanent habitation throughout the year. Habitation phases probably occurred over years to decades, interrupted by abandonment phases long enough to lead to the destruction of deserted dwellings. Several dwellings were documented during extensive excavations, revealing the scattered character of the settlement and the successive recurring habitation of the communities (*Voinea, Dobrinescu 2003; Voinea, Neagu 2008*). Absolute dates for the Hamangia III phase at Cheia range between 5214–4961 cal BC and 5047–4855 cal BC (*Balasse* et al. *2014*).

The present study details the osseous animal industry from the Cheia – *Vatra Satului* settlement, which includes the most consistent Hamangia assemblage in

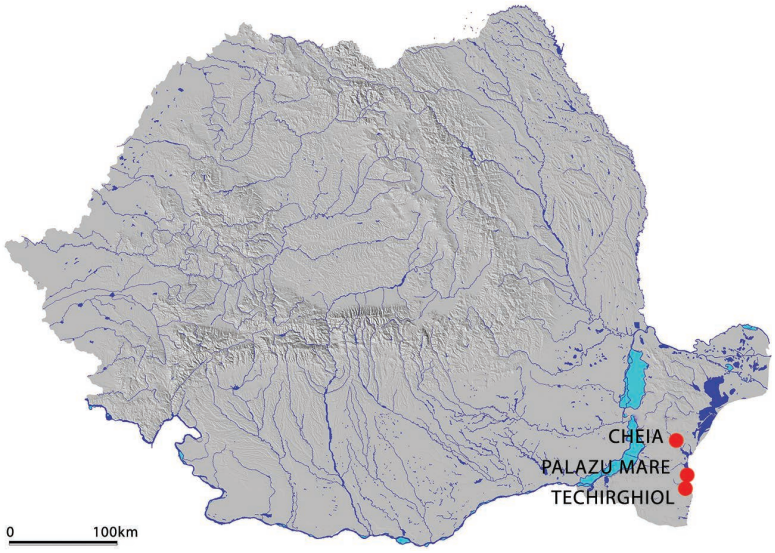

Fig. 1. Geographic location of the sites mentioned in the text.

Dobrudja (southeastern Romania). It will then compare the archaeological material from both the Prehamangia culture (the archaeological assemblage at Palazu Mare – *Malul Alb*) and other contemporary Hamangia cultural sites (*e.g.*, Techirghiol – *Dealul Paloda-Minerva*). The purpose of a broader view is to outline a general picture of the evolution of the osseous industry in the context of the neolithization process of Dobrudja in order to identify constants and changes across each cultural stage.

Archaeological assemblage

The osseous industry at the settlement of Cheia analysed in this study includes 396 artefacts (Tab. 1) that belong to the four types of products and by-products resulting from the technologies used for the transformation of raw materials (finished pieces, preforms, blanks and waste). The most numerous are the finished objects, with a total of 373 (94.4%), and there are also four preforms (1%), 13 blanks (3.2%), and six remnants of debitage (1.4%). The pointed tools are made especially from caprines (*Ovis aries/Capra hircus*). Caprine metapodials are procured for transformation by a quadri-partition method with double grooving to create pointed tools. Other important typological categories represented are hammers made from the bones of large mammals (cattle – *Bos taurus* and hemione – *Equus hemionus*), and rings made from blanks of caprine femurs. Numerous *Testudo* carapace fragments bear various traces of use-wear on their surfaces, and were probably containers. Some of the *Unio* shells have not been technologically transformed, but functional marks on the ventral edge attest to their use as tools. The tooth was only used to make a pendant. The Hamangia communities had *Cardium* and *Spondylus/Glycymeris* shell ornaments. At the Cheia settlement, the technological processing of antler is not attested.

This is the most consistent assemblage analysed so far, belonging to the Neolithic in the Dobrudja region. The other two assemblages used for comparison are significantly smaller (see Tab. 1). Thus, the collection from Palazu Mare – *Dealul Mare* includes a total of 25 finished pieces, two blanks, and 18 debitage remains. The typological picture is very interesting (Tab. 1). Quasi-universal pieces in prehistoric assemblages (*e.g.*, pointed tools, bevelled tools, spatulas) are poorly represented or even absent. Instead, the most numerous are the long bones of *Bos taurus* what were used in percussion and grinding activities. In second place are the containers made from *Testudo* carapaces. We also note the presence of three pointed tools, two flattened astragali, two perforated phalanges, one spatula, one pressure flaker, and one adornment. For bone, the categories of blanks and waste have helped us to reconstruct the debitage method through quadri-partition with double grooving and the method of segmenting rings on a blank in volume (of which we have no finished pieces). At Techirghiol – *Dealul Minerva-Paloda*, 52 pieces could be attributed to a typological category, while eight pieces of bone were considered blanks. In terms of typology, pointed tools prevail (n=22),

Raw material	Processing stage	Typological category	No. of items		
			Cheia	*Palazu Mare*	*Techirghiol*
Bone	Finished piece	Pointed tool	140	3	22
		Hammer	19	10	
		Ring	11		1
		Spatula	9	1	3
		Needle	8		
		Bead	3		1
		Bevelled tool	2		6
		Pendant	1		
		Scraper	1		
		Perforated phalanx	1	2	
		Handle			2
		Flattened astragalus		2	1
	Preform		4		
	Blank		13	2	8
	Waste		6	18	
Carapace	Finished piece	Container	134	5	1
Shell	Finished tool	Scraper	35		9
		Bead	5	1	
		Appliqué	3		2
		Bracelet			1
Antler	Finished piece	Pressure flaker		1	
		Bevelled tool			1
		Hammer			2
Tooth	Finished piece	Pendant	1		
		TOTAL	**396**	**45**	**60**

Tab. 1. Typological categories organized according to raw materials.

followed by scraping tools made from shell (n=9), bevelled tools (n=7), spatulas (n=3), and handles (n=2) made from bone, hammers (n=2) made from antler, one flattened astragalus (n=1), one container (n=1) made from carapace, and from the category of ornaments there are two appliqués, one tubular bead, and one bracelet, all made from shell.

Bone

Finished pieces

Pointed tools (n=140). The most important typological sub-category (n=105) is the pointed tools (Fig. 2.a,f) made from caprine metapodials by a quadri-partition method with double grooving. It is an extremely unitary assemblage at the *chaîne opératoire* level. The shaping operation destroyed most of the debitage marks, but with some pieces the striations specific to the grooving procedure are still visible. The general use of quadri-partition by double grooving is indicated by the presence of striations along the medullary cavity (Fig. 2.b,g). Thus, in the first stage of manufacture the bipartition was achieved by double grooving. The two halves obtained were subsequently bipartitioned again, with the grooving applied to the inner side. When preserved, the proximal end and, sometimes, the debitage edges were regularized by abrasion (Fig. 2.c). For the final shaping, scraping was applied along the entire circumference (Fig. 2.d,h). For several specimens, we observed that towards the distal end abrasion was applied along the entire circumference.

The sharp end is generally compacted, with the appearance of a small rectilinear surface formed by use-wear, macroscopic polish, and the disappearance of technological traces (Fig. 2.e,i). On the mesial area a polished area develops (Fig. 2.j), characterized by flattening of the surface and irregular striations, probably the result of a friction process. We also observed that certain pieces show use-wear, resulting from handling, but the use-wear is not present at the level of the active end.

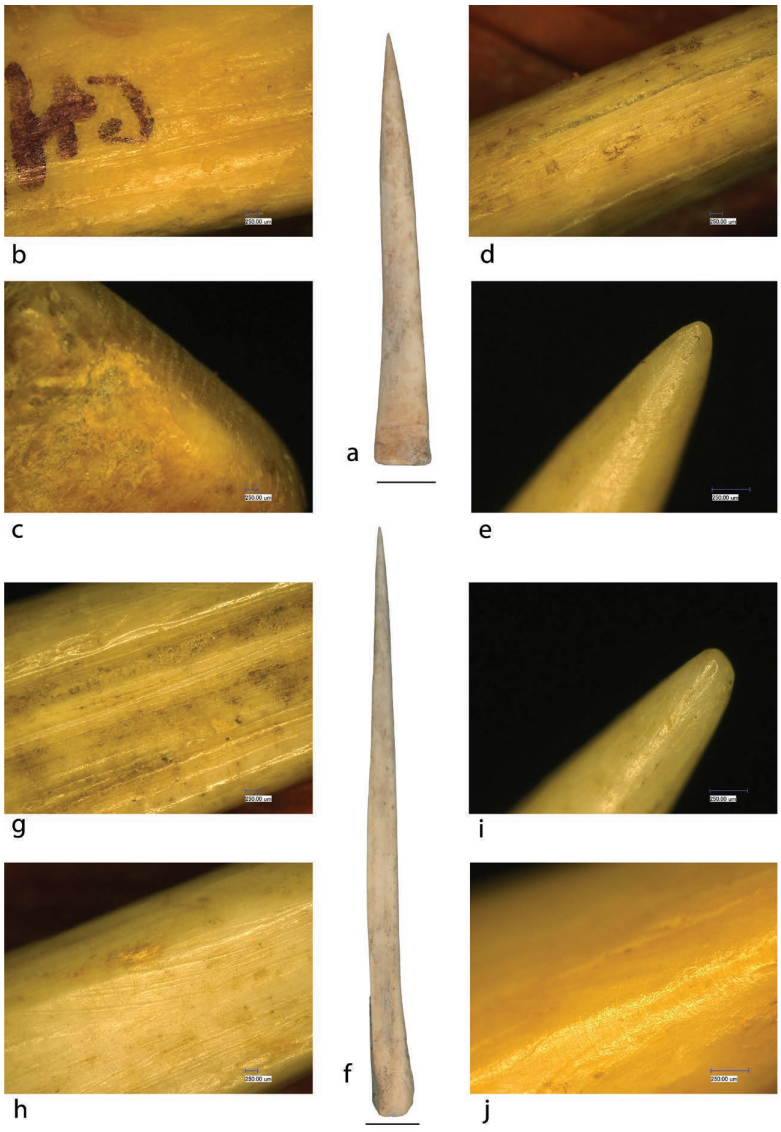

Fig. 2. **a,f** ***bone pointed tools made by quadri-partition with double grooving;*** **b,g** ***grooving marks;*** **c** ***proximal end detail;*** **d,h** ***scraping marks;*** **e,i** ***active end details;*** **j** ***use-wear area.***

Six pointed bone tools that were analysed were made by a bipartition method (Fig. 3.a,d). However, sometimes the manufacturing procedures were unidentifiable because the proximal end and debitage edges were carefully regularized (Fig. 3.b,e,h). A few other cases where the manufacturing procedures are still visible consisted of grooving and percussion (Fig. 3.f), or double grooving. Longitudinal scraping (Fig. 3.c) was applied around the entire circumference in order to shape the distal ends, which are characterized by a use-wear (Fig. 3.g) similar to that present at pointed tools manufactured using the quadri-partition method.

Another sub-category is that of the pointed tools made from the *Bos taurus* ribs (n=16). The rib was bipartitioned longitudinally by percussion (Fig. 4.a,e) after which a blow was ap-

plied to create the end. For some specimens, no attention was paid to cleaning the spongy tissue. Bilaterally, scraping (Fig. 4.b) or abrasion (Fig. 4.f) were applied to ensure the convergence of the edges. The end is blunt, with a small rectilinear surface and transversal functional striations (Fig. 4.d,g). In addition, a use-wear area was observed on the mesial region (Fig. 4.c) as a result of friction in the hand.

Two specimens from ribs were made on volume blanks (Fig. 4.h). To create the active end, a percussion blow was applied. The debitage edges were regularized by longitudinal scraping or by bilateral abrasion (Fig. 4.i). The pieces were used, developing a use-wear area at the median level with polish and modification of the external structure. The end is smoothed with polish and loss of raw material (Fig. 4.j).

An atypical specimen from the Cheia settlement (Fig. 5.a) was made from a flat bone of a medium-sized mammal. A splinter was extracted without us knowing the procedures because the debitage edges were regularized by abrasion (Fig. 5.b). At the meso-distal region, a longitudinal scraping was applied around the entire circumference (Fig. 5.c). The end is strongly rounded, with small depressions over which intense use-wear is superimposed (Fig. 5.d). Other specimens are strongly fractured, so that we can no longer reconstruct the debitage procedures. However, it is not excluded that some of these belonged to the category of pointed tools made by quadri-partition with double grooving, since this was the most frequently used procedure within the archaeological assemblage.

In contrast, in the Prehamangia contexts from Palazu Mare, this category is poorly represented with three specimens, of which only one is unbroken. This refers to a caprine metapodial that was processed using a longitudinal debitage method through quadri-partition, in which grooving was involved. Almost the entire surface was regularized through scraping. The significance of pointed tools in domestic activities seems to be a characteristic of the Hamangia culture, as they also represent the most numerous typological category at the Techirgiol site. The manufacturing procedures are identical to those seen with pieces from Cheia: quadri-partition with double grooving and bipartition through percussion or a combination of percussion and grooving. Pieces with flat blank predominate, but there are a few specimens with blanks in volume. The active end was created through percussion and shaping the debitage edges, or directly by applying scraping or abrasion around the entire circumference at the distal level.

Hammers (n=19). For this typological category, bones from large mammals (*Bos taurus* and *Equus hemionus*) were used, especially humeri, femurs and tibias (Fig. 5.e,h). The resulting pieces were large and could be easily held in the hand, contributing resistance to shocks. The blanks preserve the skeletal morphology. Segmentation of the bone was performed by percussion, with the segmentation edge preserved with a rough appearance. For this reason, they are quite difficult to differentiate from the biostratinomy or taphonomy of faunal remains (*e.g.*, broken bones for marrow extraction).

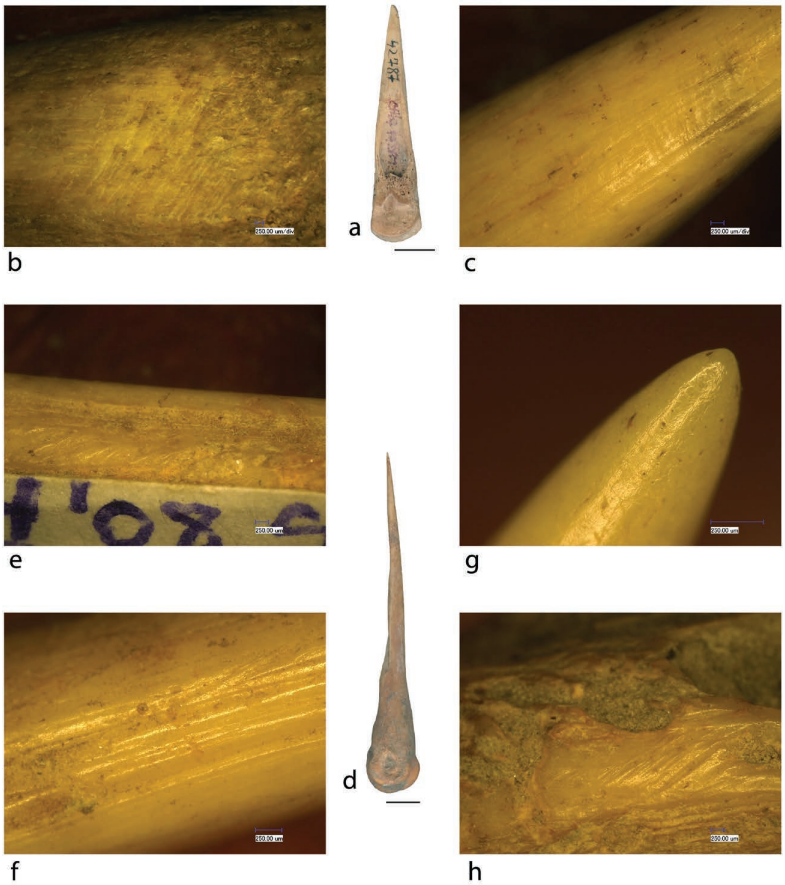

Fig. 3. **a,d** ***bone pointed tools made by bipartition;*** **b,e,h** ***abrasion marks;*** **c** ***scraping marks;*** **f** ***grooving marks;*** **g** ***active end detail.***

Hammers also appear at Palazu Mare, being the main typological category with seven specimens from Prehamangia contexts and three specimens from Hamangia I-II contexts. *Bos taurus* metatarsals and metacarpals segmented by percussion were used. The debitage edge seems to have been used for percussion, and hence the chipping fractures developed at the periphery of the debitage end. At some specimens, at the level of the epiphysis, significant detachments of material or cracks developed on the surface are evident. We can assume that these hammers had two active fronts. Unexpectedly, hammers of this type do not appear at Techirghiol, but the typological category is represented by two specimens made of antler.

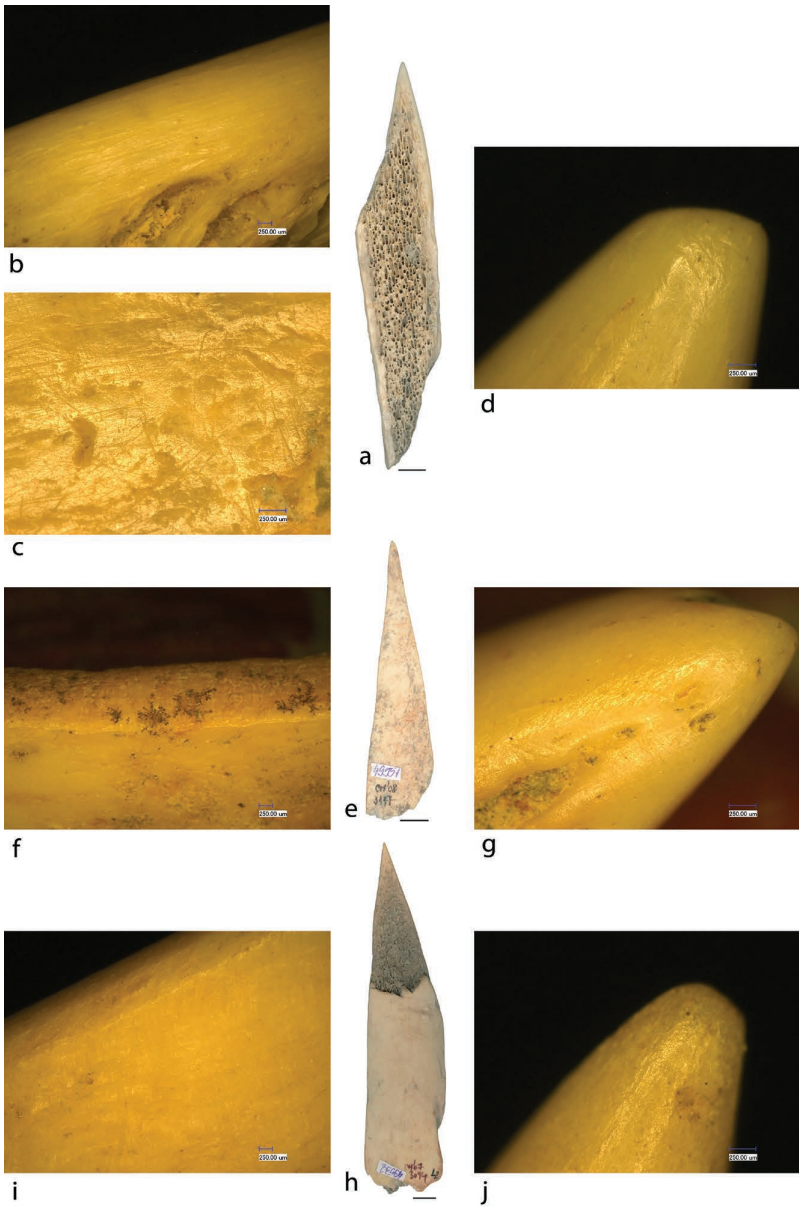

Fig. 4. **a,e,h *pointed tools made from ribs;* b *scraping marks;* c *use-wear on the mesial side;* f,i *abrasion marks;* d,g,j *active end details.***

Rings (n=11). Rings (Fig. 6.a,f,k) were obtained by a sawing procedure with an abrasive fibre. The technological striations of the segmentation procedure are hardly identifiable, because the segmentation edge was consequently altered by abrasion (Fig. 6.c,h). There are only a few specimens where cutting marks (Fig. 6.g) are visible at the periphery of the segmentation edge. These cutting marks could come from the initial delineation procedure identified in the case of some blanks (see also *Mărgărit, Voinea 2020*). For one specimen (Fig. 6.b), the direction of the segmentation groove could not be determined due to the fragmentation of grooves with a U-section and fine striations. Additionally, the segmentation edge was shaped by abrasion, and the medullary canal was cleaned and widened by scraping, further obscuring directional identification of the segmentation (Fig. 6.d,i). A single finished item was discovered at Techirghiol obtained through the same bone transformation scheme as that identified at the Cheia site.

Spatulas (n=9). For this typological category, cattle ribs were used (Fig. 7.a,d). The flat blank was obtained by percussion or by scraping (Fig. 7.b,f), over which abrasion was superimposed (Fig. 7.e). The active end was created by abrasion applied bifacially. We no longer see these abrasion marks on most of the pieces, because the active end is extremely worn. On a few specimens, the abrasion marks are so evident that it seems to indicate a resharpening. The same procedures of obtaining spatulas by bipartitioning the ribs with percussion and shaping by abrasion is also attested at Palazu Mare, where one specimen comes from, and at Techirghion with three items. At the Cheia settlement, two specimens are on volume blanks (Fig. 7.i). To create the active end, a percussion blow was applied, after which it was modified by abrasion (Fig. 7.j-k).

Needles (n=8). All needles (Fig. 8.a,f) were obtained from caprine metapodials. They are typologically dif-

ferentiated from the pointed tools by the presence of a perforation. The blanks are flat, being obtained by quadri-partition. We could not identify the debitage procedures for all the needles because the proximal end and the superior side were rigorously regularized by abrasion. However, for some specimens we could see that there was double grooving (Fig. 8.b,h) due to the presence of diagnostic marks on the inferior side. At the meso-distal region, a longitudinal scraping was applied around the entire circumference in order to create a sharp end (Fig. 8.c,g). On the proximal end of the tool, a perforation was made by either unifacial rotation from the inferior side or by bifacial rotation (Fig. 8.e). The distal end (Fig. 8.d,i) has a rounded morphology with macroscopic polish, and a general disappearance of technological marks, while the functional striations are arranged transversely. On some pieces, the perforation is laterally deformed with a small concavity and the smooth appearance of the perforation wall (Fig. 8.j).

A second subcategory of needles presents another system of thread attachment at the proximal end (Fig. 8.k). The blank was obtained by the same method of quadri-partition by double grooving. The shaping procedures were also applied by the same techniques: the proximal and distal ends were rigorously abraded, and scraping was applied around the entire circumference. On the proximal end, however, a groove is evident, made by sawing (Fig. 8.l) which was applied around the circumference to allow the attachment of a thread. The end (Fig. 8.n) is affected by use-wear, with a significant modification of the initial volume, resulting in the disappearance of technological traces and their replacement with functional transversal marks. At the proximal (Fig. 8.m) and mesial areas (Fig. 8.o), an area of use-wear is present: characterized by macroscopic polish, flattening of the surface, and functional striations resulting from contact with the hand.

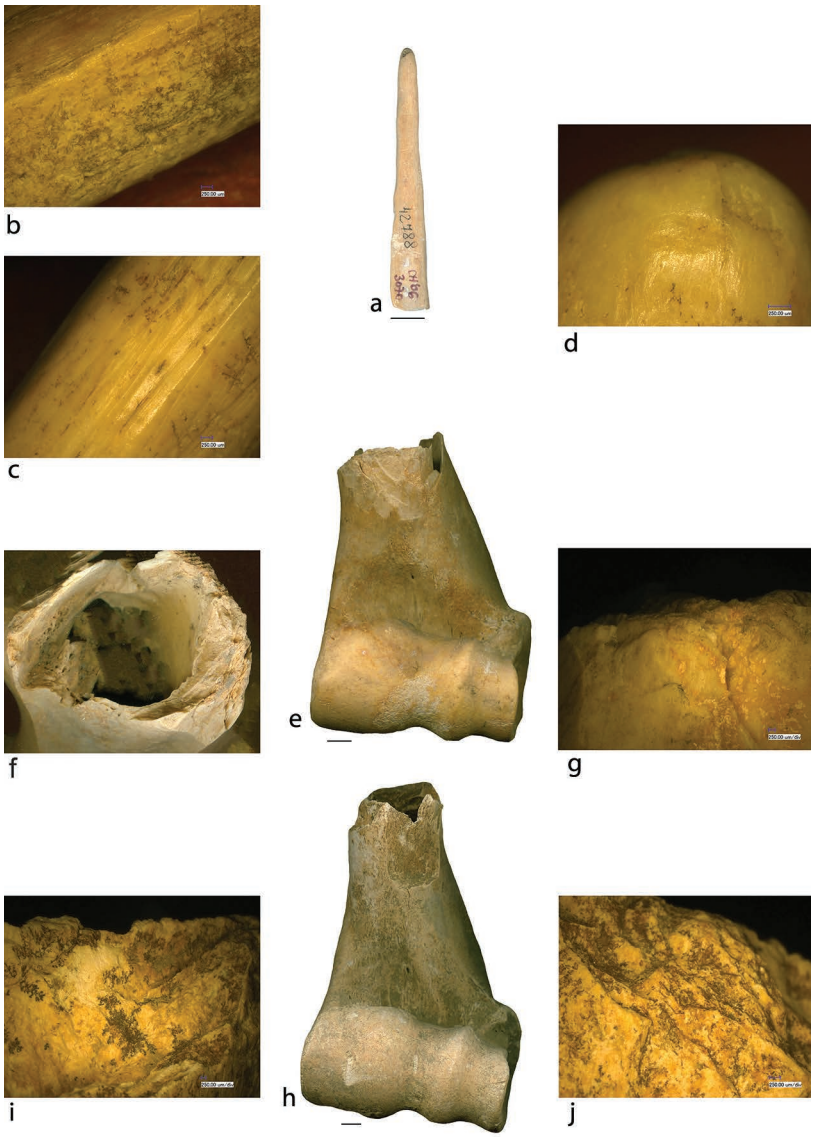

Fig. 5. **a** ***bone pointed tools;*** **b** ***abrasion marks;*** **c** ***scraping marks;*** **d** ***active end detail;*** **e,h** ***hammers;*** **f-g,i-j** ***marks of the percussion procedure.***

Beads (n=3). Three tubular beads (Fig. 9.a) were manufactured from small mammal diaphyses. The blank volume is obtained by sawing (Fig. 9.b) at both ends, with the detachment being completed by bending (Fig. 9.c). The segmentation edges were regularized by abrasion. When the use-wear is advanced (Fig. 9.d), the abrasion is hardly visible and the end is characterized by a rounded wall and a small concavity associated with a flattened facet with strong polish (Fig. 9.e). Such a tubular bead was made from a bird bone at the Techirghiol site. The blank is in volume, obtained by cutting the ends. The epiphyses were finally removed by bending hence the small V-shaped fracture. Then, the segmentation edge was regularized by abrasion.

Bevelled tools (n=2). This typological category is represented by two pieces. In the first specimen (Fig.

9.f), the flat blank was obtained by longitudinal bipartition without being able to identify the procedures, because bilaterally the piece was modified by longitudinal scraping (Fig. 9.g). The active end was created by bifacial abrasion (Fig. 9.h) applied at the distal end. This is characterized by small fractures and perpendicular striations. We think that it was an intermediate tool/split wedge. The second piece (Fig. 9.k) is fractured meso-proximally with strong macroscopic use-wear that eliminated many technological marks. It is a flat blank, obtained by longitudinal debitage which involved grooving (Fig. 9.l-m). The surface of the piece is entirely abraded. The distal end is partially fractured (Fig. 9.n). It is characterized by strong polish and short, oblique use-wear striations (Fig. 9.o). The bevelled tools are more numerous at the Techirghiol site, with six specimens having a unitary processing scheme. The items were made on blanks in volume. At the proximal level, the epiphysis was eliminated by percussion, without regularizing the debitage edge. The active end was also arranged by percussion, superimposed by a shaping by abrasion.

Pendant (n=1). A bird phalanx 1 was used (Fig. 10.a) which still preserved the natural shape of the bone. At the distal epiphysis, a perforation was created by bilateral rotation (Fig. 10.b). The piece was used for a long time because the pressure of the wire led to the rounding and deformation of the wall (Fig. 10.c) and the appearance of a concavity (Fig. 10.d). The area of deformation corresponds to a use-wear facet consisting of surface flattening and macroscopic polish (Fig. 10.e).

Scraper (n=1). In this case, a splinter from the diaphyseal wall of a long bone was used. We were unable to identify the longitudinal debitage method, since the debitage edges and the inferior side were regularized by scraping (Fig. 10.h-i). Segmentation was applied by sawing with superimposed abrasion. The active end is strongly concave from being practically exhausted. It shows abrasion striations (Fig. 10.g), which suggests that it was periodically reshaped to maintain its efficiency. This abrasion superimposes a surface with a strong polish (Fig. 10.f). The piece seems to have been used for cleaning wood in an identical way to tooth scrapers (*Mărgărit, Boroneanț 2021*).

Perforated phalanx (n=1). A cattle phalanx 1 (Fig. 10.k) was perforated on one side using percussion (Fig. 10.l) on the diaphisis of the dorsal face. Above the perforation, a use-wear area has developed with

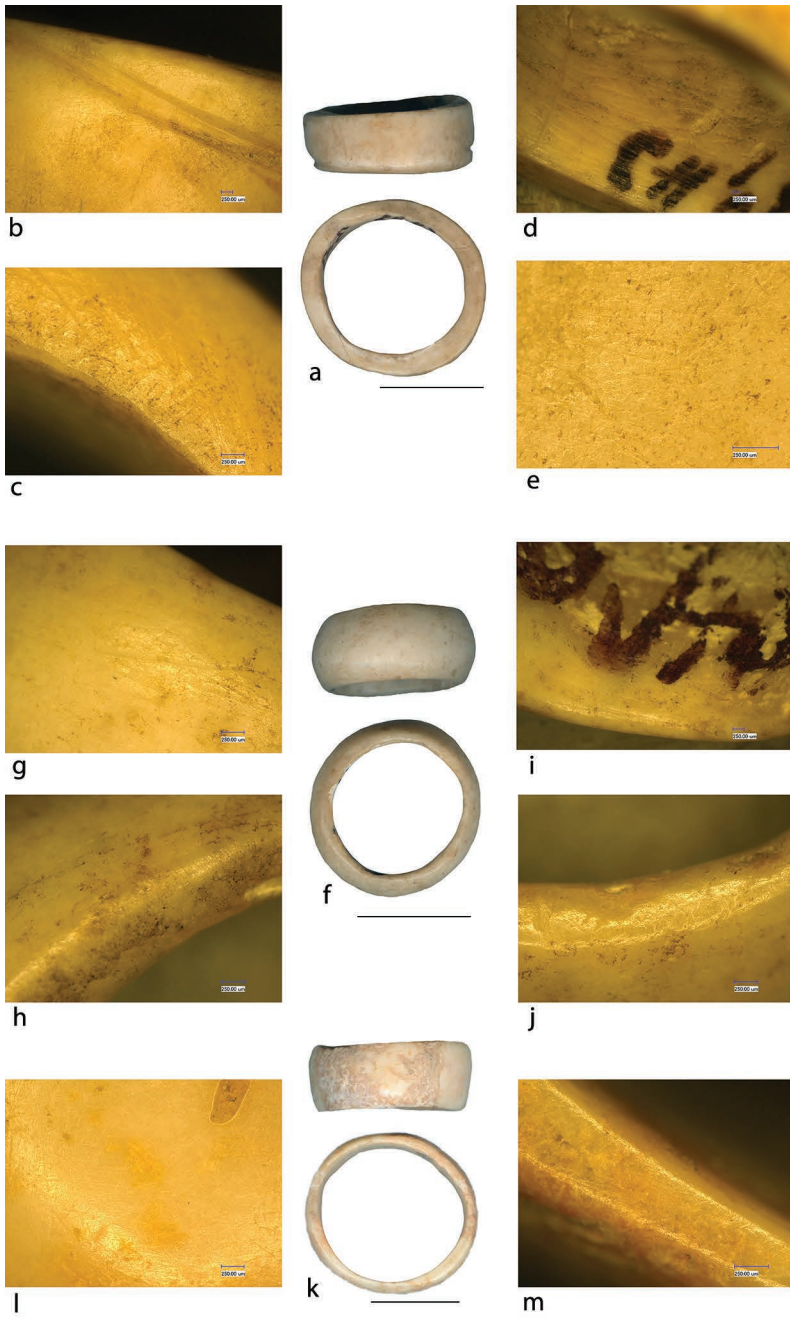

Fig. 6. **a,f,k *bone rings;* b,g *segmentation marks:* c,h *abrasion marks;* d,i *scraping marks;* e,j,l-m *use-wear areas.***

flattening and macroscopic polish (Fig. 10.m). Under the microscope, a series of longitudinal striations appeared as a result of use.

Preforms (n=4)

One of the preforms (Fig. 11.a) appears to be in the process of transformation into a needle from a caprine metapodial. It is a meso-proximal fragment, made into a flat blank that was obtained by double grooving (Fig. 11.c-d). The proximal end (Fig. 11.c) and the debitage edges (Fig. 11.d) were arranged by abrasion. On the inferior side, a rotational perforation (Fig. 11.e) was initiated.

Another preform was to be transformed into a ring (Fig. 11.f). The blank was obtained by sawing with an abrasive fibre. The specific striations (Fig. 11.g) are visible on the wall of the blank. The segmentation edge was not shaped. On the medullary canal, a transversal scraping (Fig. 11.h) was applied to the longitudinal axis, intended to clean the walls and widen the hole.

One of the preforms (Fig. 11.i) was to be transformed into a pointed tool. The importance of the piece lies in the fact that both the marks of the debitage operation and the traces from the beginning of the shaping operation are preserved. The preform was made on a flat semi-finished product obtained by quadri-partition by double grooving (Fig. 11.j), which had suffered an accident when it was detached by indirect percussion. On the meso-distal area, along the entire circumference, longitudinal scraping was applied (Fig. 11.k) to create an end with a sharp morphology. The piece was not finished.

Blanks (n=13)

A diaphysis (Fig. 11.l) of a small mammal was used as a blank, segmented from the parental bone by sawing at both ends. The marks are visible (Fig. 11.m-n). No shaping process had occurred. It was intended to be a tubular bead.

Four other blanks illustrate the technological manufacturing scheme for obtaining rings. They preserve one or more grooves drawn by sawing, applied with the help of a flint piece. The technological marks are arranged transversely to the long axis of the bone, but differ significantly from those made with abrasive fibre because they are deep, irregular and occur at the periphery of the segmentation edge. Numerous cutting marks appear, resulting from the tool

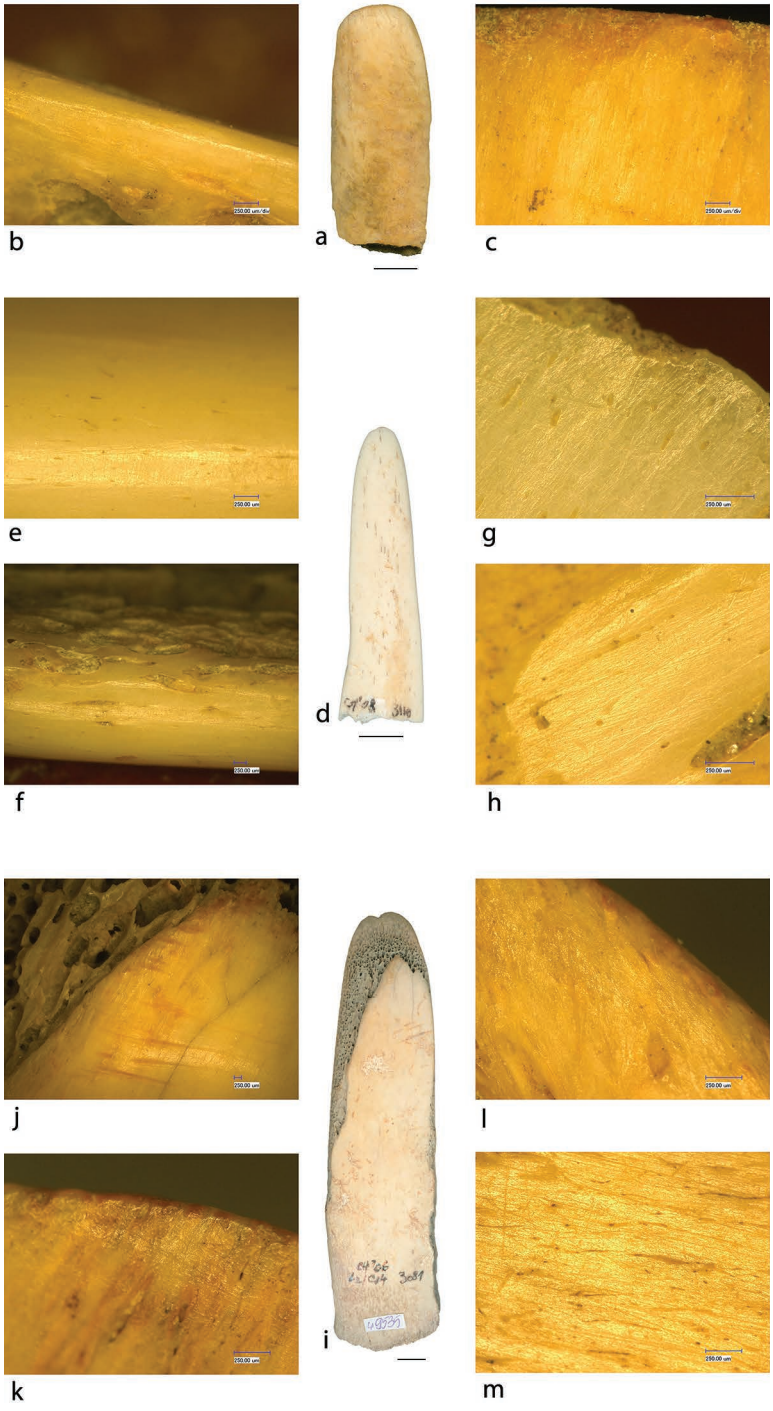

Fig. 7. **a,d,i *bone spatulas;* b,f *bipartition by scraping;* c,g-h,l *active end details;* e,j-k *abrasion marks;* m *use-wear area.***

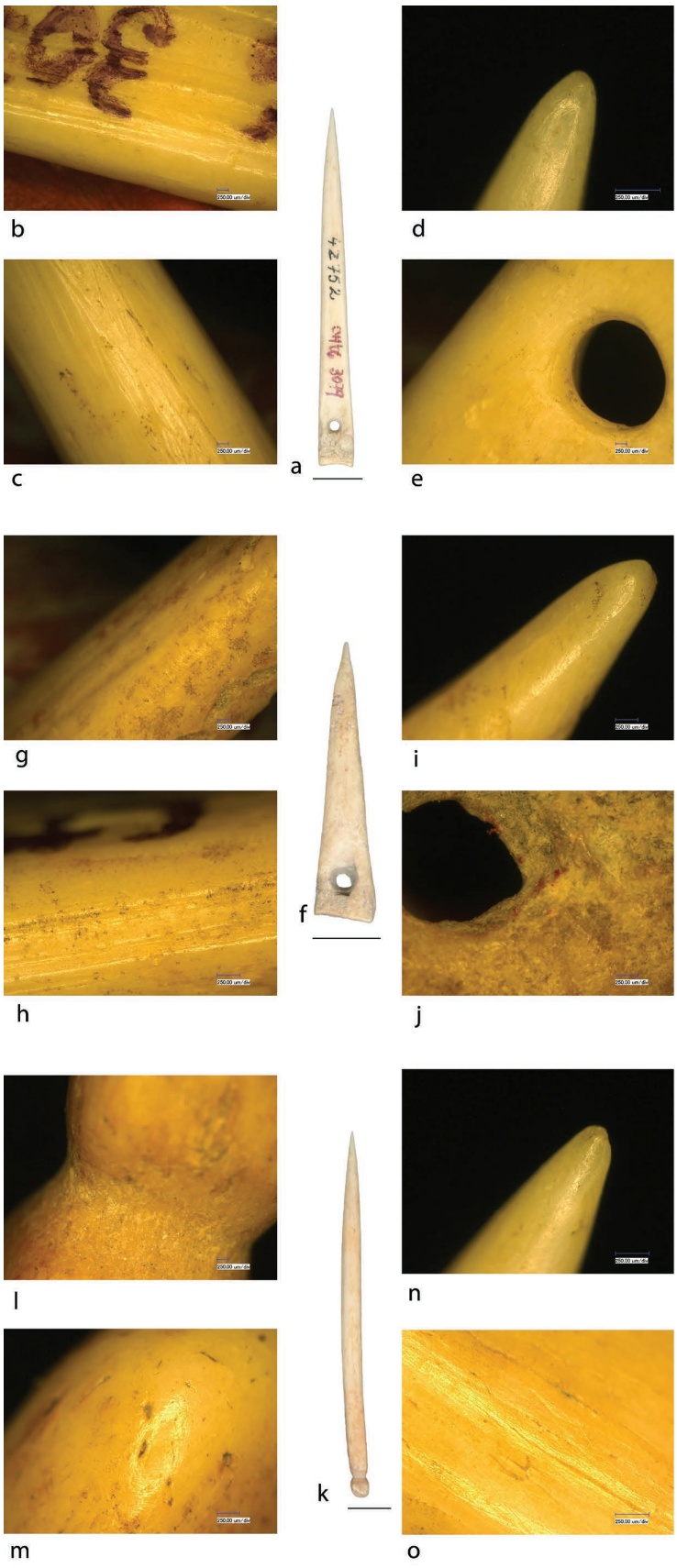

Fig. 8. **a,f,k** ***bone needles;*** **b,h** ***grooving marks;*** **c,g** ***scraping marks:*** **d,i,n** ***end details;*** **e,j** ***perforation details;*** **l** ***sawing marks;*** **m,o** ***use-wear areas.***

slipping in production. The striations are grouped in series that intersect with each other. Moreover, the groove is not continuous, like the one made with fibre, because the tool was progressively turned around the diameter of the bone (unlike in the case of fibre segmentation, the procedure starts from a single direction maintained until the final detachment). One such caprine femur specimen (Fig. 12.a) preserves four grooves made by sawing (Fig. 12.b) with the help of a flint tool. This is a delineation procedure what allowed for a pre-visualization of the width of future rings. This bone reflects the method of serially obtaining rings.

Another caprine femur (Fig. 12.c) is exceptional because, through its preservation, it contributes significantly to the reconstruction of the technological scheme for the serial production of the rings. No less than nine grooves (Fig. 12.d) were traced with a flint tool to delimit the width of the future rings. The detachment was to be carried out by sawing with abrasive fibre, as demonstrated by the first groove, where the process was completed and the second groove, where it was initiated. A blank of the same category is also present at the Palazu Mare site. It was obtained through a segmentation procedure with abrasive fibre applied to both ends. The shaping operation did not occur, and therefore it remained in the blank stage.

Two caprine metapodials (Fig. 12.e) are transversely fractured – hence, probably, their abandonment. Five other pieces in this category have a trapezoidal morphology, representing a quarter of the diameter of a bone (Fig. 12.g). Both walls of the pieces bear traces of detachment by double grooving (Fig. 12.e,h). At the ends, the segmentation marks could only result from bending. This excludes the use of the extraction method, indicating instead that longitudinal debitage by bipartitioning was initially used. This was achieved by double grooving, continued by detaching the two halves by indirect percussion. These two halves were then bipartitioned

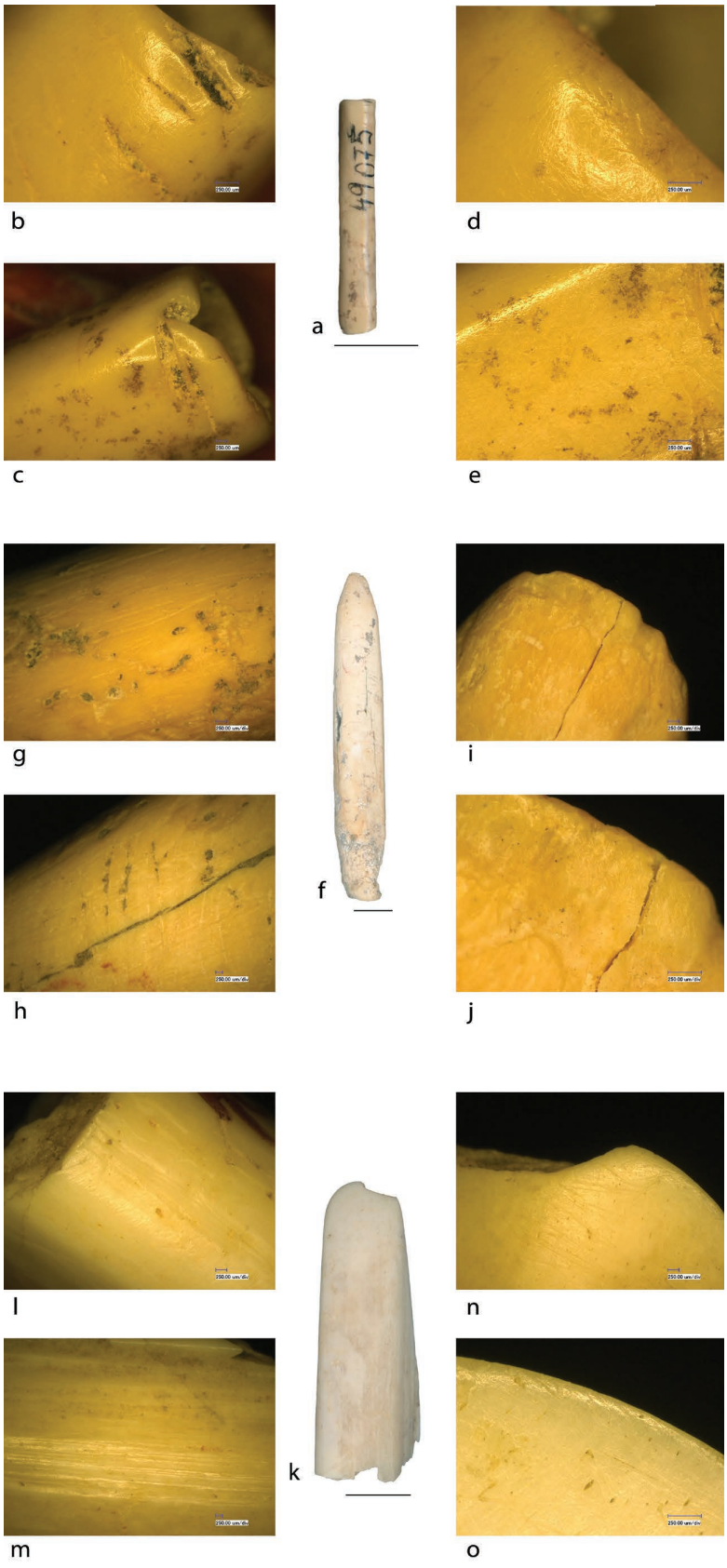

Fig. 9. **a** ***bone bead;*** **b** ***sawing marks;*** **c** ***bending marks:*** **d** ***abrasion of segmentation edge;*** **e** ***use-wear facet;*** **f,k** ***bone bevelled tools;*** **g** ***scraping marks;*** **h** ***abrasion marks;*** **i-j,n-o** ***active end details;*** **l-m** ***grooving marks.***

by the same procedure. The epiphyses were preserved at some specimens, while in others they were removed by bending. Eight blanks from the Techirghiol site are in various stages of processing, from bones on which the longitudinal groove was just initiated to blanks already detached and representing a quarter of the bone's diameter.

Waste (n=6)

Two remains (Fig. 12.i) – diaphyses from medium-sized mammals – were left after the segmentation of the bone, prior to obtaining the ring blanks. Long and parallel striations, located transversely on the long axis, were preserved at the ends of one of the specimens (Fig. 12.j-k). When the bone wall was thinned sufficiently on the waste specimens, bending was applied. The pieces are important, because they contribute significantly to the reconstruction of the technological manufacturing schemes employed, especially since the waste artefacts are often not mentioned in studies. Four femurs, a humerus and a tibia of *Ovis/Capra*, two femurs and a metatarsus of *Bos taurus* and three diaphyses of bones from a medium-sized mammal from the site of Palazu Mare preserve traces of a segmentation procedure with abrasive fibre on their surfaces. These examples of waste most likely resulted from the procedures of obtaining rings on a blank in volume, and demonstrate the older tradition, prior to the Hamangia culture, of production of rings in series.

Four bone fragments are likely debris of the technological scheme for obtaining the pointed tools by longitudinal debitage with quadri-partition by double grooving. Grooves are visible in various stages of their tracing. One caprine metapodial fragment (Fig. 12.l) was abandoned at an early stage of processing because, most likely, it fractured transversely and no longer had the dimensions necessary to ob-

tain a finished piece. The bipartition was initiated by grooving (Fig. 12.m) using the median depression that prevented the lateral sliding of the flint piece. On another piece, the bipartition procedure was slightly more advanced in the manufacturing scheme where the groove had formed. On a third piece, there was a fairly well-formed groove and the separation of the two semi-finished products by indirect percussion had already begun, as indicated by a median crack. However, the detachment procedures were initiated too early, triggering the fracturing of the item. The longitudinal groove is even deeper on a fourth piece, where the bone wall was completely removed in the medial area. The detachment of the two blanks had not been started. Three caprine bone fragments from the Palazu Mare site also preserve traces of longitudinal debitage and were probably intended to be transformed into blanks by quadripartition with double grooving. They fractured transversely and the technological processing was not continued.

Carapace

Carapace (n=134). Fragments of *Testudo* sp. carapaces (Fig. 13.a,h) bear various technological and use-wear marks on their surfaces. They are likely fragments of small containers which were used and then abandoned. The first interventions in the technological scheme on the carapace are those of separating the carapace from the plastron. This intervention took place by breaking peripheral plates three to seven on the two sides where the bone thickness is the smallest. This was followed by the loosening of the peripheral plates by forcing the joints with the pleurals. Finally, both the extremities and the interior were finished by removing and abrading the vertebral apophyses (*Radu* et al. *2022*). At Cheia, the carapace fragments show technological marks that illustrate the ways of processing and transforming them. Some of them have undergone a cutting procedure from the interior side. Striations are evidence for the application of this procedure. The cutting edges were abraded (Fig. 13.b-d), on variable areas, to give the piece a regular shape. Other specimens do not preserve cutting marks, but often one of the sides was regularized by abrasion. A single carapace fragment was perforated by bifacial rotation.

Fragments of carapace were also found at the sites of Palazu Mare and Techirghiol. Even though we cannot reconstruct the full shape of the artifacts and the fragments do not bear specific technological traces, as is the case at the site of Cheia, five fragments of carapace from Palazu Mare may also represent fragments of containers.Traces of use-wear are visible. Two of the fragments were perforated by unifacial rotation from the lower side. At Techirghiol there are two such

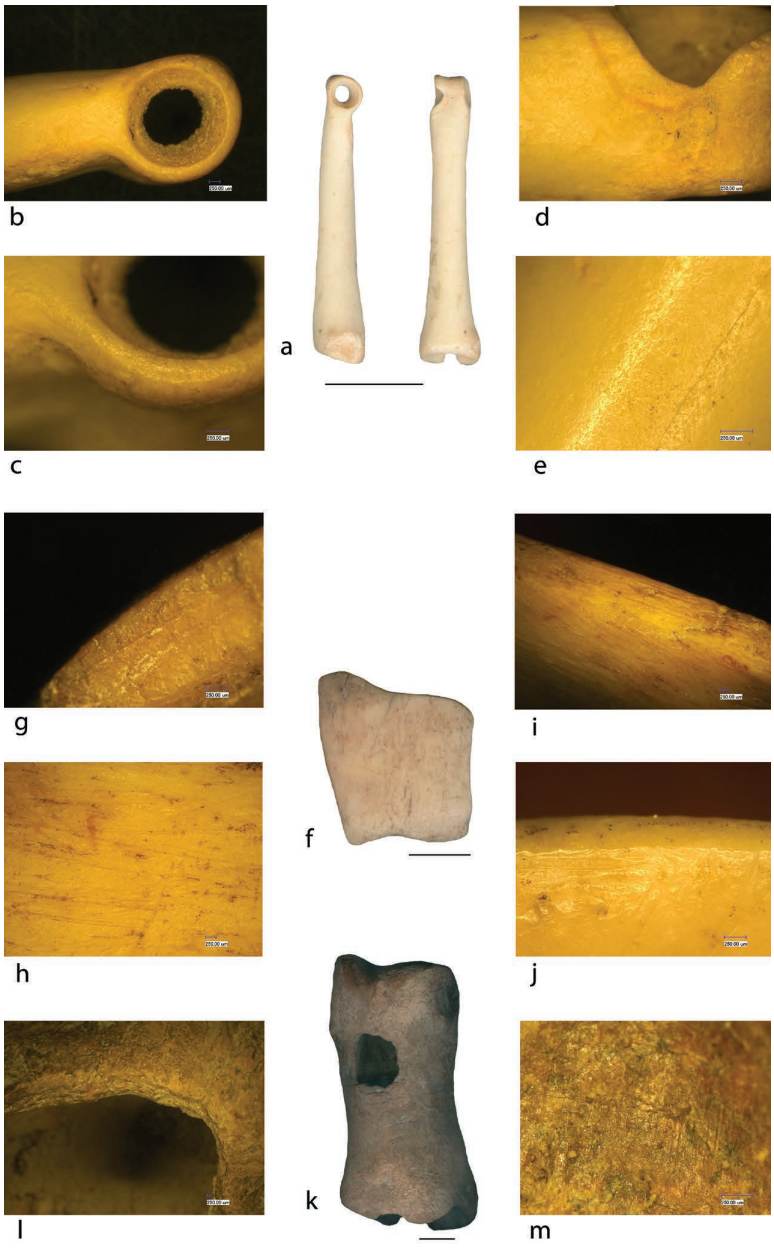

Fig. 10. **a** ***bone pendant;*** **b** ***perforation detail;*** **c-e** ***use-wear details;*** **f** ***bone scraper;*** **g** ***abrasion marks;*** **h-i** ***scraping marks;*** **j,m** ***use-wear area;*** **k** ***perforated phalanx;*** **l** ***perforation detail.***

fragments: the first shows use-wear traces typical of a container, the second was perforated by unifacial rotation.

Shell

Scrapers (n=35). A series of shells from the genus *Unio* (Fig. 14.a) show different types of use-wear marks on their surfaces. Of these, we recovered 22 that have use-wear marks on the ventral edge, nine have mixed use-wear marks on the ventral edge and the anterior side, and four items have complex use-wear on the anterior, posterior and ventral edges (*Mărgărit* et al. *2021*). There are no technological marks for retouching or shaping the pieces, this macroscopic observation being confirmed by the microscopy analysis. Nine *Unio* shells were used without being technologically processed at the Techirghiol site. On a few pieces from the Cheia site, pigment spots are present on the interior side (Fig. 14.f) (*Dulamă* et al. *2021*). Consequently, the pieces were used in their natural shape.

Appliqués (n=3). Three *Cardium* shells (Fig. 15.a) were perforated (Fig. 15.b) on the umbo of the shells. The perforation was made by abrasion (n=2) (Fig. 15.c) or by pressure (n=1). This represents the only intervention on the shell. The use-wear is characterized by the deformation of the perforation towards the end, and the creation of a small depression (Fig. 15.d-e). Macroscopic polish is evident at the use-wear site. We assume the individual sewing of the pieces as appliqués. Two such appliqués were also made at Terchirghiol by perforating the shells with percussion.

Beads (n=5). The *Spondylus* shell was used as raw material for making beads (Fig. 15.f). Three pieces have a tubular morphology, one has a bitronconical morphology, while the fifth is only a fragment. All pieces have a bifacial perforation (Fig. 15.g) and rigorously shaped ends. Use-wear is present on all pieces, but is not similar in its intensity. One of the pieces has advanced use-wear with two marked concavities at the ends (Fig. 15.i), asso-

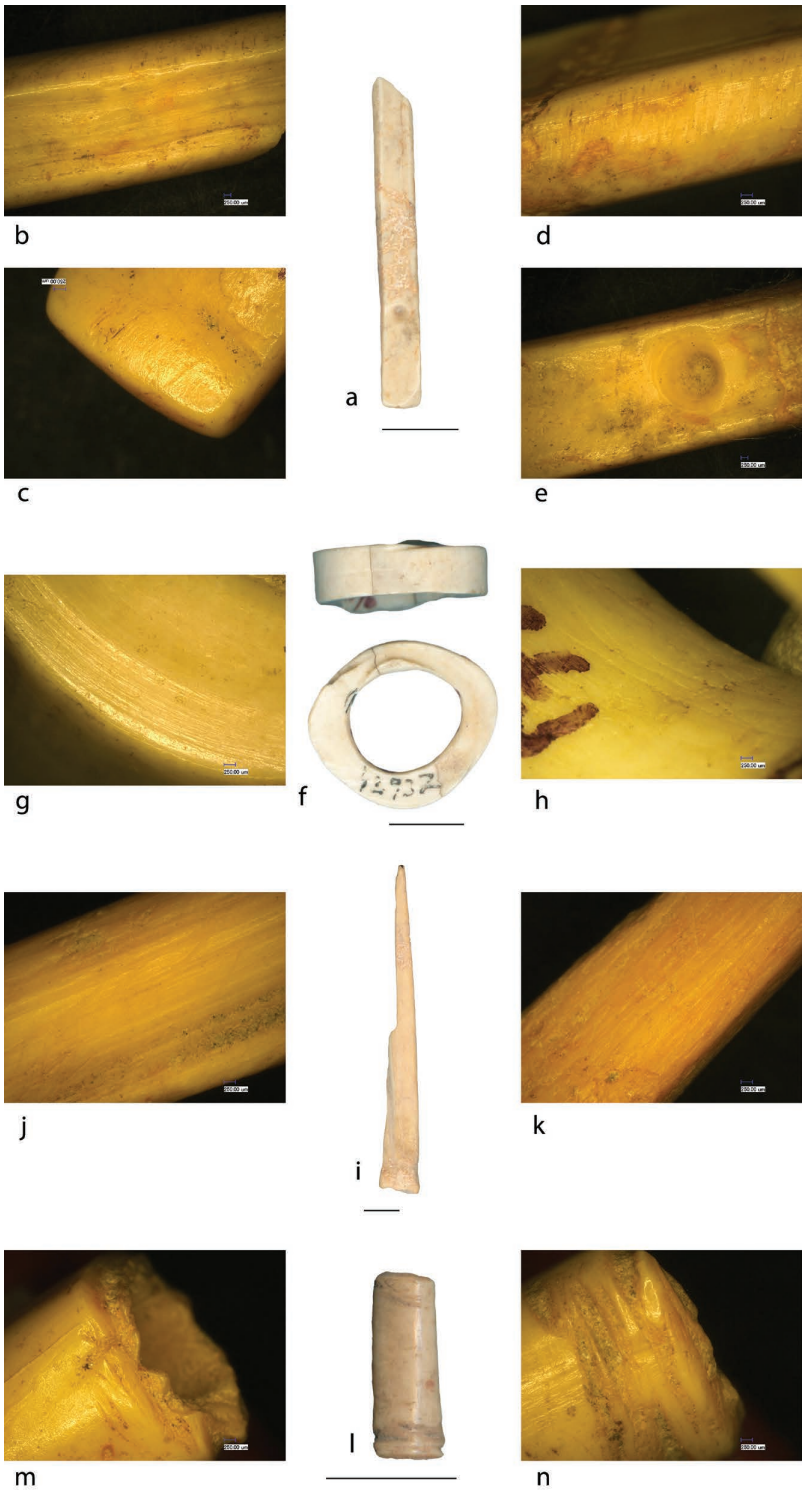

Fig. 11. **a** ***needle preform;*** **b,j** ***grooving marks;*** **c-d** ***abrasion marks;*** **e** ***detail of perforation;*** **f** ***ring preform:*** **g** ***sawing with vegetable fibre;*** **h,k** ***scraping marks;*** **i** ***pointed tool preform;*** **l** ***bead preform;*** **m-n** ***sawing marks.***

ciated with a flattened use-wear facet (Fig. 15.j) which modified the section of the piece from rectangular to almost triangular. The perforation is also deformed towards the facet (Fig. 15.h). The rotation striations are no longer preserved inside the perforation. A similar piece was also found at the Palazu Mare site, illustrating advanced use-wear, with a marked concavity at one of the extremities, associated with a flattened facet.

For the Cheia settlement, an anthropomorphic pendant made from *Spondylus* shell was also published, but we did not have the opportunity to analyse it. It has a schematic shape, with a cylindrical perforation on the abdomen area. The body details are suggested through the different undulations of the surface, as well as through the incisions that delineate the legs, abdomen, neck and arms. Only the legs are separated at the lower area by a vertical incision. The surface of the piece was carefully shaped (*Voinea 2010*; *Voinea* et al. *2014*).

Tooth

Pendant (n=1). The wild boar (*Sus scrofa*) canine from a male (Fig. 15.k) was used to make an adornment, namely a pendant. It is a flat blank, made from a splinter of the root of the tooth. The blank was obtained by percussion, after which the debitage edges and the inferior side were regularized by abrasion (Fig. 15.l-m). The concave edge shows longitudinal scraping marks (Fig. 15.o), over which the use-wear polish is superimposed demonstrating that the piece was initially used as a scraper. It is not excluded that after numerous rearrangements it was recycled into a pendant. The piece was originally published (*Voinea* et al. *2014*) as having a perforation at each end made by rotation (Fig. 15.n). At the time of studying the assemblage, the piece was fractured at one end.

An overview of the first osseous industries from Dobrudja

Raw materials

The Palazu Mare – *Malul Alb* settlement contains, at the current stage of research, the oldest Neolithic occupations on the territory of the Dobrudja. Domestic species at Palazu Mare have a share of 95% of the total fauna. In later phases domestic fauna retain their predominance by reaching percentages of over 98% in Hamangia I-II. Cattle are placed first (60.1% – Prehamangia culture; 88.3% – Hamangia I-II culture), followed by caprines with a share of 34.6% in the Prehamangia and 10% in Hamangia I-II. Hunting contributes to both sequences, with low percentages of wild fauna but with large and medium-sized wild animals (especially hemion and cervids) (*Voinea* et al. *2023*). Within the Hamangia Cheia settlement, analysed here in detail, the percentage of domestic animals is 91%, especially cattle (48%), and caprines (41%) (*Bălăşescu, Radu 2021*). Meat requirements were also supplemented by game, especially large mammals (equids and cervids). The mobility of the Hamangia communities along the Casimcea Valley – a passageway between the central Dobrudja karstic zone and the west-pontic zone – is indicated by the presence at Cheia, of fish and marine

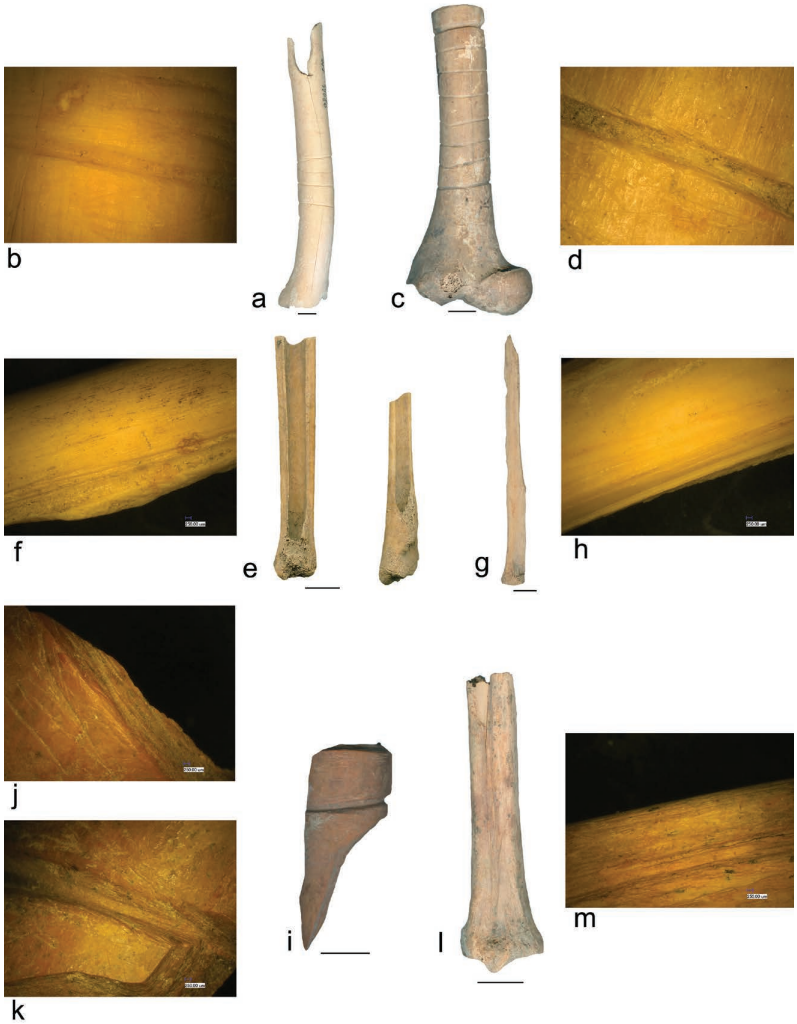

Fig. 12. **a,c,e,g *blanks;* b,d,j-k *sawing marks;* f,h,m *grooving marks;* i,l *debitage waste.***

molluscs (*Bălăşescu, Radu 2004; 2021; Bălăşescu 2008; Radu 2008; Tornero* et al. *2013*), but also by isotopic analyses (*Balasse* et al. *2014*). At another Hamangia site, Techirghiol – *Dealul Minerva*, domestic species have a share of 88.1%. For the majority of complexes, cattle bones dominate (57.5%) followed by sheep and goat bones (27.1%) (*Bălăşescu, Radu 2021*). We observe that the evolutionary picture is unitary throughout the entire chronological sequence discussed, without significant variations.

For the Prehamangia culture, bones from domestic species were used almost exclusively for manufacturing worked artefacts, with *Bos taurus* accounting for the highest in proportion, followed by *Ovis aries/Capra hircus*. From wild species, the carapaces of tortoise were used. Antler occupies a secondary place in the assemblage and the existing pieces cannot provide us with information related to the method of acquisition (gathered *vs*. debited from the skull). We have no attested imports so far (*Voinea* et al. *2023*). However, it should be noted that all the Prehamangia pieces come from a unique archaeological context, and further research is needed to validate these preliminary observations. The pieces from Hamangia I-II contexts are too few (seven pieces) to be able to identify specific data at the level of raw material selection.

For the archaeological Hamangia site at Cheia, the raw materials used (Tab. 2) highlight the predominance of *Ovis aries/Capra hircus* bones, followed by *Bos taurus*. Bones from wild species were also used, such as *Equus hemionus* or *Aves* sp. Other types of blanks, procured from local wild species, were also exploited such as *Testudo* carapaces, *Unio* sp. and *Cardium* sp. shells, and *Sus scrofa* teeth, as well as also exotic ones, such as *Spondylus* sp. shells. At the Cheia settlement, the processing of deer antler is not attested. This seems to be a specific characteristic of the site, since several artefacts made of deer antler were identified at the Hamangia settlement of Techirghiol – *Dealu Minerva*. In the latter site, at the level of bone selection, *Bos taurus* comes first, followed by *Ovis aries/Capra hircus*. Processed bones from wild species of *Cervus elaphus*, *Capreolus capreolus* or *Aves* sp. appear, as well as shells of *Unio* sp., *Cardium* sp. or *Glycymeris* sp. (*Mărgărit* et al. *2022*).

Technical transformation schemes

At the Cheia settlement, the presence of items still being processed helped us to identify the techniques

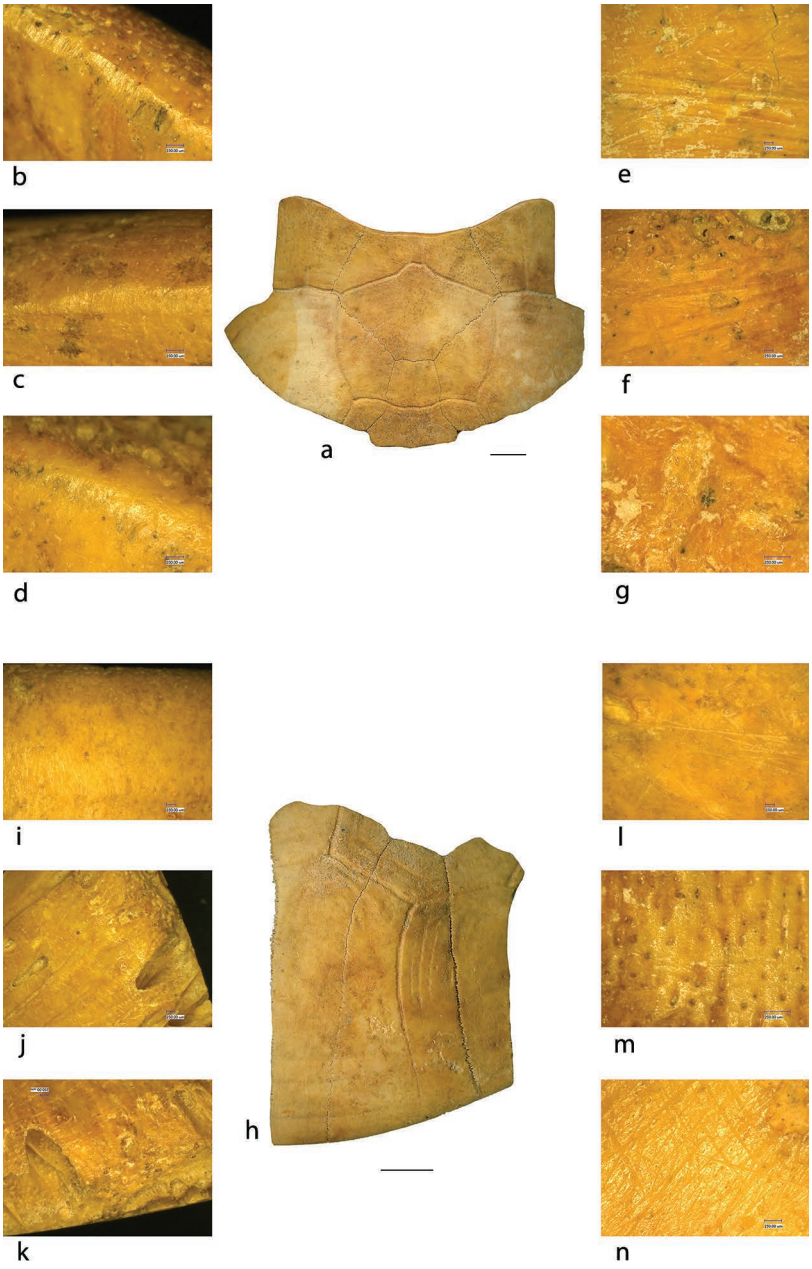

Fig. 13. **a, h** ***Testudo carapace containers;*** **b-d** ***abrasion of the debitage edge;*** **e-g,i-l** ***functional striations on the interior side;*** **m-n** ***use-wear on the exterior side.***

used in the first technological stages of raw material transformation. The marks of the debitage operation are usually removed by subsequent technological interventions. In our discussion, weareparticularly interested in the bones from which most pieces were made and whose processing variants are more diverse compared to, for example, the tortoise carapace. During the debitage operation, mainly flat blanks were obtained (n=164). The type of blank is determined mainly by the typological category (*e.g.*, pointed tools – flat blanks *vs.* hammers or rings – blanks in volume). The existence of complex transformation schemes (*e.g.*, pointed tools obtained by quadri-partition) in opposition to extremely simple schemes (*e.g.*, hammers) also draws attention. Regarding the flat blanks, the preponderance of a transformation scheme by quadri-partition is observed, and the main procedure was that of double grooving. Most of the pointed tools were made using this debitage method, which illustrates a high productivity within the assemblage since up to four blanks could be obtained from a single bone. Secondarily, bipartition was also used, which integrated several variants: double grooving, a combination of grooving and percussion, or percussion and scraping. In the case of the transformation scheme by segmentation, two procedures were applied that are in fact clearly individualized according to the typological categories: percussion for hammers, and sawing for rings. And in the case of the rings, productivity is high per bone as demonstrated by the pieces found which were undergoing processing. These transformation schemes were also identified in the Prehamangia culture at the Palazu Mare site (*Voinea* et al. *2023*), but also in other Hamangia sites, such as the one at Techirghiol – *Dealul Minerva-Paloda* (*Mărgărit* et al. *2022*). In the context of these sites, there were identified as detachment procedures a transversal debitage to which a transformation scheme by segmentation was used. Additionally a longitudinal debitage was also used in combination with a transformation scheme by bipartition or quadri-partition to produce worked bone artefacts. In the longitudinal debitage methods with bipartition and quadri-partition, the double grooving was used first and, more rarely, the combination of grooving and percussion. In the transversal direction, percussion and sawing were used. With small variations specific to each of the mentioned sites, we see that the procedures involved in the debitage operations are unitary, with no variations attested from one chronological phase to another. Closely technologically related to these pieces are needles. These were used for sewing, using either vegetable or animal fibres.

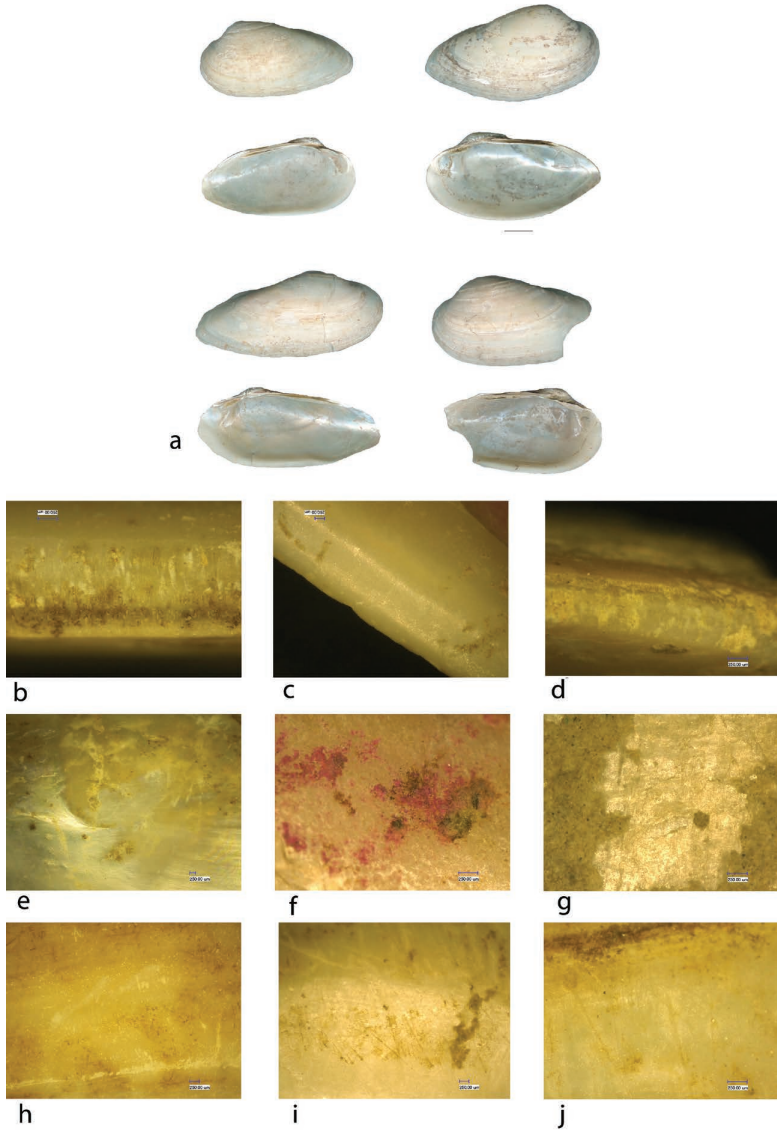

Fig. 14. **a Unio** ***shells;*** **b-d** ***use-wear on the ventral end;*** **e,g** ***use-wear on the interior side;*** **f** ***traces of pigment;*** **h-j** ***use-wear on the exterior side (dorsal side).***

For surface modification, abrasion was the most commonly used technique. This is followed by scraping for sharpening the ends, sometimes in combination with abrasion. In the case of volume modification, perfora-

tion made by rotation and, in one case, by percussion were attested. Sawing is also observed on some needles. Abrasion and scraping for surface modification, and perforation by rotation and percussion for volume modification, were also identified at both Palazu Mare and Techirghiol. Surface modification and perforation appear to be quasi-universal techniques in prehistoric sites that cannot constitute cultural indicators, as is the case with some of the techniques used in the debitage operation.

For tortoise carapace, the technological interventions are minimal: a segmentation scheme by cutting and abrasion are the only surface modification procedures. The volume modification was achieved in a single case by perforation in rotation. For the other similar carapace pieces from Palazu Mare or Techirghiol, we did not identify traces of a segmentation procedure because we are only able to analyse fragments. Instead, perforation by rotation was used to modify the volumes.

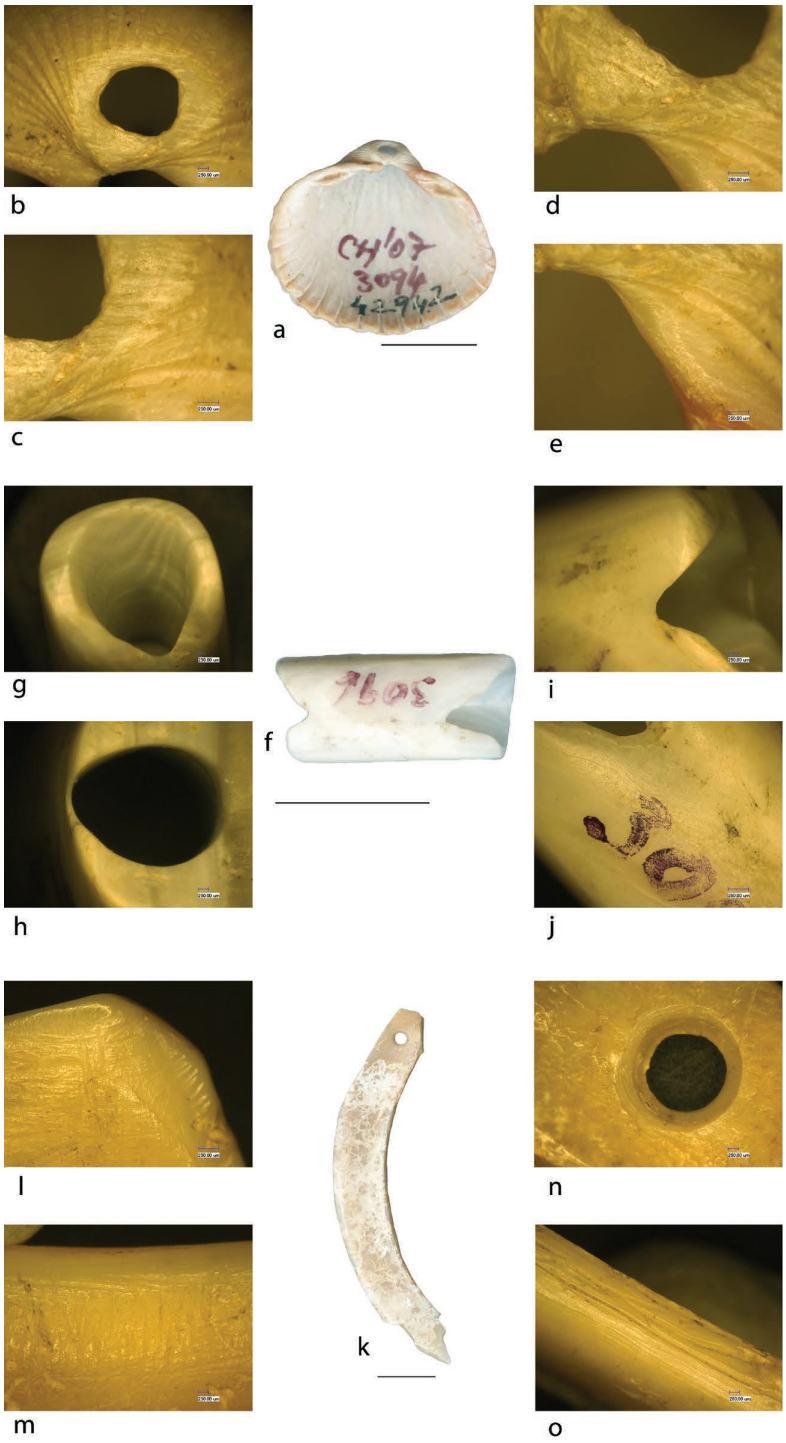

Fig. 15. **a** ***Cardium shell ornament;*** **b,g,n** ***perforation details;*** **c,l-m** ***abrasion marks;*** **d-e,i-j** ***use-wear areas;*** **f** ***Spondylus shell bead;*** **h** ***perforation deformation;*** **k** ***tooth pendant;*** **o** ***scraping marks.***

Shell scrapers did not have technological interventions, but for the manufacture of ornaments, the complexity of the technological schemes was variable. The simplest involved the use of volume modification by abrasion or pressure (*Cardium* shells). Complex transformation schemes were applied in the case of *Spondylus* shell ornaments consisting of longitudinal debitage by successive partitions, and a transversal one through segmentation. In none of these cases can we identify the technological debitage procedures due to the surface modification by abrasion. The volume modification was achieved by perforation in rotation.

Finally, the tooth was processed through longitudinal debitage involving a bipartition transformation scheme by percussion. The surface modification procedures were abrasion and scraping, and the volume modification procedure was perforation by rotation.

Functional hypotheses

The most important typological category is that of the pointed tools, at both the Cheia and Techirghiol settlements. The series of pointed tools analysed are technologically and functionally extremely coherent. For the Cheia assemblage, microscopic and experi-

mental analyses were carried out, which established the activities within which they were used. On some pieces the surface has extensive and visible polish, with superficial changes of the initial volume (an alternation of small depressions visible only under a microscope). Functional striations are not long, but they are shallow and arranged approximately transversal to the axis of the item (but rather irregular). An abrasive but not very hard material was likely processed, suggesting intense friction. The evolution of the use-wear is comparable to the one developed on the experimental pointed tools used for vegetable fibre processing. In a second situation, the volume changes are macroscopically visible and deeper. The material worked was harder than in the first case, but not as abrasive. Functional striations are long, regular, and arranged approximately longitudinally along the axis of the items, clearly indicating the direction of motion, and use-wear triggered by wood working appears compatible with this (*Mărgărit* et al. *2023*).

Another representative category is that of hammers made from large mammal bones. Such hammers also appear at the Prehamangia Palazu Mare site, where they constitute the main typological category, demonstrating an older tradition, prior to the Hamangia culture. What caught our attention is the fact that at the periphery of the segmentation plane (which functioned as a working edge) there are longitudinally developed, overlapping fractures with non-uniform morphologies (Fig. 5.f-g,i-j). Most likely, the epiphysis functioned as a handle and was percussed with the segmentation edge. The working edge has fractures on the periphery and the surface has a polish localized on small areas. Macroscopically, the surface appears rather rough because the small successive fractures maintain this visual aspect. Without a rigorous experimental programme it is difficult to say what materials they were used for, only that they were used in a hard percussion action, applied axially. They are not unique pieces, and bones similar in their mode of use have already been published for PPN sites from Jordan, Anatolia and Iran, for the Early European Neolithic, Linear Pottery Culture in Europe or Early Chalcolithic from Bulgaria (*Stordeur 1988; 1994; Sidéra 2010*).

Rings were present in both the Prehamangia and Hamangia contexts. On the surface of the items, two areas of use-wear could be identified. The first develops at the periphery of the segmentation edge, towards the medullary canal and consists of the elimination of abrasion marks, surface flattening, and the formation of macroscopic polish (Fig. 6.j,m). The second area is located on the external side (Fig. 6.e,l) on the median region and appears possibly as a result of prolonged manipulation. It is characterized by the same phenomenon of flattening of the bone convexity and the appearance of irregular striations. The morphology of the pieces analysed in this study seem compatible with rings, although the small diameter of the caprine bones shows that the pieces could not be used as rings to be worn by adults on the fingers. If they were not ornaments they could possibly be used to hold hair. Another functional hypothesis associates these rings with processing baskets made from vegetable fibres (*Sidéra 2000*). The rings caught and held the wicker bundles that were woven into baskets. For the Cheia settlement this hypothesis is supported by the presence of a significant number of pointed tools, which by morphology and development of use-wear do not seem to

Raw material	*Ovis aries/ Capra hircus*	*Bos taurus*	*Sus scrofa*	*Equus hemionus*	*Aves* sp.	*Testudo* sp.	*Unio* sp.	*Spondylus* sp.	*Cardium* sp.	Indeterminate sp.
Canine			1							
Carapace						134				
Shell							35	5	3	
Phalanx		1			1					
Rib		26								
Femur	3	5		1						
Metapodialus	125									
Humerus		9		1						
Radius		1								
Coxae		1								
Tibia		2		1						
Long bone diaphysis	14									27
TOTAL	142	45	1	3	1	134	35	5	3	27

Tab. 2. Raw materials used in the manufacture of the osseous industry at the Cheia settlement.

be associated with hunting activities, but rather the same activity of weaving vegetable fibres.

The spatulas could be used to process various materials, albeit of low hardness. This observation is postulated by the differences in the appearance of the active ends. Some pieces have longitudinal striations, especially on the superior side, and macroscopic polish (Fig. 7.c,g-h). In other cases, the active end is characterized by a macroscopic polish that modified the external structure of the bone, and under the microscope fine, short striations are visible, arranged perpendicularly (Fig. 7.l). At the median region, an area with a macroscopic polish developed as a result of the manipulation (Fig. 7.m).

Scrapers made of *Unio* shells appear to be a characteristic of the Hamangia culture, which are not yet attested at the Prehamangia Palazu Mare settlement. An experimental workshop of *Unio* shells, which were devoid of technological modifications, resulted in clear diagnostic traces of use-wear after repeated work with ceramics, demonstrating their use for pottery processing (*Mărgărit* et al. *2021*). The first area of use-wear can be identified macroscopically on the ventral edge. It becomes rectilinear, compacted, and develops a smooth texture. The use-wear is invasive, extending in association with functional marks and towards the interior side. Analysed under a microscope, the functional marks are long, regular and deep (Fig. 14.b-d). They are arranged transversely, from which it is clear that these shells were used for scraping and not for a cutting operation that would have generated marks which developed longitudinally. A second diagnostic use-wear area develops on the internal side on the median region. Macroscopically, we could identify an alternation of bright and opaque areas (Fig. 14.e-f). The immediate suggestion was that of a rubbing process, after which the superficial layer of nacre was removed. Under the microscope, we could better identify these different areas. They are not characterized by the presence of any type of striations. Furthermore, there are items in which the rubbing process seems to have been longer, so that we can identify surface exfoliation (Fig. 14.g). The third area of use-wear can be identified on the dorsal side. Macroscopically, it appears as a flat surface with small areas of exfoliation. Under the microscope, an alteration of the natural structure of the shell is visible which takes on a homogeneous appearance (Fig. 14.h). In this case we can assume that it is a process effected by the rubbing of hands. There are, however, items where the dorsal side is more affected by use-wear, the surface being strongly flattened with the development (seen under the microscope) of long and deep scratches (Fig. 14.i-j). What caught our attention initially was the extremely uniform character of use-wear marks identified for the archaeological specimens. We can thus assume that they were used as tools in a similar way for processing a similar single type of material, An experimental study (*Mărgărit* et al. *2021*) demonstrated the use of these shells for processing ceramics, which further supports a uniform use.

Tortoise carapaces (*Radu* et al. *2022*) are present in all three archaeological sites we compared, in both the Prehamangia and Hamangia sequences, demonstrating in this case the continuation of traditions among two different populations. A series of marks on the surface of the fragments indicate their use. The interior side is covered with deep incisions, arranged transversely to the axis of the piece (Fig. 13.e-f,l). The incisions were created by the repeated passage of a flint tool. Over these incisions is superimposed a use-wear polish, with fine, sporadic striations (Fig. 13.g). On some specimens, towards the ends, the interior side is cracked and superficially exfoliated with macroscopic polish and fine striations (Fig. 13.i-k). Use-wear is also present on the exterior side of some pieces, as indicated by certain flattened areas. These areas are associated with macroscopic polish and fine transverse striations (Fig. 13.m-n). In our opinion, their origin is not technological but functional, and is the result of friction processes.

Conclusion

We can conclude that in both chronological phases – the Prehamangia and Hamangia cultures – bones from the main domestic species (*Bos taurus* and *Ovis aries/Capra hircus*) were predominantly used. The osseous industry reflects the pastoral economy specific to these communities. The technologically processed bones were recovered from household remains after the slaughter and consumption of these animals. Another common raw material in these sites is the tortoise carapace. Within the Hamangia culture, more varied blanks/raw materials were exploited in relation to the previous stage, including imports. However, research into the Prehamangia Palazu Mare settlement is at an early stage, and the picture can still support readjustments. But even in this intermediate phase of analysis we can see that there are no significant variations at a typological

or technological level, with similar processing schemes prevailing in both stages, such as quadri-partition by double grooving to obtain pointed tools or segmentation by sawing to process rings. The predominant typological categories seem to be correlated to the same domestic economies, being used mainly for the processing of vegetable fibres (pointed tools) and leather (spatulas), flint (hammers), wood (pointed tools, bevelled tools), ceramic processing (*Unio* shell, spatulas), containers (tortoise carapace), and so on.

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Pottery, language and iron: reassessing Luukonsaari and Sirnihta Wares and their cultural context in Early Iron Age Finland

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ABSTRACT – *This paper examines two Late Bronze Age and Early Iron Age pottery types in Finland, Luukonsaari and Sirnihta Wares, which were previously poorly defined and dated. New radiocarbon dates and Bayesian modelling place Luukonsaari Ware in* c. *2800–2100 cal BP and Sirnihta Ware in* c. *2000–1450 cal BP. These periods were crucial for the emergence of coastal farming and inland hunter-gatherer societies. The study explores typological and chronological variations, connections with other pottery types, influences from Textile Ware, and links to proto-languages. It also discusses the arrival of Saami languages, early iron production, and the cultural context of these pottery groups.*

KEY WORDS – *Finland; Late Bronze Age; Early Iron Age; pottery; Luukonsaari Ware; Sirnihta Ware; iron production; Proto-Saami; Proto-Finnic*

Lončenina, jezik in železo: ponovno vrednotenje posod vrste Luukonsaari in Sirnihta ter njihov kulturni kontekst v starejši železni dobi na Finskem

IZVLEČEK – *V članku preučujemo dva tipa posod, Luukonsaari in Sirnihta, iz pozne bronaste in starejše železne dobe na Finskem, ki sta bila prej slabo definirana in datirana. Novi radiokarbonski datumi in Bayesovo modeliranje jih umeščajo v čas med 2800–2100 cal BP (Luukonsaari) in med 2000–1450 cal BP (Sirnihta). Ti obdobji sta bili ključni za začetek obalnega kmetovanja in lovsko-nabiralne skupnosti v notranjosti. V študiji raziskujemo njune tipološke in kronološke različice, povezave z drugimi vrstami keramike, vplive lončenine, okrašene z motivi tkanja, in povezave s prajeziki. Razpravljamo tudi o prihodu samijskih jezikov, zgodnjem pridobivanju železa in kulturnem kontekstu teh posod.*

KLJUČNE BESEDE – *Finska; pozna bronasta doba; starejša železna doba; lončenina; posode Luukonsaari in Sirnihta; proizvodnja železa; proto-samijski jeziki; proto-finski jeziki*

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Introduction

Bronze Age and Early Iron Age pottery in Finland (*c.* 3500–1600 cal BP) has largely been characterized by the dichotomy between coastal and inland potteries. The coastal Paimio and Morby potteries were characteristic of agriculturally oriented societies on the western and southern coasts of Finland, while the Finnish inland was in the hands of hunter-gatherers who prepared Textile Ware and, after that, asbestos- or mica-tempered Säräisniemi 2 Wares with their various subgroups (Fig. 1; *Carpelan 1965; 1979; Lavento 2001a*).

Originally, when the Säräisniemi archaeological assemblage was described in Finland by Julius Ailio (*1909*), he used the terms Säräisniemi 1 Ware for Stone Age pottery and Säräisniemi 2 Ware for Bronze and Iron Age pottery (also *Äyräpää 1951*). As Mika Lavento and Mervi Suhonen (*2024.438*) have pointed out, even the Säräisniemi 2 assemblage in this eponymous discovery is really far too heterogeneous to be described under one umbrella term. Still, Säräisniemi 2 lives on in the research history as a way to refer to the pottery of theEarly Iron Age in eastern and northern Finland. Säräisniemi 2 was later divided into four asbestos- or mica-tempered Late Bronze Age and/or Early Iron Age variants (= Early Metal Period in Finnish terminology), namely Luukonsaari, Sirnihta, Kjelmøy and Anttila Wares, all named after their important find places in eastern and northern Scandinavia (*e.g., Äyräpää 1951; Carpelan 1965; Meinander 1969*).

The exact chronology of these four pottery types has remained somewhat ambiguous, even though their general dating to the Bronze Age and Early Iron Age has not been challenged (*e.g., Carpelan 1979*). The northern variants, Kjelmøy and Anttila, have been studied more actively, and their chronology has been attested in various projects and papers (*Carpelan 1965; Kehusmaa 1985; Jørgensen, Olsen 1987; Lavento 1992; 2001a; Jørgensen et al. 2023*). By contrast, the southern variants, Luukonsaari and Sirnihta, have not been subjected to any chronological and typological scrutiny, with the exception of Russian studies concerning Luukonsaari pottery (*e.g., Kosmenko 1993; Zhulnikov 2009*). In this paper we focus on these two understudied variants, Luukonsaari and Sirnihta.

Luukonsaari pottery has been defined as an asbestos-tempered, thin-walled and technically high-class product. Its special features are an inward bevelled rim and a decorative pattern including a stacked board or a drawn comb-stamp belt a bit below the rim, flanked by groups of stamped impressions (*Äyräpää 1951; Meinander 1969; Kosmenko 1993; Zhulnikov 2009*). According to Carl Fredrik Meinander (*1969.61*), this pattern is reminiscent of the one in Early Iron Age Morby Ware of the southern and western coast of Finland, which gave him a reason to parallel these types both typologically and chronologically. In addition to Meinander's association of Luukonsaari and Morby, it is now also possible to see a typo-chronological connection between Sirnihta and Morby (see below the dis-

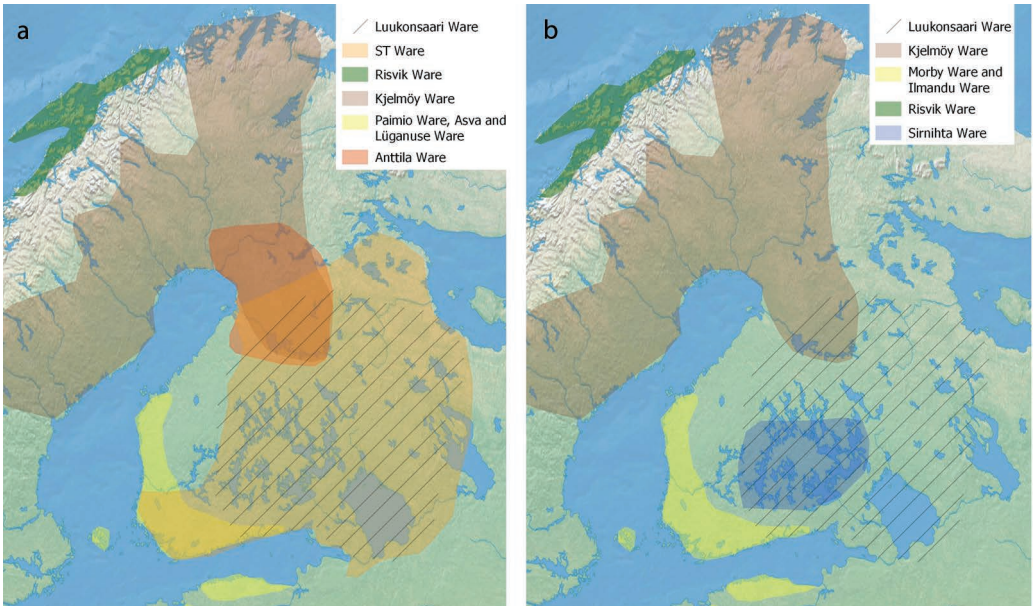

Fig. 1. The main distribution areas of some relevant pottery groups during the Late Bronze Age (a) and Early Iron Age (b) in Finland and in the neighbouring areas (according to* Lavento 2001a; Zhulnikov 2009; Lang 2020; Jørgensen *et al.* 2023; Saipio 2023*) (drawing Petro Pesonen; background map Natural Earth Data).

cussion on the pottery of the coastal areas of Paimio and Morby in the Late Bronze Age and Early Iron Age). When compared to Luukonsaari, Sirnihta pottery has received even less attention, but Lavento (*2001a.116*) describes it as mainly asbestos-tempered and clearly profiled in its form. In addition, Sirnihta Ware includes embossed lines, which are different from other pottery and these lines also form an ornamentation with framed friezes. Sirnihta Ware seems to be limited to Finnish territory, except for some possible examples from Sweden (*Hedman 1993; Lavento 2001a.117*).

In this paper, we aim to tackle both the typology and the chronology of Luukonsaari and Sirnihta Wares. We study the typology and investigate the main characteristics of these pottery types by compiling all known finds defined as Luukonsaari and Sirnihta Wares from Finland, and by analysing this material. The purpose is not to create a new typology, but to find out if the current typology holds strong and how it is reflected in chronological terms. The absolute chronology of Luukonsaari and Sirnihta pottery types is explored with the help of new radiocarbon datings and Bayesian modelling of them. The role of iron production is also investigated by means of chemical analysis of slag and pottery pieces from the key Luukonsaari Ware sites Juvonen and Jyrinlahti 1 in Liperi, eastern Finland.

A solid typological background is needed in order to discuss more general questions such as what are the typological and chronological connections of Luukonsaari and Sirnihta Wares with other pottery groups known from the period and region in question (listed in Figure 1). We will also explore the connections between these pottery groups and other contemporary phenomena such as the beginning of iron production and the formation of Saami and Finnic languages in the area. As we have calibrated the radiocarbon dates in cal BP format we also use BP as the unit when referring to languages. While this is an unconventional way to refer to linguistic dating – BC/BCE being a more conventional one – this is done in order to ease the comparison between the timings of these two fields.

In what follows, we will present the time frame and study area, after which we move on to the materials and methods and results. We do not include any new linguistic data or results as our paper is mainly an archaeological one. In the discussion we consider our findings in different contexts – including a linguistic one – and compare our archaeological findings to those that have been presented in previous archaeological and linguistic literature. Finally, we summarize our main findings in the conclusions.

Time frame and study area

Our study area consists of eastern Finland, that is, the lake area of inland Finland, the area of Lakes Saimaa, Pielinen and Päijänne, and some minor water bodies encompassing the inland area roughly between 60 and 65 degrees latitude north (Fig. 2). Chronologically the study covers the Late Bronze Age (*c.* 3000–2500 cal BP) and Early Iron Age (*c.* 2500–1600 cal BP) with some references to the Final Neolithic (4400–3900 cal BP), Early Bronze Age (3900–3000 cal BP) and Late Iron Age (1600–800 cal BP) as well. These periods and the main pottery groups in different parts of Finland and northern Fennoscandia are listed in Table 1. The time frames follow Finnish prehistoric chronology (*e.g., Nordqvist 2018; Pesonen 2021*).

Materials and methods

Pottery

The study material has been retrieved from Finnish archaeological collections, studied in detail in the projects 'Argeopop' and 'Kipot ja kielet' (Beakers and Spea-

	calBP	Finnish coastal areas	Northern Fennoscandia	Finnish inland areas
Final Neolithic	4400-3900	Kiukainen Ware	-	Palajguba Ware
Early Bronze Age	3900-3000	Paimio Ware	Lovozero Ware, Vardøy (IT) Ware, Sorsele (textile) Ware	Textile Ware/Sarsa-Tomitsa Ware, Anttila Ware
Late Bronze Age	3000-2500	Paimio Ware, Morby Ware	Risvik Ware, Kjelmøy Ware	Textile Ware/Sarsa-Tomitsa Ware, Luukonsaari Ware, Anttila Ware
Early Iron Age	2500-1600	Morby Ware	Risvik Ware, Kjelmøy Ware	Textile Ware/Kalmistonmäki Ware, Luukonsaari Ware, Sirnihta Ware
Late Iron Age	1600-850	Iron Age pottery	-	(Sirnihta Ware/'Konnevesi Ware')

Tab. 1. Chronological table of the main pottery groups in Finland and northern Fennoscandia from the Final Neolithic until the Iron Age. The chronological phases and geographical areas discussed in this paper are marked in grey.

kers) in 2010–2011 and 2019–2020 (*Pesonen, Sundell 2011; Moilanen* et al. *2020; Pesonen* et al. *2024*). In these projects – among other things – most of the pottery material in the collections was examined and roughly classified into existing typological groups. This gave us the basic information that we could use as the starting point of our study. For the purpose of the current paper, we studied the materials in more detail, including Bronze or Iron Age asbestos- and mica-tempered ceramics in the collections of the National Museum of Finland and the Kuopio museum of cultural history. In addition to Luukonsaari and Sirnihta Wares, Kjelmøy, Anttila, Lovozero and Imitated Textile Ware (IT or Vardøy) potteries were also studied. However, in this paper, Luukonsaari and Sirnihta Wares receive the main attention, and the information collected from the other mentioned types will be utilized later in a more comprehensive study of Bronze Age and Early Iron Age pottery.

We defined the characteristics that mark the traditional typologies of Luukonsaari and Sirnihta Wares. This was done by comparing the notes in the literature and the actual pots. We focused on the following attributes: size of the pots, the shape of the bottom and the rim, and the decorative patterns. The attributes thus retrieved were documented and the sherds were photographed. We attempted to form the material into vessels, which would be used as comparative study units. This list of attributes forms the basis for this study, and these attributes can also be used in further endeavours concerning the other branches of Bronze and Iron Age pottery types in Finland (including Lovozero, IT, Kjelmøy and Anttila Wares). The full table of attributes and photos is presented in Appendices 1 and 2, available online at https:// doi.org/10.4312/dp.52.4.

Radiocarbon dates

Chronology is an essential part of any typological study – there cannot be one without the other. In this paper we present 29 new radiocarbon datings. These dates, together with the radiocarbon dates obtained in earlier projects, form the core of any chronological points suggested here. In the end, we had four kinds

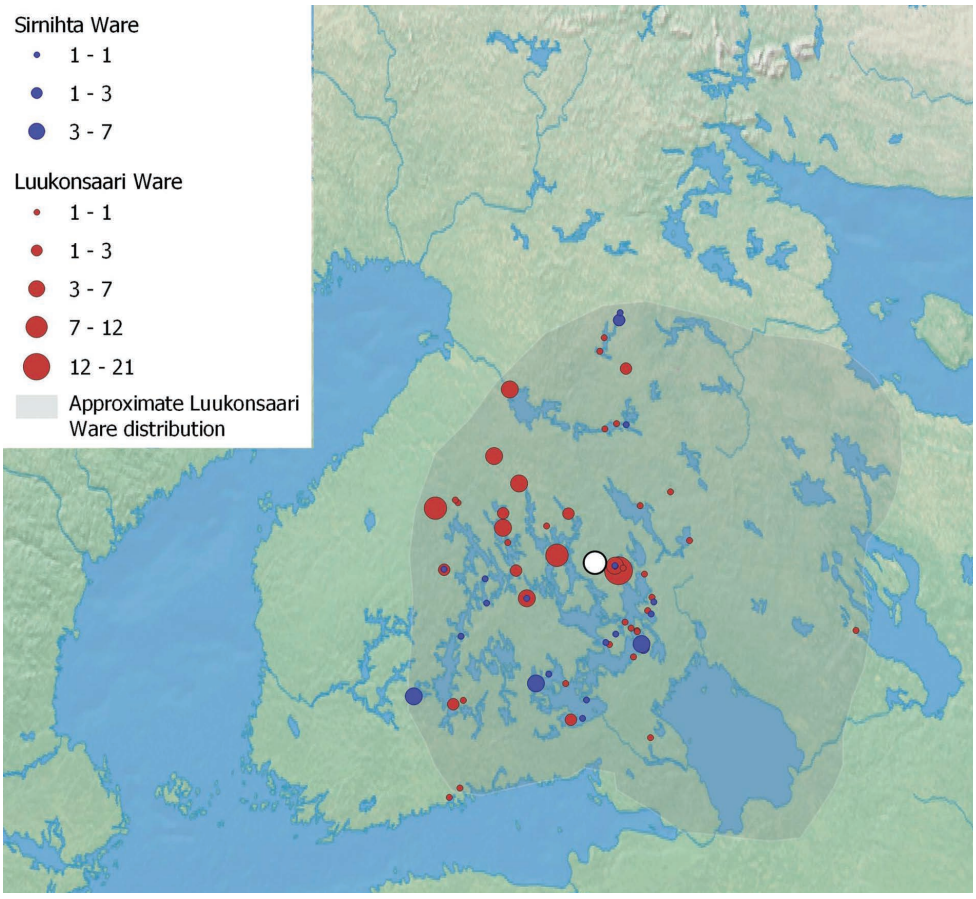

Fig. 2. The distribution of Luukonsaari and Sirnihta Wares and the number of identified vessels in Finland and some sites in Russia. The grey area describes the known distribution of Luukonsaari Ware in Russia (according to* Kosmenko 1993.91*) and Finland. The Paakkila asbestos deposit is marked with a white circle (drawing Petro Pesonen; background map Natural Earth Data).

of radiocarbon dates in our dataset (n=124; Appendix 3 (online at https://doi.org/10.4312/dp.52.4): (i) direct datings from the pottery crust (n=32), (ii) context datings from the sites with Luukonsaari or Sirnihta Ware (n=40), (iii) other datings connected with early iron manufacture (n=2), and (iv) datings classified as 'general', that is, such datings that are contemporary with the general dating scheme of the pottery varieties but are not directly connected to either of the pottery groups (n=50). For the purposes of the chronological modelling done in this paper (see the section on chronology, below), obviously only the dates in groups 1 and 2 could be used, while the others form the general chronological context of the period in question. Most of the radiocarbon dates are from Finland but some of the Luukonsaari-connected radiocarbon material derives from Russia. The radiocarbon dates do not represent the distribution area evenly: the dates are biased in favour of some prominent sites and many of the find sites have no radiocarbon dates at all. This is partly because the charred-crust potential for radiocarbon dating exists only rarely and even then, only at some of the sites.

The contents of charred crusts have not been studied in this connection. Given that all the pots derive from inland regions, no marine reservoir effects are expected, and freshwater reservoir effects are considered unlikely because of the non-calcareous bedrock and groundwater (see *e.g., Pesonen* et al*. 2012; Pesonen 2021*; although also see *Zhulnikov* et al. *2012*). The charred crusts were scraped from the insides of the vessel walls.

There are three types of visualization methods to show the possible ranges of the radiocarbon dates. The first of these is the stacked probability distribution, from which a rough beginning and end for the respective assemblage can be visually distinguished. This is the traditional way of presenting the radiocarbon dating of archaeological assemblages. The second way to present the distribution is to form a sum curve. Despite the many problems associated with this approach (*e.g., Carleton, Groucutt 2021*) it is commonly used as an indicator of the period and its internal intensity. The third approach is the modelling of dates, which has its roots in Bayesian statistics (*e.g., Bayliss 2009*; *Bronk Ramsey 2009*). When applied to archaeology and specifically to radiocarbon dating, it means in practice the condensation of error margins based on the distributions of the entire set of dates. As a result, certain start and end years for the archaeological periods in question are obtained from this analysis. In this paper we use all three types of visualization methods to show the possible ranges of the radiocarbon dates connected with Luukonsaari and Sirnihta Wares.

Chemical analysis of pottery and slag

For chemical characterization and material identification, we analysed the chemical compositions of slag from the Juvonen and Jyrinlahti 1 sites in Liperi and ceramic vessel fragments from the Jyrinlahti 1 site using non-invasive energy dispersive X-ray fluorescence (ED-XRF) analysis. The chemical analysis of slag aimed to provide material confirmation of iron smelting at the sites and to examine the potential processing of other metals, such as copper, at the same locations.

We chose seven ceramic samples from slag-rich contexts to examine the relationship of the metal-processing practices and the ceramic vessels. The instrument used for the chemical data acquisition is a University of Helsinki owned Rigaku NEXDE VS bench-top spectrometer, operated in a helium atmosphere in point analysis mode (beam diam. 3mm). The reported results are surface-measured normalized mean values of 3–5 analyses per ceramic sherd (for more details of the analytical set-up see Holmqvist *et al.* (*2020*)). The chemical data was processed with statistical methods to confirm data comparability and identify multivariate compositional patterns (the slag data processing and results are explained in *Pesonen* et al. *forthcoming*).

Results

Typology of Luukonsaari and Sirnihta Wares

Altogether 168 ceramic vessels were separated in the material designated as Luukonsaari- or Sirnihta-type pots. The main characterizing attributes emerging are 'classic' Luukonsaari-type rim shapes in Luukonsaari Ware and complex decorative patterns together with a profiled or straight vessel rim in Sirnihta Ware. In the following sections the characteristics of the pottery material are summarized.

Type/style

Of the 168 vessels, 130 were identified as Luukonsaari vessels, and 38 as Sirnihta vessels. Not all attributes could be identified for all vessels, which is why the quantities vary in different feature descriptions.

The size of the pots

The size of the pots was estimated with the aid of three variables: wall thickness, rim thickness and diameter

(estimated by comparing the edge of the vessel to arcs drawn on paper in the shape of a circle). Luukonsaari and Sirnihta pots had approximately equally thick walls and rims (Tab. 2). There is a small difference between the median diameter of the pots, although this, is only 2cm (Tab. 2; Fig. 3). When turning to the capacity of the pots, the smallest vessels compare to modern mugs with a volume of 2 to 3 decilitres, and the largest vessels to modern buckets with a maximum volume of 10 litres. Overall, Luukonsaari vessels seem to be a bit larger than Sirnihta vessels, but the difference is not particularly noteworthy. The vessels are not large ones, the mean volume being around 4-6 litres with many of them much smaller.

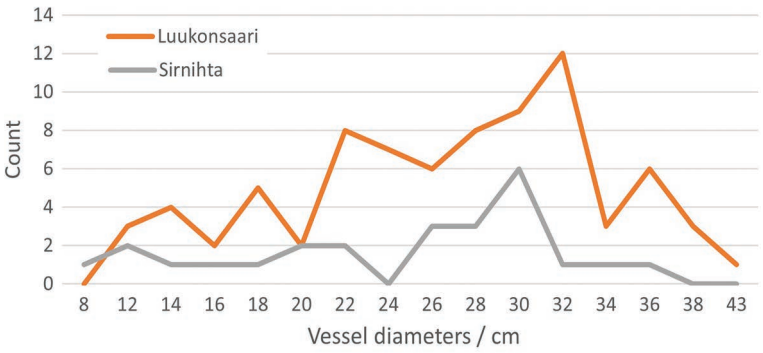

Fig. 3. The frequencies of vessel diameters of Luukonsaari and Sirnihta pots.

Bottom shape

There are a few vessels that have body profiles including the intact bottom. The most notable of these is the classic Luukonsaari vessel from the Koitö cairn site in Porvoo, southern Finland (Fig. 4.a). This is a unique find both in its find context and geography: the vessel was discovered in a burial cairn far from the central area of Luukonsaari distribution in the inland lakes' region. A further eight Luukonsaari vessels have been found with flat bottom pieces, many of these decorated. The diameter of the bottom is invariably smaller than the diameter of the rim, indicating a blunted conical shape, as in the case of the Koitö vessel. The measurable bottom pieces in Luukonsaari pots are 5–10cm in diameter. The Sirnihta material has six flat bottom pieces, many of them undecorated. In some Sirnihta pots, for instance, in vessel 248010002_7 (Fig. 4.b), the rounded shape of the wall and the small size of the vessel is reminiscent of Late Iron Age profiled bowls with a tapering neck. The measurable bottom pieces of Sirnihta Ware are 5–18cm, showing larger variation than Luukonsaari and indicating a cylindrical rather than a conical form of the pot. Overall, both Luukonsaari and Sirnihta vessels are flat-bottomed and some of the vessels' bottom pieces are also decorated. There is evidence of a blunted conical form in Luukonsaari Ware and a cylindrical form with tapering neck in Sirnihta Ware.

Rim shape and profile of the vessels

Of 116 vessels with an identified rim, 89 were classified as Luukonsaari and 27 as Sirnihta. Twelve have S-profiling of the upper wall, whereas 104 are straight. Of the profiled vessels, three are Luukonsaari and nine Sirnihta vessels. Straight walled vessels are mostly Luukonsaari (86) but 18 of them are Sirnihta style. According to these figures, Sirnihta Ware is more frequently profiled (approx. 33%) than Luukonsaari Ware (ap-

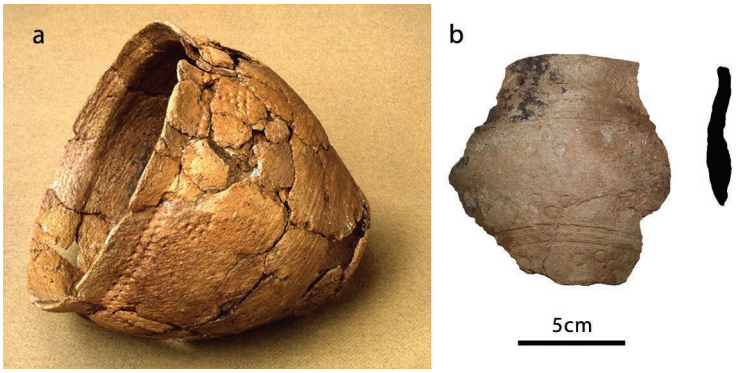

Fig. 4. Examples of vessel shapes from:* a *Porvoo Koitö (Luukonsaari Ware, vessel Porvoo_1, KM 8891);* b *Kitee (Kesälahti) Sirnihta (Sirnihta Ware, vessel 248010002_7, KM 18910:263) (photos: Finnish Heritage Agency (a) and Petro Pesonen (b)).

	Luukonsaari Ware				Sirnihta Ware			
	Mean	Median	Range	n	Mean	Median	Range	n
Wall thickness	6.70 mm	7 mm	3-11 mm	100	6.35 mm	6 mm	3-9 mm	34
Rim thickness	10.19 mm	10 mm	4-15 mm	74	9.04 mm	9 mm	5-17 mm	25
Diameter	26.67 cm	28 cm	12-43 cm	79	24.32 cm	26 cm	8-36 cm	25

Tab. 2. Basic information on the size of the pots.

prox. 3%), but straight walls are the more common type in both styles.

Rim shapes were divided into four groups (Tab. 3). The first of these is the 'classic' Luukonsaari profile with a strongly inward bevelled lip of the rim, which is present only in the Luukonsaari type (in *c.* 80% of them). The second is a round or rounded rim shape, often occurring with profiling of the upper wall. This feature occurs in both types but is more common in Sirnihta vessels (Tab. 3). Of the S-profiled Luukonsaari vessels, all have a classic inward bevelled rim, while in Sirnihta Ware seven of the S-profiled vessels have a rounded rim shape and two have a straight rim shape. The third group is a straight rim with a sometimes inward-slanting top. These are roughly equally common in both types of pots (Tab. 3). The fourth group includes straight rims but with a lip part that protrudes notably outward. This feature is present mainly in Sirnihta pots (Tab. 3). Overall, the main rim feature of Luukonsaari vessels is the 'classic' Luukonsaari rim with inward bevelled lip. In addition, plain straight rims are present, and some pots also have round or rounded rims. Sirnihta pots are more often profiled than Luukonsaari pots and often have roundor rounded rims. Two different types of straight rims are also seen, one straight and even, the other outward protruding; both of these types are equally common.

Temper

Both Luukonsaari and Sirnihta vessels are invariably tempered with asbestos, which is often chopped into small pieces. Sometimes the asbestos is in a stick-like form. In two cases of Luukonsaari Ware, there also seems to be a talc inclusion within the asbestos temper. No other tempering materials were observed.

Decoration

When a vessel is fragmented in the archaeological context, more wall pieces survive than rim and bottom pieces simply because wall pieces are more numerous. This is also why the decorative elements are often easier to discover than those connected to the shape of the vessels. Decoration was found for 137 vessels, and specifically for 106 Luukonsaari (out of 130) and 31 Sirnihta vessels (out of 38). Commonly, both Luukonsaari and Sirnihta Wares have only one decorative element per pot (Tab. 4). Pots with two decorative elements also occur while pots with three elements are very rare (Tab. 4). There are also some undecorated pots in the material, but in many cases, due to fragmentation, it is difficult to say if the vessels were originally undecorated or the lack of decoration is just a result of the lack of survival.

The decorative complexity can be divided into three classes: (i) simple rows of stamps, (ii) complex decoration often including drawn lines/comb stamps and sometimes 'fringes' of decorative elements above or below the drawn section, (iii) complex decoration with framed friezes (Tab. 4). The complexity of the decoration often correlates with the number of elements present. Simple decoration is common in both wares, while complex decoration with drawn lines/comb stamps is more common in Luukonsaari Ware (Tab. 4). The complex drawn panel is in fact one of the characte-

	Rim shape group	n	*Luukonsaari*		*Sirnihta*		*Example*
			n	%	n	%	
1	Classical Luukonsaari-rim	71	71	79,8	0	0	
2	Round or rounded rim, sometimes profiled	20	5	5,6	15	55,5	
3	Straight rim, sometimes a bit inward slanting	17	12	13,5	5	18,5	
4	Straight rim, but with a notable outward protruding	8	1	1,1	7	25,9	
	Not observable (not counted in the percentages)	52	41		11		

Tab. 3. Rim shapes and their commonness in Luukonsaari (n=89) and Sirnihta (n=27) ceramics with examples.

ristics of Luukonsaari Ware. In Sirnihta Ware the complex pattern includes, for instance, embossed fish-bone patterns. Complex, framed friezes are the least common type of decoration and are seen only in Sirnihta Ware (Tab. 4). In all the decorated pots of Luukonsaari and Sirnihta Wares, the decoration covers only the upper wall of the vessel body, with some exceptions mainly in Sirnihta Ware. There are both decorated and undecorated bottom plates in both types.

Comb stamps are the most common decorative elements on Luukonsaari Ware, and they are often accompanied by grooves or small stamps (Tab. 4, Fig. 5). Small stamps denote various kinds of dots and notches, and they are found in 35 vessels. The 'stopped frieze', made by drawing a comb stamp with 'stops', is characteristic of Luukonsaari pottery and there are at least 20 such motifs, but there are at least 33 more vessels where drawn comb stamp, grooves or dots repeat the same zonal idea as in the stopped frieze vessels. Most interestingly, Luukonsaari decoration illustrates several additional motifs above or below this frieze. The most common ones are triangles in 20 vessels, most of them together with friezes. In one case the triangle may be interpreted as depicting a hut (Fig. 5.c; vessel 594010013_6). Several comb stamp features depicting a cross (n=2) or bent cross (n= 7) appear, the most famous of them being the vessel from the Jyrinlahti 1 site in Liperi where a bent cross is illustrated with a possible boat figure and sails (Fig. 5.b,d; vessel 426010009_7; *Pesonen, Ahola 2022*). There is also one vessel from the Kudoma XI site in Russian Karelia with crosses and coniferous-like motifs (*Kosmenko 1993.137*).

	Luukonsaari (n=106)		Sirnihta (n=31)		Total n
Basic	**n**	**%**	**n**	**%**	
One decoration element	72	67	15	48	87
Two decoration elements	33	31	15	48	48
Three decoration elements	1	2	1	2	2
Complexity					
Simple rows of stamps	60	56	14	45	74
Complex with drawn panel or other complex pattern	45	42	5	16	50
Complex with framed friezes	0	0	12	39	12
Undefined	1	2	0	0	1
Elements		*			
Comb stamp	73	68	17	55	84
Grooves or lines	30	28	19	61	49
Small stamps (dots & notches)	35	33	4	13	39
*percentage sum is over 100 % because in many cases several types of elements are used in one vessel.					

Tab. 4. Decorative elements and their commonness in Luukonsaari (n=130) and Sirnihta (n=38) types, where 106 of the Luukonsaari vessels and 31 of the Sirnihta vessels have decoration on them.

Comb stamps are also common on Sirnihta Ware, while other decorative elements include grooves or lines and small stamps (Fig. 6; Tab. 4). In addition, there is one example of a circular ring stamp decoration. In Sirnihta Ware the decoration consists of friezes that often form a framed composition, and in these cases there are often stamp groups beneath the frieze: triangles, zig-zag patterns, and slanting rows. This kind of decorative pattern is also familiar in southern Finnish Morby Ware as well as in northern Scandinavian Kjelmøy Ware. Even though Luukonsaari

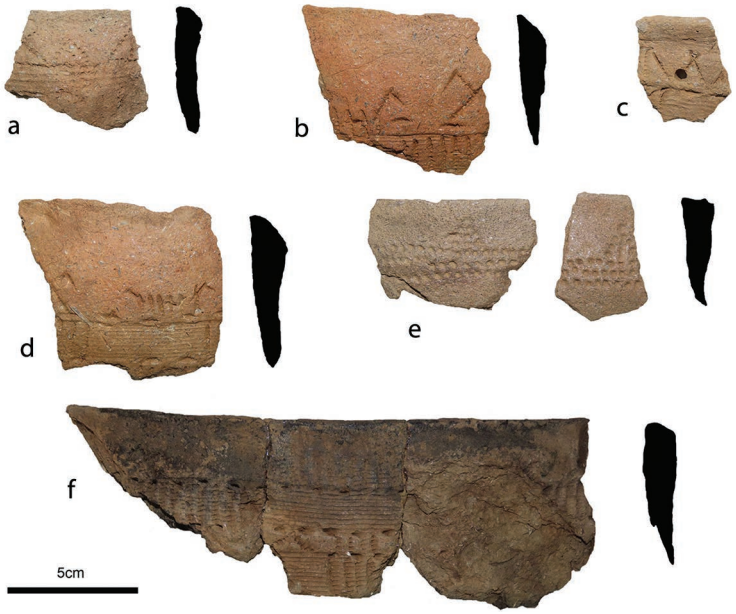

Fig. 5. Luukonsaari Ware:* a *Liperi Jyrinlahti 1, vessel 426010009_2, KM 29547:1,* b *Liperi Jyrinlahti 1, vessel 426010009_7, KM 31057: 90,* c *Pieksämäki Vemmellahti, vessel 594010013_6, KM 22367: 1635,* d *Liperi Jyrinlahti 1, vessel 426010009_7, KM 31057:148,* e *Kuopio Luukonsaari, vessel 297010001_3, KM 16492:4,* f *Pieksämäki Vemmellahti, vessel 594010013_1, KM 22436:338 (photos Petro Pesonen).

Ware also has frieze and additional stamps patterns, it still does not have the framed friezes, and in this sense Meinander's (*1969*) original association of Luukonsaari Ware with Morby Ware would fit better with Sirnihta Ware and Morby Ware. This is also chronologically much more convenient and coherent.

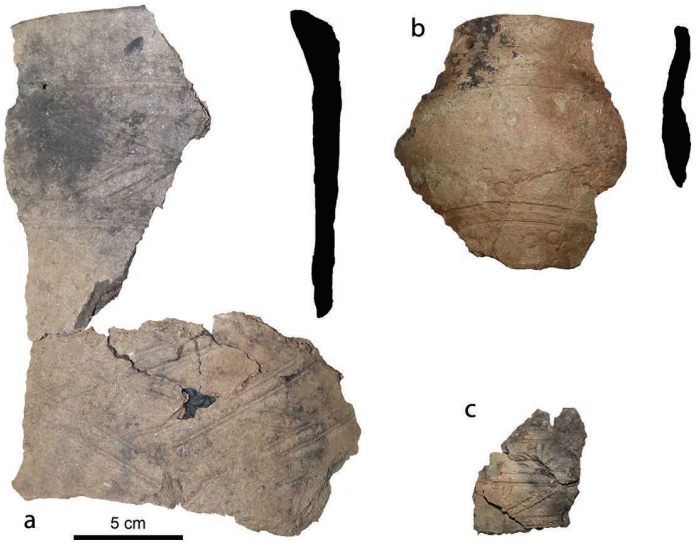

Fig. 6. Sirnihta Ware:* a *Hankasalmi Salo, vessel 77010001_1, KM 5427:249,* b *Kesälahti Sirnihta, vessel 248010002_7, KM 18910: 263,* c *Kesälahti Sirnihta, vessel 248010002_10, KM 18910:277 (photos Petro Pesonen).

The chronology of Luukonsaari and Sirnihta Wares

The majority of the obtained radiocarbon dates were within the previously suggested time frame. However, we also got some unexpected results, which are nevertheless explainable. A sample from a vessel at the Varaslampi site in Joensuu (vessel 1; KM 19471:769) gave a Late Neolithic date (Ua-75791; 3940±32 BP; 4380±65 cal BP). Obviously, an asbestos-tempered variant of Middle and Late Neolithic asbestos-tempered pottery was dated in this instance (*i.e.,* the pottery represents Pöljä Ware). In addition, based on the radiocarbon dates, two of the pots with a typological resemblance to Sirnihta Ware with relatively early dates are, based on our study, considered to represent late Sarsa-Tomitsa Ware with an asbestos temper (Liperi Jyrinlahti 1, vessel 8, KM 31057:246, with a date Ua-75790; 2482±30 BP; 2580±83 cal BP and Suomussalmi Joenniemi, vessel 1, KM 20375:3; 23701:537 with a date Hela-103; 2470±85 BP; 2545±115 cal BP).

We also dated some burnt animal bones from the suspected Luukonsaari and Sirnihta contexts. The dates fall within the same chronological horizon as the pottery material, with some exceptions. These particular exceptions are (i) a mammal bone sample from the Pulmionlampi A site in Mikkeli (former Ristiina), south Savo, where the dating is Mesolithic (Ua-75803; 8164±33 BP; 9110±70 cal BP) and has thus no connection with the pottery from this particular site; (ii) a big mammal bone sample from the Meijerinkangas site in Pielavesi, north Savo, with a Late Neolithic dating (Ua-76542; 3920±29 BP; 4350±55 cal BP); and (iii) a big mammal bone sample from the Mäntyniemi II site in Kitee (former Kesälahti), north Karelia, again with a Mesolithic date (Ua-76543; 7468±32 BP; 8275±50 cal BP). The Mesolithic dates bring a new chronological horizon into the discussion within the regions in question but are not connected to the subjects of this paper. Interestingly, all these sites with exceptional bone datings have also yielded asbestos pottery. The situation illustrates the multi-periodical nature of the sites in the lake region of the Finnish inland – something that always must be kept in mind when doing context dating.

The unmodelled calibration of charred-crust dates shows the general succession of pottery dates (Fig. 7). The sum curves of the same dates give another kind of visual impression of the sequences (Fig. 8). However, neither of these visualizations gives us actual dates, which is why we also modelled them. Modelling the dates gives emphasized start and end boundaries for each sequence, in this case the start and end of the existence of pottery types Luukonsaari and Sirnihta according to radiocarbon dates.

The modelling of the radiocarbon dates in a cultural phase-wise manner is not a standard way of doing Bayesian analysis of radiocarbon dates, which is usually performed within stratigraphical units (*e.g., Bayliss 2009; Bronk Ramsey 2009; Oinonen* et al*. 2013*). Nevertheless, this phase-wise modelling has been done successfully with Finnish Neolithic pottery types in identifying the starts, ends and potential gaps in pottery sequences of the region (*Pesonen* et al*. 2012; 2019; Pesonen, Oinonen 2019; Pesonen 2021).*

In this case we performed a simple modelling of two pottery types with no supposed connection of the types, and thus without a direct continuation between the two. While there are also some context dates available, here we used only the direct dates of the charred crust from the vessel walls, which have proved

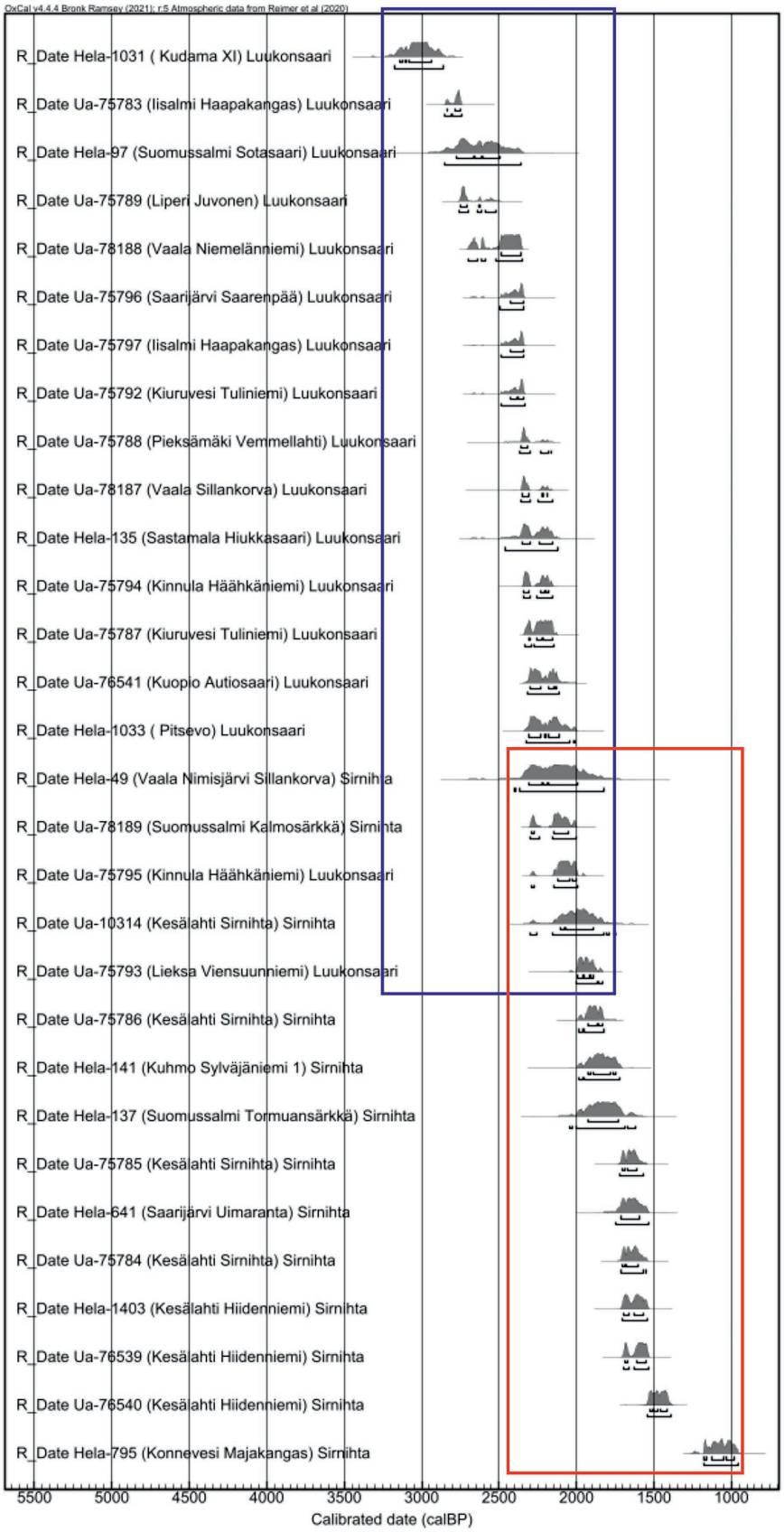

Fig. 7. Stacked probability distributions of direct datings from charred crust in Luukonsaari and Sirnihta vessels within traditional typologies. Calibration with Oxcal 4.4 version (*Bronk Ramsey 2009*) and IntCal20 calibration curve (*Reimer *et al.* 2020*). The blue frame indicates the maximum duration of Luukonsaari Ware and the red frame indicates the maximum duration of Sirnihta Ware based on these radiocarbon dates.

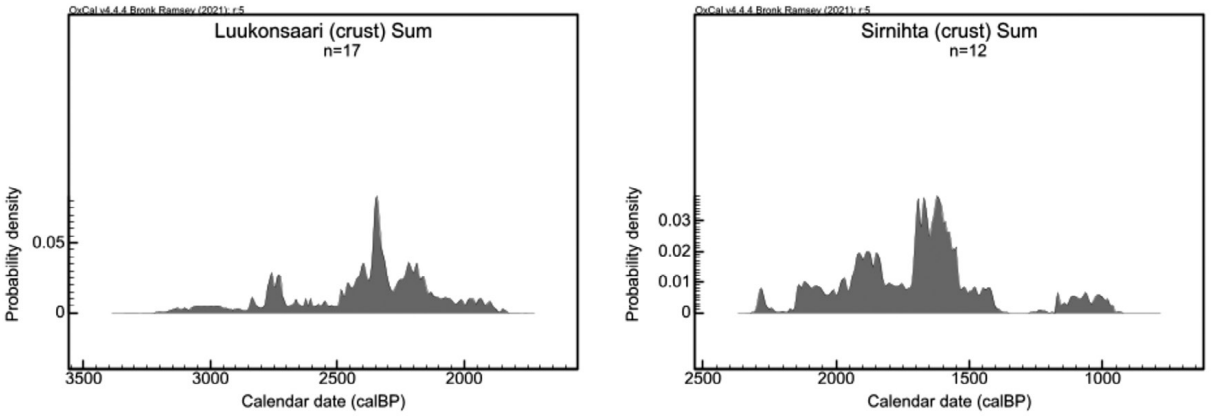

Fig. 8. Sum curves of the same Luukonsaari and Sirnihta Ware charred crust dates as in Figures 7 and 9. Note: the curves are not to the same scale. Calibration with Oxcal 4.4 version (*Bronk Ramsey 2009*) and IntCal20 calibration curve (*Reimer *et al.* 2020*).

to be the most reliable material – at least when it comes to material where no reservoir effects are thought to be present (*e.g., Pesonen 2021.56*). For the 'core dates' of the pottery types we also used some selected context dating. The Bayesian modelling was done within the Oxcal programme (v. 4.4) as explained in Christopher Bronk Ramsey (*2009*) with the newest set of calibration curves, IntCal20 (*Reimer* et al. *2020*). We did not take into account any possible reservoir effects, either marine or freshwater. The possibility of a marine reservoir effect was excluded as the sites are situated inland. Moreover, no freshwater reservoir effect has been proven to exist in Finland (see discussion in *Pesonen 2021.49–51*; see however *Zhulnikov* et al. *2012*).

We found that both types have a 1000-year, non-overlapping period of use, Luukonsaari *c.* 2955–2060 cal BP and Sirnihta *c.* 2035–1070 cal BP (Fig. 9). Given the small number of samples and variation in defining the style, the long duration may be taken as a potential variation in types and potential existence of other types within these typological classes as now defined.

We also approached the obvious problem of duration longevity by gathering the most 'clean in style' sites together to figure out what would be the core dates for the two styles. Considering the research history and the number of vessels and radiocarbon dates, these sites would be Iisalmi Haapakangas, Kuopio Luukonsaari, Liperi Juvonen and Jyrinlahti 1, and Pieksämäki Vemmellahti for Luukonsaari Ware and Kesälahti Sirnihta and Hiidenniemi for Sirnihta Ware. These are the sites that have yielded both considerable correspondent pottery material and many radiocarbon dates for it. There are also some new burnt bone dates from these sites which were taken into account. In the case of Luukonsaari, the modelling changes the picture to give the 'core' dating of Luukonsaari from *c.* 2815 to 2125 cal BP (~800–100 cal BC). Sirnihta core dates are from *c.* 1980 to 1445 cal BP (~AD 0–550). See Figure 10 and Table 5.

Chemical analysis of slag and ceramics from two Liperi sites

Based on the chemical analysis, we can confirm that the analysed slags are ferrous (with Fe_2O_3 concentrations varying from *c.* 5 to 90wt%), confirming iron smelting at the Juvonen and Jyrinlahti 1 sites in Liperi. There are no indications of processing of other metals, such as copper, at the sites (*Pesonen* et al. *forthcoming*).

To characterize ceramic fabrics, possible local ceramic manufacture and use of ceramics in iron processing, seven ceramic vessel fragments from five separate vessels (Tab. 6) were geochemically profiled via non-invasive surface analysis. The ceramics were manufactured using non-calcareous clay, and while all seven ceramic fragments show relatively high iron concentrations (≥ 13wt%), two fragments in particular (a rim sherd of the asbestos-tempered Jyrinlahti 1 vessel 426010009_5 [KM 31057:16] and Jyrinlahti 1 Textile Ware vessel 426010009_9 [KM 31057:247] with rock-inclusions) show anomalously high Fe_2O_3 content for ceramic fabrics, at over 30wt%. Temper materials affect the bulk chemical compositions measured for ceramic fabrics, and previous studies have identified the use of both iron-containing anthophyllite and actinolite asbestos as tempers of prehistoric pots in the region (*Lavento, Hornytzkyj 1996; Oinonen* et al. *2014*). However, while extensive anthophyllite temper appeared to increase the MgO concentrations in ceramic pastes (a similar effect shown here particularly in the MgO values of the Jyrinlahti 1 vessel 426010009_5

body fragment [KM31057:66] and vessel 426010009_7 [KM31057:90]), the iron concentrations remained at *c.* 10wt% (*Oinonen* et al. *2014.Tab. S2*), which are in line with Fe levels reported for ceramic fabrics from the Finnish region in other studies (*Holmqvist* et al*. 2018; 2020*). Hence, although bulk analysis cannot exclude the use of unusually Fe-rich clays or tempers in these pots, it remains possible that the higher range Fe values derive from use-phase or post-depositional association with iron-rich materials causing ferrous enrichment on the vessel surfaces. While we cannot conclude whether these ceramics were directly used in iron smelting, on a general level asbestos-tempered non-calcareous ceramics would present ideal thermal-shock and heat resistance properties for this purpose in this regional and chronological context (see *Hulthén 1991; Sundquist 1999)*.

As for the chemical profiles and possible compositional relations of the analysed ceramics, the sample is too limited to evaluate whether they represent local raw materials and manufacturing. However, most of the analysed ceramics display fairly similar chemical profiles compositionally (Tab. 6; Fig. 11), which can be indicative of local or regional potting activities, although this cannot be exclusively concluded due to our limited

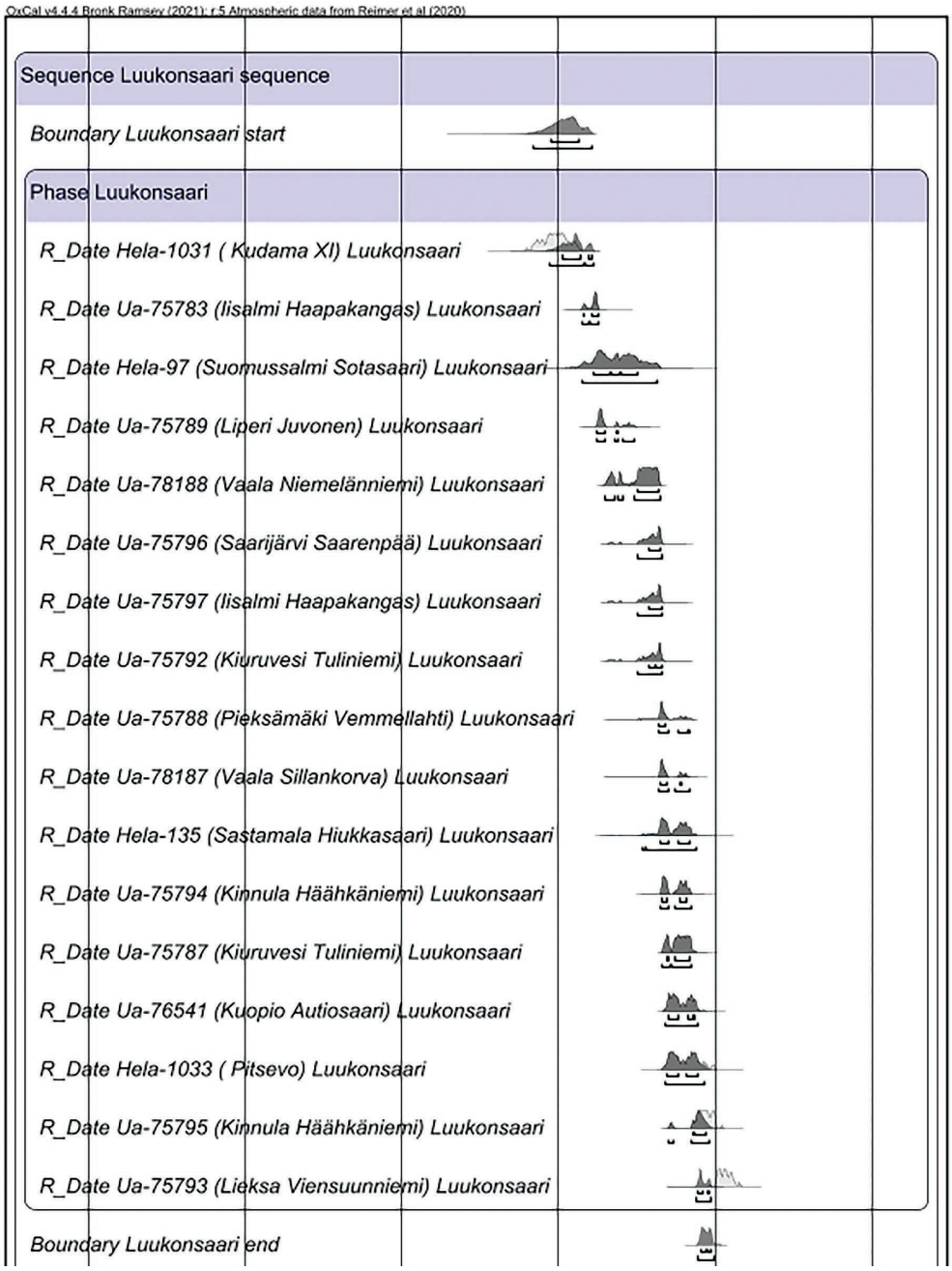

Fig. 9. Modelled dates of charred crust in Luukonsaari and Sirnihta Wares.

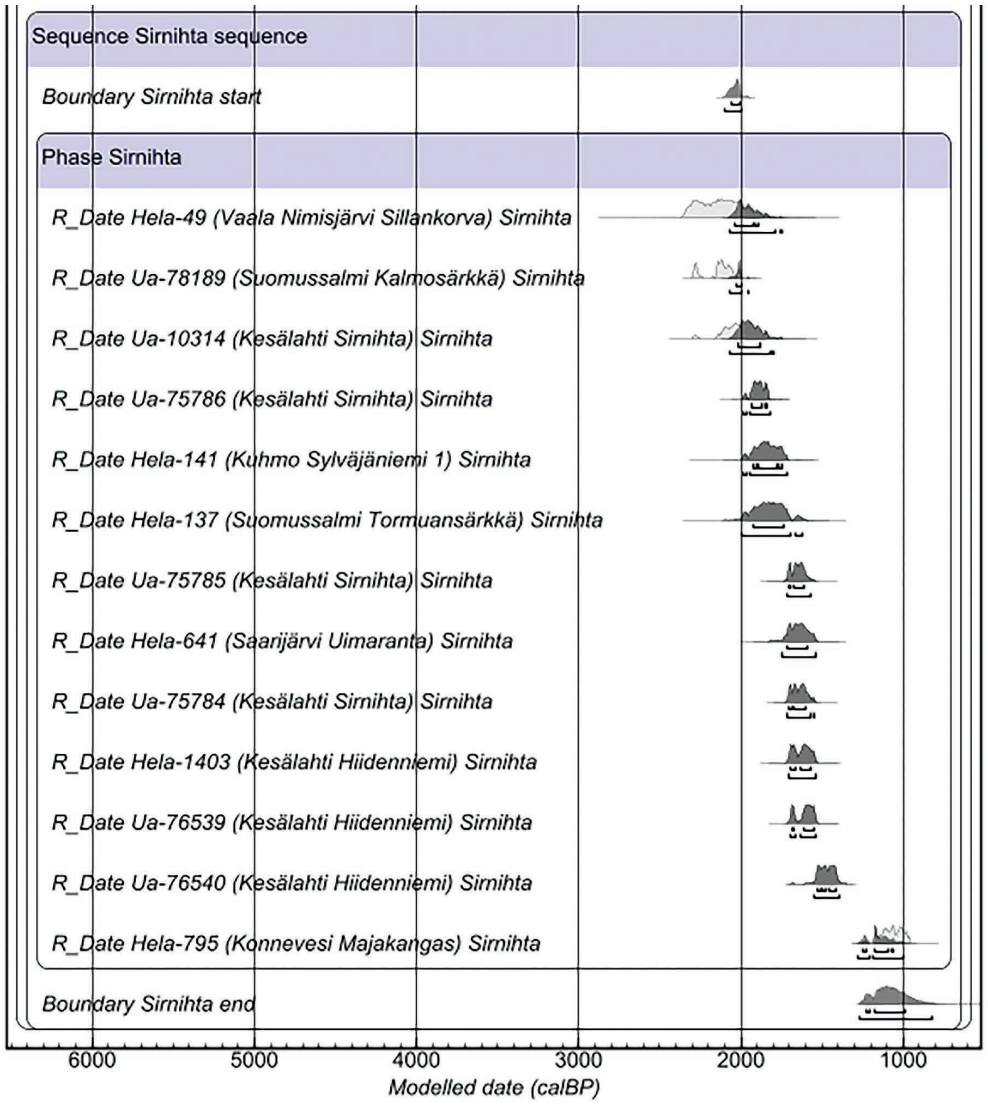

Fig. 9. Continued

sample and the lack of comparative materials. Of the two ceramic samples with the exceptionally high Fe levels (Jyrinlahti 1 vessel 426010009_5 rim-part [KM 31057:16] and the ST Ware vessel 426010009_9 [KM 31057:247]), the ST Ware vessel plots separately from the other samples in the statistical tests (Fig. 11), whereas the vessel 426010009_5 fragment (KM 31057:16) concentrations are within the range of the other ceramic samples (Tab. 6). The ST Ware sherd (KM 31057: 247) presents trace elemental values, for instance, for NiO, Rb_2O, SrO, Y_2O_3, ZrO_3 and BaO (Tab. 6), which disassociate it from the other samples' chemical profiles and suspected local (?) source area. It thus appears to be either an import, a representative of a different clay source, or the trace elemental concentrations measured from this object show similar, possibly use-derived enrichment with regard to its iron values.

Discussion

Typological and chronological variation within Luukonsaari and Sirnihta potteries

In the previous sections, we modelled Luukonsaari and Sirnihta dates, both of which would spread to a 1000-

	95.4% cal BP	68.3% cal BP	mean cal BP	median cal BP	core median cal BP
Luukonsaari begin	3165-2785	3055-2865	2965±100	2955	2815
Luukonsaari end	2110-2010	2095-2020	2060±30	2060	2125
Sirnihta begin	2100-1995	2060-2005	2040±25	2035	1980
Sirnihta end	1265-820	1220-960	1055±120	1070	1445

Tab. 5. The modelled dates of the beginning and end boundaries of the Luukonsaari and Sirnihta Wares.

year era – intuitively a very long period considering pottery types. It is thus very probable that there have been developments within the types, and there may be local and chronological variants that are now lumped together as a single type. For example, the youngest Sirnihta-connected date from the Majakangas site in Konnevesi is 500 years younger than any of the other dates assigned as Sirnihta type (Hela-795: 1160±45 BP,

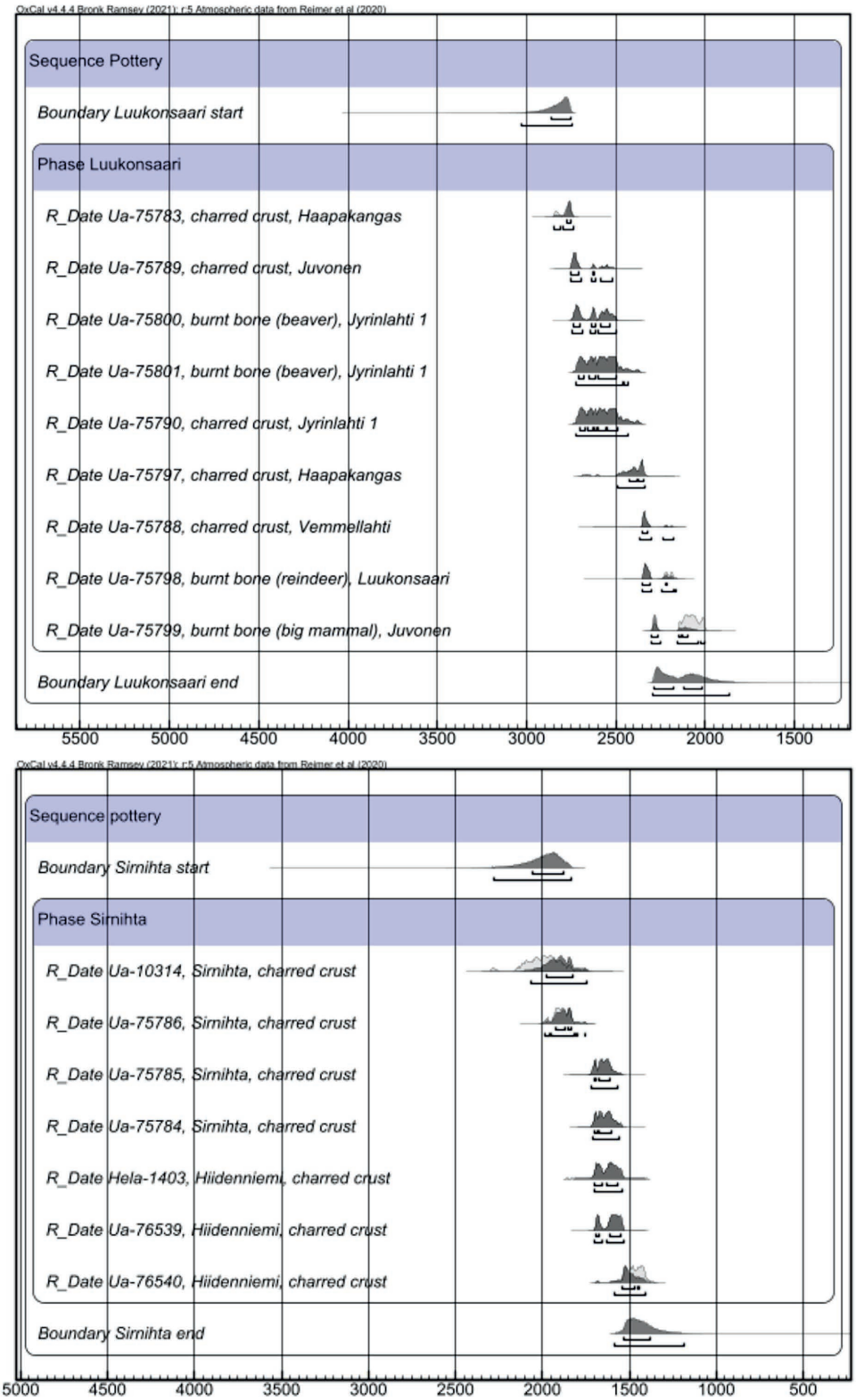

Fig. 10. The modelled dates of the core sites in the material for Luukonsaari Ware and Sirnihta Wares, respectively.

			MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Cr_2O_3	MnO	Fe_2O_3	NiO	CuO	ZnO	Rb_2O	SrO	Y_2O_3	ZrO_2	BaO
Vessel code	**NM**	**Ware**	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
426010009_5 rim	31057:16	Luukonsaari	3.82	8.07	43.95	2.14	5.24	1.78	1.15	0.15	1.30	31.00	2184	242	1949	365	384	64	656	1833
426010009_5 body	31057:66	Luukonsaari	12.12	10.26	54.51	2.66	3.71	1.32	0.63	0.14	0.28	12.85	2854	199	683	185	109	22	139	616
426010009_6	31057:87	Luukonsaari	6.94	10.44	43.23	12.58	5.14	4.38	1.05	0.17	0.46	14.56	881	87	1078	176	325	30	320	1187
426010009_7 rim	31057:90	Luukonsaari	12.06	9.37	54.69	2.38	4.06	1.15	0.72	0.28	0.16	13.29	510	62	865	131	188	24	213	552
426010009_7 rim	31057:148	Luukonsaari	4.82	12.06	49.79	3.03	3.56	1.12	1.01	0.21	1.48	21.51	865	77	857	283	224	35	398	1064
426010009_8	31057:194	ST(?)	6.82	14.31	55.02	2.44	2.55	1.63	0.94	0.18	0.40	13.89	1553	41	495	168	167	37	256	668
426010009_9	31057:247	ST	<LOD	10.16	35.23	3.07	5.97	3.18	2.49	0.06	0.31	37.73	190	102	855	950	865	173	1174	3451

Tab. 6. ED-XRF measured chemical data for Jyrinlahti 1 ceramic surfaces. Selected elements only. P_2O_3 values were excluded from the statistical analysis due to potential post-depositional enrichment.

1072±67 cal BP; Fig. 12.b). It would thus be just as feasible to call this particular vessel 'Konnevesi Ware', especially when considering the fact that this vessel does not by any means represent a typical example of Sirnihta Ware, but is instead a simple undecorated vessel.

Moreover, the dates of the vessels designated as Luukonsaari Ware include some rather suspect ones, such as the one for the vessel from the Viensuunniemi site in Lieksa (Ua-75793: 2003±30 BP, 1937±42 cal BP). Typologically, the vessel could be seen as a mixture between Luukonsaari and Sirnihta Wares. In line with this it has a dating at the very youngest end of all Luukonsaari dates. The vessel has a somewhat Luukonsaari-typical drawn pattern, but made with lines rather than comb stamps (see Fig. 12.a).

Taking into account the results of the core site dating exercises performed above, it is only reasonable that these dates and vessels should be dated as outliers or preferably as typo-chronological variations that existed during the time in question. At least the Majakangas vessel is clearly out of the range of other Sirnihta dates, and it represents a so far unique example of the asbestos pottery tradition reaching to the Viking Age. Apart from the asbestos-ware vessel, the Majakangas site has yielded a Viking Age cremation with iron artefacts, bone tools, and pottery (*Vanhatalo 2005*).

Comparison with other contemporary ceramics in Fennoscandia

The Luukonsaari and Sirnihta Wares were not the only types of pottery produced in eastern Fennoscandia during the Late Bronze Age and Early Iron Age. In the northern parts of Fennoscandia, asbestos-tempered Lovozero, Vardøy (IT) and Sorsele (textile) Bronze Age ware production was ceasing during the time of the beginning of the Luukonsaari production. In addition, in the coastal northern Atlantic, Risvik Ware with asbestos temper was also present during the Late Bronze Age and Early Iron Age (Fig. 1) (*Jørgensen, Olsen 1987; Jørgensen* et al. *2023*). These groups are, however, either temporally or spatially rather distant from Luukonsaari and Sirnihta and are not discussed here in further detail. Instead, we focus on groups which likely had more relevance to the emergence and existence of Luukonsaari and Sirnihta ceramics.

Other Säräisniemi 2 ceramics: Kjelmøy and Anttila

Kjelmøy Ware in the north is largely contemporary with Luukonsaari Ware, as is Anttila Ware in the Kainuu and the north Ostrobothnia regions (Fig. 1; Tab. 1; Fig. 16; *Carpelan 1979; 2004; Jørgensen, Olsen 1987; Lavento 2001a; Jørgensen* et al. *2023*). Some Kjelmøy Ware postdates the end of Luukonsaari Ware, and thus is also contemporaneous with Sirnihta Ware, whereas the production of Anttila Ware ceased before the Early

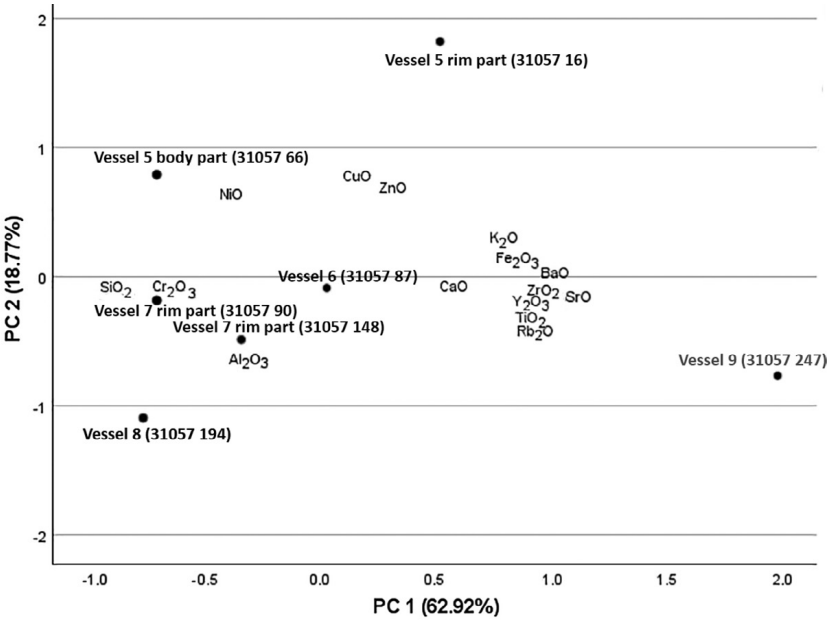

Fig. 11. Principal component analysis (PCA) plot of the ED-XRF chemical data (Al_2O_3, SiO_2, K_2O, CaO, TiO_2, Cr_2O_3, Fe_2O_3, NiO, CuO, ZnO, Rb_2O, SrO, Y_2O_3, ZrO_2 and BaO) for Jyrinlahti 1 ceramic fragments; the first three components equal 90.97% of the total variance of the dataset. For Vessel 5, a rim and body part were analysed (samples KM 31057 16 and 66, respectively), and Vessel 7 is represented by two rim-fragments (samples KM 31057 90 and 148).

Iron Age. Anttila Ware coexisted with Sarsa-Tomitsa Ware, Luukonsaari Ware and Kjelmøy Ware during the Late Bronze Age, especially in the Kainuu region.

Kjelmøy Ware has some resemblance to Sirnihta Ware, especially in the use of decorative friezes, while Luukonsaari and Kjelmøy Wares do not appear to have any particularly clear typological connection. The Kjelmøy vessels were decorated with a frieze featuring patterns formed by long lines creating lattice-like or zig-zag designs, which were bordered by horizontal lines. Betweenthe lines, point-like indentations, short comb stamps, or fingernail impressions were pressed (Fig. 13.a). Considering the partial overlap in time during the Early Iron Age, it is possible that Kjelmøy and Sirnihta Wares represent the same idea of decoration that is seen with Morby Ware, even though all are geographically separate (Fig. 1). There are similarities in temper with both Sirnihta and Luukonsaari ceramics, as Kjelmøy Ware is partly asbestos-tempered, though the temper varies and also includes mica and shell tempers (*Jørgensen, Olsen 1987*). Lavento (*2001a.116*) finds that Kjelmøy Ware and Textile Ware resemble each other closely, raising interesting perspectives on the origins of the former. Anttila pottery (Fig. 13.b) seems to be a local pottery of the Kainuu (and north Ostrobothnia) region, north of the area occupied by the potters making Luukonsaari and Sirnihta Wares. In contrast to other ceramics of the 'Säräisniemi 2' sphere, Anttila Ware is not tempered with asbestos, but almost invariably with talc and mica (*Lavento 2001a.115*), making its appearance glossy and soapy. Anttila Ware is usually fairly simple in decoration, consisting mainly of simple grooves in the upper part of the vessel walls, though sometimes more complex decorations with friezes also occur (*Lavento 2001a.115*). There seems to be little or no similarity between Anttila Ware and Luukonsaari Ware, but it is still hard to say this with much confidence, as Anttila Ware remains relatively poorly studied. Lavento (*2001a.115*; see also *Carpelan, Uino 2022*) has suggested that Anttila Ware may have its origin in textile pottery.

Textile Ware legacy and asbestos temper in Luukonsaari and Sirnihta potteries

The carriers of textile-impressed pottery of the Bronze Age (in Finland, often called Sarsa and Tomitsa types or ST Ware, or simply Textile Ware), are interpreted as filling a population gap at the turn of the Late Stone Age and Early Bronze Age in eastern Fennoscandia from *c.* 3900 cal BP onwards (*Meinander 1954b; Lavento*

Fig. 12.* a *the vessel from the Viensuunniemi site in Lieksa, eastern Finland (vessel 422010023_1, KM 14690),* b *the vessel from the Majakangas site in Konnevesi, central Finland (vessel 275010015_1, KM 34052) (photos Petro Pesonen).

2001a; Tallavaara et al. *2010; Sundell 2014; Saipio 2023*). This gap is also seen as a discontinuum of pottery raditions between the Late Neolithic Stone Age and Bronze Age (*e.g., Lavento 1998*). The spread of textile-impressed pottery was perhaps induced by a push of the Seima-Turbino phenomenon and possible climatic events during the time (*e.g., Helama, Oinonen 2019; Grünthal* et al. *2022; Helama 2024*; however, also see *Holopainen* et al. *forthcoming*).

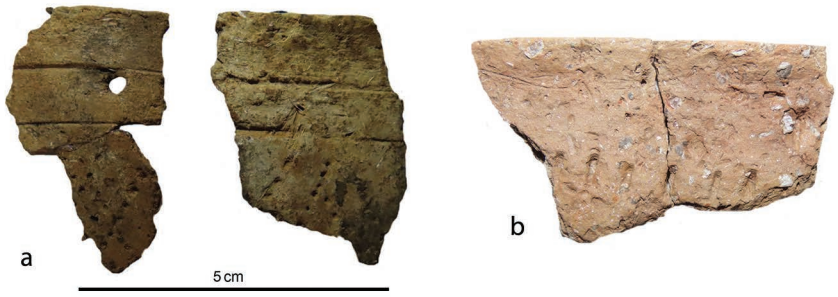

Fig. 13.* a *Kjelmøy Ware from the Neitilä 4 site in Kemijärvi, NE Finland (vessel 320010014_23, KM 16553:1287), and* b *Anttila Ware from the Vasikkaniemi SW site in Kuhmo, NE Finland (vessel 290010053_7, KM 29136:101 (photos Petro Pesonen).

Textile impression is not peculiar only to Textile Ware. but is also found in some Late Neolithic pottery types in Finland, such as Kiukainen Ware and Pöljä Ware (*Lavento 2001a; Carpelan, Uino 2022*). Textile Ware was usually tempered with crushed stone, but asbestos temper also occurs, (in the Tomitsa and Kainuu groups) in the area of northern Saimaa and Kainuu (*Lavento 2001a.83–84)* – the same area where Luukonsaari ceramics have also been found.

Before the use of asbestos in Textile Ware and in Luukonsaari and Sirnihta Wares, it had been used in several pottery types during the Late Neolithic Stone Age, such as Pöljä and Orovnavolok Wares. A special feature in producing asbestos ceramics is the limited availability of asbestos. It could have been obtained relatively easily from the Paakkila quarry in Tuusniemi, north Savo (*Meinander 1959; Lavento, Hornytzkyj 1996*), which is in the middle of the distribution areas of Textile Ware, Luukonsaari Ware and Sirnihta Ware (Fig. 2), but other, smaller outcrops may also have been available (*Aurola, Vesasalo 1954; Hytönen 1999; Lavento 2001a.49; Nikkarinen* et al. *2021; Nordqvist, Mökkönen 2021*). Thus, to manufacture ceramics with asbestos tempering, knowledge of the sources of asbestos must have been passed on within communities and trade networks. It is possible that the asbestos was traded and this trade was controlled by a certain group (see also *Lavento 2003.263*).

Due to the scarcity of asbestos as the tempering material and the know-how or networks needed to find or receive it, one would expect a continuity from one asbestos pottery type to another. This spatial and temporal continuity is not, however, seen between the asbestos-tempered Late Neolithic potteries and Textile Ware as these Late Neolithic potteries disappeared before the arrival of Textile Ware (*e.g., Lavento 1998*). The 'reinvention' of asbestos tempering took place in Textile Ware and the Luukonsaari Ware of the northern Saimaa and Kainuu region during the Bronze Age, and thus a continuity in the usage of asbestos is seen between Textile Ware and Luukonsaari Ware and then between Luukonsaari Ware and Sirnihta Ware.

The use of asbestos temper after the Late Neolithic pottery was reinvented in Textile Ware and Luukonsaari Ware. Within Textile Ware it is illustrated by a vessel from the Liperi Jyrinlahti 1 site (vessel 426010009_8; Fig.14.a), which was found at the same site together with Luukonsaari Ware and one vessel of crushed stone-tempered Textile Ware (Fig. 14.c). The vessel is, as was noted, asbestos-tempered and bears a framed-frieze decoration, small dots, and textile surface treatment. The framed-frieze decoration and textile surface connect the vessel to the Tomitsa or Kainuu Textile Ware subgroups (*Lavento 2001a.83-84*). The vessel is dated to the end of the Textile Ware period (Ua-75790; 2482±30 BP; 2580±85 cal BP mean date). Interestingly, the vessel's dating is younger than any other charred-crust dates from Textile Ware with rock temper (*cf. Lavento 2001a.102*). Another vessel also connected to the late phase of Textile Ware was found at the Suomussalmi Joenniemi site (vessel 777010117_1; Fig. 14.b) with framed-frieze decoration, ring stamps and asbestos temper. This vessel was even dated slightly younger than the Jyrinlahti pot (Hela-103; 2470±85 BP; 2545±115 cal BP mean date).

Karelian Kalmistonmäki pottery has been considered the youngest group of Textile Ware (*Lavento 2001a; 2001b*) and sometimes also considered part of the Olhava group in northwest Russia (*Juškova 2011*) dating to 2800–2500 cal BP (*Lang 2020.175*). According to Meinander (*1954b*) and Lavento (*2001a.86*), Kalmistonmäki Ware was decorated with twisted cord im-

pressions and small pits, which, however, do not appear in the pots from the Jyrinlahti 1 and Joenniemi sites. The vessels from Jyrinlahti 1 and Joenniemi are thus not typologically close to Kalmistonmäki-group pottery. Instead, it seems that in addition to the Kalmistonmäki Ware, another Textile Ware group, but with an asbestos temper, was still produced in the Late Bronze Age, 2650–2450 cal BP in the Finnish inland.

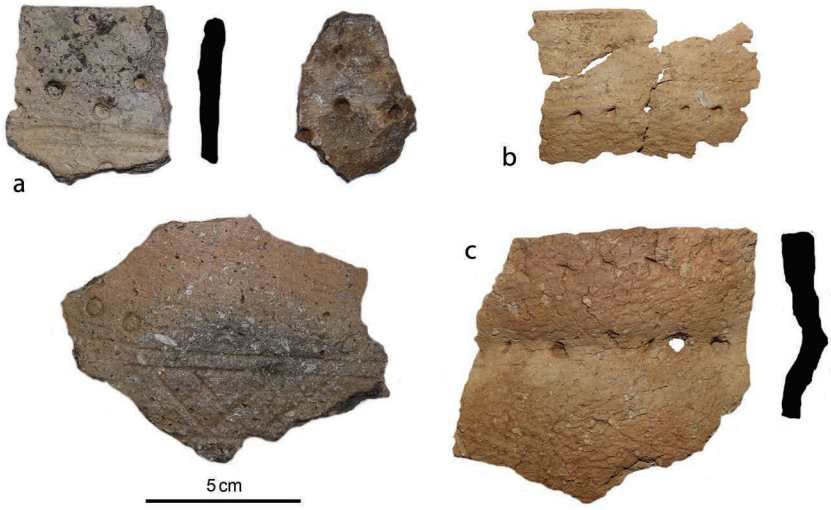

Fig. 14. **a** ***asbestos-tempered Textile Ware from Suomussalmi Joenniemi, vessel 777010117_1, KM20375:3, Hela-103: 2470±85 BP, 2545±115 cal BP,*** **b** ***asbestos-tempered Textile Ware from Liperi Jyrinlahti 1, vessel 4260910009_8, KM 31057:194, Ua-75790: 2482±30 BP, 2580±85 cal BP,*** **c** ***rock-tempered Textile Ware from Liperi Jyrinlahti 1, vessel 426010009_9, KM 31057:247 (photos Petro Pesonen).***

The internal chronology of Textile Ware is still far from clear (*Lavento 2001a.107*). However, it seems that the manufacturers of textile ceramics had enough contacts with populations producing asbestos ceramics to adopt the use of asbestos temper as a component in their ceramics. In addition to using asbestos as the temper material, the decorative pattern with friezes and the fact that the decoration is focused on the top of the vessel also connects the vessels of Textile Ware and Luukonsaari Ware. Studying the relationship of Luukonsaari and Textile Ware in more detail is, however, beyond the scope of this paper. Nevertheless, including the possibility that asbestos tempering was reinvented by Textile Ware and then by the Luukonsaari potters gives us intriguing insights into the asbestos-related dynamics and contacts between different groups.

Coastal Paimio and Morby ceramics in the Late Bronze Age and Early Iron Age

Traditions other than asbestos pottery prevailed incoastal southern and western Finland, and earlier research has shown a continuum from Late Neolithic Kiukainen Ware to the Early Bronze Age Paimio Ware and to the Late Bronze Age and Early Iron Age Morby Ware (Fig. 15; *Meinander 1954a; 1954b; Edgren 1999; Asplund 2008*), which were all characteristic ceramics of the coastal people of Finland (Fig. 1). On the southern shore of the Gulf of Finland, in Estonia, Asva and Lüganuse Wares were used in parallel with Paimio Ware, and Ilmandu Ware was used in parallel with Morby Ware (*Lang 2020*). In fact, according to Valter Lang (*2020. 178*), Morby and Ilmandu Wares belong to the same group of ceramics, as does Paimio with coarse-grained Asva and Lüganuse. The reason why these are known by different names is due to the fact that they exist on different coasts of the Gulf of Finland, and thus they have traditionally been studied separately.

Despite the fact that this continuum has been seen in earlier studies, Lang (*2020*) has stressed that there are two things separating the Late Neolithic pottery from the Early Bronze Age pottery. The first is the gap in the radiocarbon dates seen both in Finland (between Kiukainen and Paimio Wares) and in Estonia (between the Late Neolithic Estonian groups and Asva and Lüganuse Wares). The second is the obvious lack of a typological

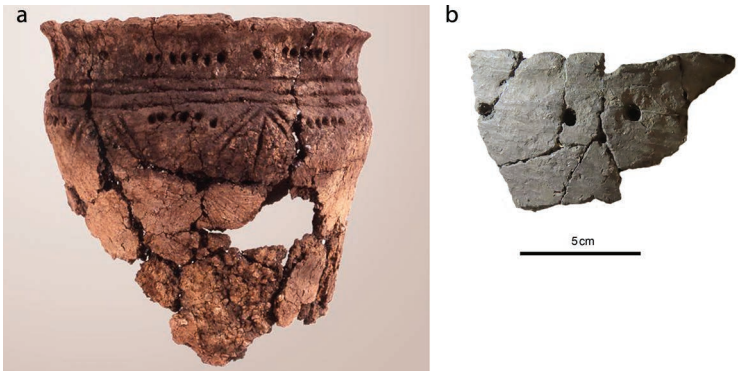

Fig. 15. **a** ***Morby Ware (KM 19383:1107a) from the Jönsas site in Vantaa, southern Finland.*** **a** ***Museovirasto,*** **b** ***Paimio Ware (ÍM 200:346) from the Otterböte site in Kökar, Íland (photo Petro Pesonen).***

continuum between the Neolithic and Bronze Age ceramic types (*Lang 2020.180*). Paimio Ware in Finland and Asva and Lüganuse in Estonia thus do not show signs of any continuation from the preceding ceramics in these areas.

When comparing Luukonsaari and Sirnihta Wares to those of Paimio and Morby Wares, the main difference is that the former pair use asbestos temper whereas in the latter this is not the case. In decorative patterns, the frieze-motif is common, especially in Sirnihta and Morby Wares, but also in Luukonsaari Ware, whereas Paimio Ware has only a simple decorative pattern with a single or a couple of rows of pits. Importantly, these pottery traditions were used in different environments, Paimio and Morby Wares in the coastal (agricultural) zone of southern and western Finland, and Luukonsaari and Sirnihta Wares in the inland (hunter-gatherer) zone of eastern Finland.

Potential connections with proto-languages

Researchers have connected different archaeological cultures to the speakers of different languages in the Finnic context for around 150 years (for a summary of different theories see *Lang 2020.28–62*). Depending on the most popular view in the discussion on the past at each time in question, the views about the appearance of Finnic (or even more specifically Finnish) and Saami in the west have also differed. For example, the Continuity Theory – which was the most common scientific paradigm about the presence of Finns (and the Saami) in Finland during the 1980s and 1990s – claimed that Finnic had been spoken in Finland since the times of comb ceramics in the Stone Age. The motivation for this theory was that no discontinuity was observed in the archaeological material, and therefore there could be no discontinuity in languages either (about the continuity theory, see *Piha 2020.44–46* and the references there). From the end of the 1990s on, however, the Continuity Theory received increasing criticism from linguists, who argued that there is no scientific proof for equating linguistic continuity with archaeological continuity. More recently, archaeological continuity since the Stone Age has also been challenged from the archaeological perspective, and several points of discontinuity have been suggested, along with potential genetic bottlenecks (*e.g., Lavento 1998; 2001a; Saipio 2008; Sundell* et al. *2014; Pesonen 2021*).

Criticism of the 'continuity theory' by linguists led to its replacement by a new paradigm according to which there have been migrations which brought languages such as Saami and Finnic to the Baltic Sea area, but the appearance of these is necessarily not visible in archaeological material (see *Piha 2020.46–47* and references there). The new paradigm thus highlighted that the correlation between archaeological and linguistic continuity can be proven only if linguistic studies on the language in question allow it (see *Häkkinen 2010a; Piha* et al. *2022. 260,457*). Due to this, we use linguistic evidence as the starting point in our linguistic-archaeological discussion below.

Proto-Saami, spoken in the area between Lakes Ladoga and Onega and inland southern Finland, is dated in Saami historical linguistics to 2600 BP at the earliest (*Aikio 2006.42,45; Kallio 2006.18*; *2009.38*).[1] Proto-Saami evolved from a Pre-Saami language form that was spoken around 3000–2600 BP, most likely somewhere in the Baltic Sea area or close to it (*Häkkinen 2010b.55,57*). This is shown by Paleo-Germanic loanwords in Saami languages (*Kallio 2009.34; Häkkinen 2010b.51,53*). However, the dating to 2600 BP is only the beginning of a long era that includes three different levels of Proto-Saami: Early (2600–2200 BP), Middle (2200–2000 BP) and Late Proto-Saami (2000–1800/1700 BP) (*e.g., Häkkinen 2010b.55,Table; Piha, Häkkinen 2020.117–118*).[2] It was only during the Late Proto-Saami phase that Proto-Saami started to spread to a larger area in Finland and Scandinavia. For example, the toponyms of Saami origin in southern and central Finland originate in language forms that resemble Late Proto-Saami (see *Aikio 2012.90*).

The earliest dating of Proto-Saami (2600 BP) is contemporary with Luukonsaari Ware in inland Finland and Morby Ware in coastal Finland. However, Late Proto-Saami and its spread to a wide area in Fennoscandia *c.* 2000 BP and some centuries after that coincided with Sirnihta Ware (Fig. 16). Valter Lang briefly discusses the connection of the northeastern group of Tapiola Ware (Textile Ware) with the West-Uralic branch, wherefrom the predecessor of modern Saami

1 The dating of the beginning of the Proto-Saami period to 2600 BP is based on the dating of the Proto-Germanic language form which, in turn, is determined by Celtic and Latin loanwords in the language (see, *e.g., Häkkinen 2010b.55; Piha* et al. *2022.457*). There is a stratum of Proto-Germanic loanwords in Saami languages, which makes it possible to connect Saami to the absolute chronology of Germanic language strata.

2 The dates of Early and Middle Proto-Saami are only estimates.

languages, Proto-Saami, was also developed (*Lang 2020.335*). The connection between the appearance of Textile Ware (*c.* 3900 BP) and the linguistic evidence about the existence of Proto-Saami in Finland (2600 BP) is, however, too distant to be convincing. In a future study we will discuss the connection between Saami and archaeological remains in a more detailed way (*Pesonen* et al. *forthcoming*; see also below).

Proto-Finnic was spoken south of the area where Proto-Saami was spoken, possibly in both southern Finland and Estonia (*Kallio 2015a*). Proto-Finnic appeared in this area during the Early Iron Age at the latest, as suggested by Germanic loanwords in Middle Proto-Finnic (*Kallio 2015b.27–28*), but possibly already during the Late Bronze Age (*Kallio 2015b.31–33*). A Bronze Age dating for the appearance of Proto-Finnic in the area of Estonia has recently also been suggested by Valter Lang (*2020*). According to Lang's theory, which is largely based on archaeological evidence, the arrival of Proto-Finnic speakers in the Baltics was almost a millennium-long process that mainly took place in four waves during the Middle and Late Bronze Age and Early Iron Age (*Lang 2020; forthcoming*) (Fig. 16). Each of these main waves is based on the appearance of a different kind of archaeological material (or 'cultural root', as Lang (*2020.126*) calls it) each of which has its origin in the east. The first of these waves is connected with the spread of a new type of ceramics to the Baltics (a southwestern group of Tapiola ceramics or Paimio/Asva Ware *c.* 3200–3000 BP), the second is connected with the appearance of fortified settlements in Estonia (*c.* 2850 BP), the third with the appearance of early tarand graves (*c.* 2600 BP) and the fourth with the appearance of cord and comb decorated pottery and shepherd's crook pins (*c.* 2300 BP).

While Lang connects the arrival of Proto-Finnic speakers with the appearance of the southwestern group of Tapiola ceramics (*i.e.* Asva/Paimio Ware *c.* 3200–3000 BP), from the linguistic perspective a more suitable connection would be that between Proto-Finnic and Morby/Ilmandu Ware, which form the latter part of the SW group of Tapiola ceramics (Fig. 16). Morby Ware is contemporaneous with both Luukonsaari and Sirnihta Wares, and it exhibits intriguing typological connections with them, particularly in the decoration focused on the neck of the vessels. The tapering neck and

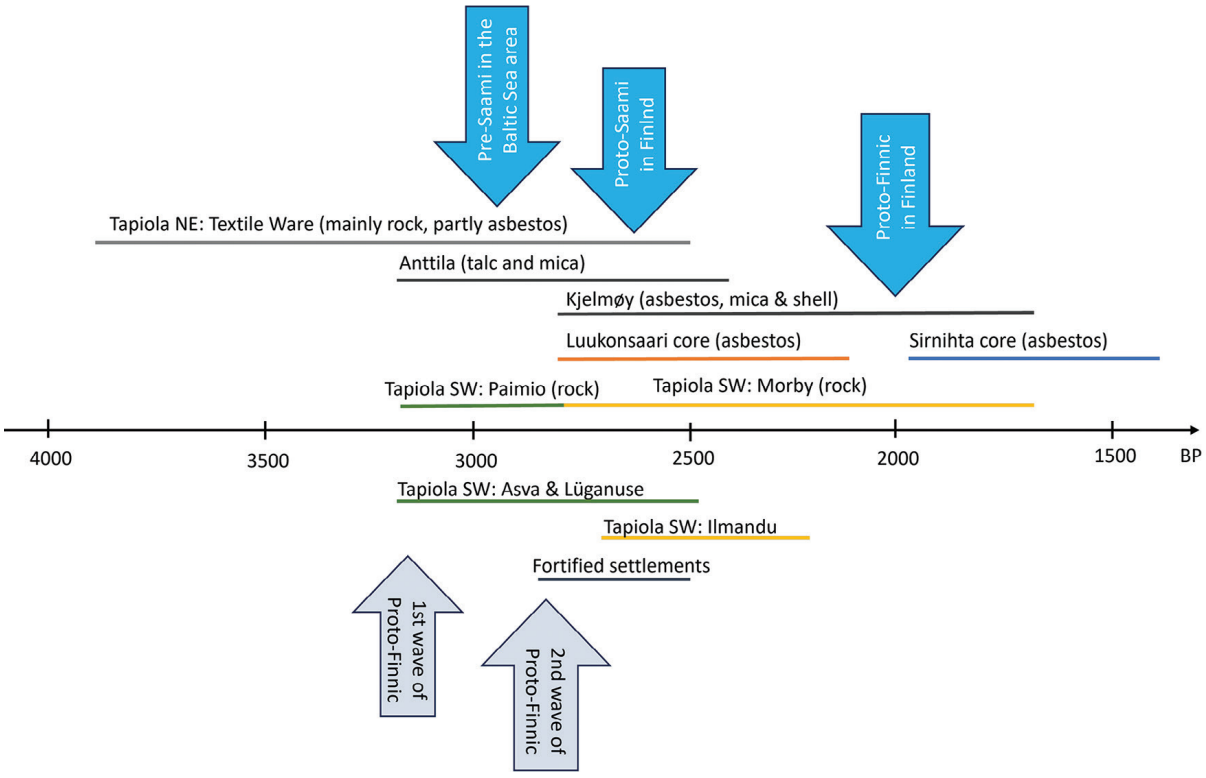

Fig. 16. Timeline of certain relevant ceramic types in Finland and Estonia. Ceramics and events that took place in Finland are listed above the timeline, while those that took place in Estonia are below the timeline. Grey arrows indicate the first two suggested arrivals of Finnic speakers based on archaeological evidence by Lang (2020), blue arrows indicate linguistic evidence about the arrivals of Proto-Saami and Proto-Finnic in Finland.

frieze decoration link Morby and Sirnihta Wares, with some Sirnihta vessels resembling Morby Ware but featuring asbestos temper. As such, if we were to connect Morby Ware to the speakers of Proto-Finnic and Sirnihta Ware to speakers of Proto-Saami, one could think about whether the similarities seen in these two types of ceramics could tell us something about the contacts between the speakers of these two proto-languages.

Luukonsaari and Sirnihta ceramics, iron production and the Saami languages

The earliest iron production sites in Finland are known from the inland areas of the country, starting from *c.* 2500–2200 cal BP onwards. Some of the earliest sites cannot be connected to any particular culture/pottery phase (*Kehusmaa 1972; Schulz 1986; Kotivuori 1996; Karjalainen 2016*), but some have a potential pottery context. Early iron production, gathering of iron ore and/or smelting, has in Finland, Sweden, Norway and northwest Russia been connected with at least Luukonsaari, Sirnihta and Kjelmøy Wares (*Hulthén 1991; Lavento 1999; Sundquist 1999; Leskinen, Pesonen 2005; Zhulnikov 2009; Karjalainen 2016; Pesonen, Ahola 2022; Bennerhag 2023*). Birgitta Hulthén has suggested that iron could have been reduced from ore in asbestos-tempered vessels, which may have been able to withstand the high temperatures required for iron production (*Hulthén 1991.34–37*). This theory has since been refuted by some scholars (*e.g., Sundquist 1999*). Nevertheless, it is evident that some vessels have been in direct contact with iron production in Early Iron Age Sweden, Norway, and Finland (see the results of chemical analysis above).

One of our future endeavours will be to explore if it is possible to study the connection of the following phenomena: Luukonsaari and/or Sirnihta Ware, early iron production, and the spread of Saami languages into eastern Fennoscandia. The age and origins of iron-related vocabulary in Saami languages shows that the Saami speakers were well aware of iron and iron production around the beginning of the Common Era, but not many centuries before it (*Piha forthcoming*). It thus seems at present that the Sirnihta group is more contemporaneous than the Luukonsaari group with the spreading of Proto-Saami. The connection between the Saami languages (speakers) and Sirnihta ceramics could be researched further by studying toponyms of Proto-Saami origin near the ceramic findspots, and this study will be conducted in the near future.

Conclusions

In this paper we have concentrated on two Late Bronze Age and Early Iron Age pottery types in Finland: Luukonsaari Ware and Sirnihta Ware. We have identified 130 vessels representing Luukonsaari ceramics and 38 vessels representing Sirnihta ceramics from the material. With the help of new radiocarbon datings of charred crust from the pottery and context dating of burnt bone it is now possible to date these two types with more precision than before. Bayesian modelling of the dates gives time ranges of *c.* 2800–2100 cal BP for Luukonsaari Ware and *c.* 2000–1450 cal BP for Sirnihta Ware. The dating of Luukonsaari Ware to the Late Bronze Age and Early Iron Age and Sirnihta Ware to the Early Iron Age opens up some interesting possibilities to explore the contacts of these pottery groups with other contemporary groups present in the area of Finland and beyond. To further evaluate the features of the pottery groups, we performed a number of chemical analyses of pottery as well as of slag from the Jyrinlahti 1 site in Liperi. In these analyses, the rock-tempered Textile Ware clearly differs from Luukonsaari Ware and possible asbestos-tempered Textile Ware.

The origins of Luukonsaari ceramics have been explored in this article within the context of textile ceramics. This is primarily because Textile Ware was usually mixed with crushed stone, but during the Late Bronze Age asbestos was also used as a temper. Moreover, the distribution areas of asbestos-tempered textile ceramics and Luukonsaari ceramics coincide in Kainuu and northern Savonia, where the main sources of asbestos are also located. It is probable that the use of asbestos has already been adopted in textile ceramics (Kainuu and Tomitsa groups) earlier in the Bronze Age, but there is no direct radiocarbon evidence of this so far. It thus remains unclear whether the roots of Luukonsaari ceramics lie in Textile Ware. In northern Scandinavia, there was asbestos-tempered Lovozero and IT ceramics already in the early Bronze Age, but their influence on the origin of Luukonsaari ceramics does not seem plausible. Some examples in the studied material are potentially interpreted as asbestos-tempered Textile Ware, and their dating goes to the end period of Textile Ware.

When considering the relationship between Luukonsaari and Sirnihta Ware, there may have been a development from the former to the latter, but there is still a potential gap between the modelled radiocarbon dates of the two types. This gap is, however, less evi-

dent when we observe all the materials analysed in this study instead of focusing only on the core sites and dates. The long, nearly 1000-year period obtained in the full analysis suggests chronological development and variation within each type. This is particularly evident in the case of a vessel from Majakangas, Konnevesi, dated to the Viking Age, which does not neatly fit into either the Sirnihta or Luukonsaari categories, and for now may be referred to as the Konnevesi type. When comparing Luukonsaari and Sirnihta potteries, we see that even though both use asbestos as the tempering material, the typological link between the two is rather weak. By contrast, both Sirnihta Ware and Luukonsaari Ware share typological features with the contemporary rock-tempered Morby Ware from the coastal regions.

It is challenging to combine linguistic and archaeological evidence as the data in both cases is often very patchy. This is inevitable, especially when talking about matters that took place a few thousand years ago as in the case of our study. Nevertheless, when talking about the Late Bronze Age and Early Iron Age, some datable linguistic evidence does exist, mainly via Germanic loanwords in both Proto-Saami and Proto-Finnic. Here we combined linguistic and archaeological evidence both geographically and chronologically and suggested that people making Sirnihta Ware possibly spoke Proto-Saami, while those making Morby Ware could have spoken Proto-Finnic. If this was indeed the case, the similarities in these two pottery types provide intriguing insights into the potential early contacts between the speakers of these two proto-languages.

In this paper we studied Luukonsaari Ware and Sirnihta Ware from the perspective of typology and chronology. Our future work will be to inspect more closely the dating and cultural context of the early iron-production sites in Finland and the linguistic testimony of toponyms of Proto-Saami origin near the iron-production sites. We aim to gain a more detailed understanding of the cultural history of iron production and its significance for communities during the formation of these languages spoken in the area of modern Finland. The study of early iron production also gives us information about the networks behind the craft, and thus gives us further insights into the contact environment in Late Bronze Age and Early Iron Age Fennoscandia.

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From macro to micro approaches in settlement archaeology: a case study of an Early Iron Age smithy at the Pungrt hillfort (Central Slovenia)

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ABSTRACT – *In this paper, we present an interdisciplinary and multiscalar study of an Early Iron Age smithy uncovered at the Pungrt hillfort in Central Slovenia. By examining and comparing the stratigraphic and artefactual evidence preserved at both macro- and micro-scales this study highlights the importance of integrated micromorphological and micro-refuse analyses in settlement contexts. Our integrated approach allowed us to identify the blacksmith's workshop and cyclical skimming of the floor surface in the wider area of the anvil, revealing the presence of lime plaster technology for the first time during this period in Slovenia. Additionally, we discuss the strengths and weaknesses of the macro- and micro-evidence examined, as well as the geoarchaeological methods used, by exploring the distinct ways in which micromorphology and micro-refuse analysis complement each other.*

KEY WORDS – *Early Iron Age; smithy; micromorphology; micro-refuse; lime floors; hammerscale; geoarchaeology*

Od makro k mikro pristopom v naselbinski arheologiji: študijski primer starejšeželeznodobne kovačnice na gradišču Pungrt (osrednja Slovenija)

IZVLEČEK – *V prispevku predstavljamo večravensko interdisciplinarno študijo starejšeželeznodobne kovačnice, odkrite na gradišču Pungrt v osrednji Sloveniji. Študija s preučevanjem in primerjavo stratigrafije in artefaktov, ohranjenih tako na makro- kot mikroravni, opozarja na pomen integracije mikromorfologije in analize mikro-odpada pri preučevanju naselbinskih kontekstov. Takšen pristop nam je omogočil prepoznavanje kovaške delavnice, cikličnega premazovanja tal okoli nakovala in prvič v tem obdobju v Sloveniji razkril prisotnost tehnike apnenih premazov. Poleg tega opozarjamo na prednosti in slabosti preučevanih makro- in mikro-dokazov ter razpravljamo o komplementarnosti uporabljenih geoarheoloških metod.*

KLJUČNE BESEDE – *starejša železna doba; kovačnica; mikromorfologija; mikroodpad; apneni tlaki; škaja; geoarheologija*

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Introduction

Understanding house floors, open spaces, and activity areas is vital to household and settlement archaeology. It provides information on the architecture, organisation of the household and settlement space, and the social and economic activities that steered daily routines and interactions (*e.g., Matthews 2005; Milek, Roberts 2013*). These interpretative venues, however, are rarely accessible by using only traditional archaeological approaches relying on macro-observations of stratigraphic and artefactual evidence. Instead, they require an integrated micro-archaeological approach (see *Weiner 2010; Milek, Roberts 2013; Milek* et al. *2014*). To this end, we combine soil micromorphology and micro-refuse analysis with macro-archaeological methods to examine floors and activities at one Early Iron Age smithy at the Pungrt hillfort: Building 24.

The two micro-archaeological methods offer a fine-grained resolution of distinct events and processes involved in the life cycle of individual households. As the study of archaeological deposits and (micro)stratigraphy in thin section, soil micromorphology can resolve < 0.010–5mm thick discrete depositional units not visible to the naked eye. In doing so, it delivers unprecedented detail and temporal resolution to site formation and taphonomic processes that may range in duration from a single event to monthly, seasonal and longer timescales (*Courty* et al. *1989; Matthews 2017*). Micro-refuse analysis can provide a key for characterising activity areas based on the reconstruction of depositional patterns of various materials and micro-artefacts, accruing, over time, across floor surfaces and reflecting distinct use-lives of the analysed space (*Tani 1995; LaMotta, Schiffer 1999; Sherwood 2001*). Whilst individually these techniques can produce key insights about a house (*e.g., Matthews 2005; Homsey-Messer, Humkey 2016*), their interpretational strength is dramatically enhanced when integrated into a multi-method dataset (*e.g., Milek, Roberts 2013*).

Both micro-archaeological methods, rarely employed in Iron Age hillfort research (but see *Sharples 1991; Golánnnová 2023; Mohammadi* et al. *2023*), are applied here for the first time within the hillfort and household archaeology in Slovenia (see also *Prijatelj* et al. *2024*). In this study, we aimed to explore and compare the nature of stratigraphic and artefactual evidence preserved at the macro- and micro-scales[1] in such contexts to assess their relative contribution to archaeological interpretation and inform future applications of such integrated methodology. The research was conducted on the Early Iron Age Building 24 and the adjacent Road 1 at the Pungrt hillfort. The stratigraphic study of architectural features and floor layer boundaries and the artefact and bone distribution analyses were compared against the results of micromorphological and micro-refuse analyses to generate new information on different architectural choices, floor construction and maintenance practices, as well as original activity areas in the building and on the street. As this paper demonstrates, it was only through this multi-scalar, multi-method approach that Building 24 was identified as a smithy.

Pungrt hillfort

The Pungrt hillfort, situated 366m above sea level on the eponymous hill, overlooks the small town of Ig and the southern outskirts of Ljubljana Marsh. The remains of the long-lived urban settlement, which functioned during the Iron Ages and Early Roman period, are representative of the rich, multi-period landscape found not only in the vicinity of Ig, but in the entire Ljubljana Marsh area (see *Vojaković* et al. *2024*). The geological bedrock of the Pungrt hill consists of Lower Jurassic bioclastic limestone and dolomitized polymictic breccia. The limestone has been attributed to the Lithiotid Limestone Member of the Podbukovje Formation due to the presence of lithiotid bivalves (*Dozet, Strohmenger 2000; Dozet 2009*) and the dolomitized polymictic breccia to the Toarcian Breccia Member due to its superposition and geometric relationships, as it vertically intersects the underlying bioclastic limestone (*Gale, Rožič 2024*). The natural soils on the mostly wooded and partly meadow-covered hill include, depending on the local topography, both shallow, incipient, and thicker, more developed soil types. The former are represented by the Leptosols and Phaeozems, and the latter by Eutric Chromic Cambisols and Luvisols (see *Vidic* et al. *2015*).

The prehistoric settlement at Pungrt covers an area of approximately 10 hectares, surrounded by a rampart that follows the topography of the hill. An additional 6 hectares to the south, enclosed by a suspected outer rampart, have not yet been examined. As a re-

1 The two terms are fluid and relational. In this study, the macro-scale data encompass all the material and information gathered during the excavation at the site, while the micro-scale data include all the data obtained through geoarchaeological sampling and subsequent laboratory analyses using stereo, optical and scanning electron microscopy.

sult, the function and chronology of this area remain undetermined. The hillfort was divided into a series of man-made terraces, which were densely populated with houses arranged in parallel rows (Fig. 1). The urban settlement was occupied, apparently continuously, for 10 centuries from the 8th/7th century BC to the 2nd century AD (see *Vojaković* et al. *2024*).

Building 24: from macro to micro evidence

Building 24 was one of the best preserved among a group of 50 that were excavated at the site during the development-led excavation in 2020–2021. Situated on the first, relatively flat and spacious terrace with deep stratigraphy, it was also one of the 14 buildings, sited adjacent to the 2m-wide Road 1. The latter ran along the inner face of the monumental stone rampart (Fig. 1) and consisted of muddy deposits interfingered with either gravelly or pebbly material.

Building 24, similar to the other Iron Age structures on the first terrace, was rebuilt several times on the same building-stance. Over the course of some 400 years (8th/7th–4th centuries BC), its complex Early and Late Hallstatt developmental sequence (Phases I and II) saw it rebuilt four times, with the consecutive buildings retaining the same position and orientation. It was abandoned sometime in the Late Iron Age (Phase III) or the Early Roman period (Phase IV), without any evidence of a catastrophic event, such as destruction by fire. In its place, a thick dark anthropogenic soil (*i.e.* Dark Earth; see *e.g., Howard 2017*) developed, suggesting a significant change in land use in this area of the settlement, probably associated with some form of agriculture. The latter has also been attested for this area in both the stratigraphic sequence and the historical sources for the Modern period (Phase V).

Macro-stratigraphic evidence

Excavation, following procedures described in Gruškovnjak *et al.* (*2025*), revealed that during its Late Hallstatt Phase IIb2 – examined in this paper – Building 24 (Fig. 2) had dry-stone foundations (stratigraphic units, henceforth SU 2049=2055, 2092), 50cm wide and 40cm high, built with stones, 25 to 80cm in size, arranged in a single or double row. The southern foundation was preserved to a length of 5.5m, the northern to 5m.

The limestone foundations of the walls, which do not exceed a distance of 6m, and the absence of pits for

Fig. 1. Pungrt hillfort. Late Hallstatt period composite plan of the excavated area (figure by P. Vojaković).

post holes in the interior of the building, indicate a timber-framed construction, characterized by the beams connected by cross-jointing at the corners (*Črešnar 2007.16–18; Dular 2008.341; Vojaković 2013. 305–306*). While no timber was preserved in relation to Building 24, a long piece of the charred square beam was recorded for Building 2, confirming the existence of timber-framed buildings on the site, which were also evidenced by daub fragments with wood impressions uncovered throughout the site.

The stone foundations were thus the only elements of standing architecture preserved and available for macroscopic analysis. The lithofacies types the stones belong to were classified according to the updated Dunham classification (*Lokier, Al Junaibi 2016*), while the shaping of the stone was assessed according to the criteria in Petra Žvab Rožič *et al.* (2022).

The variety of lithofacies types employed for the stone foundations included Bivalve Floatstone, Lithiotid Floatstone to Rudstone, Oncoid Cortoid Packstone and several fine-grained limestone lithofacies (Carbonate Mudstone with rare fossils, Peloid Wackestone). The former are indicative of the Lithiotid Limestone Member (according to *Gale 2015* and *Djurić* et al. *2022*), while their biostratigraphic age can be assigned based on the presence of lithiotid bivalves to the upper part of the Lower Jurassic (Pliensbachian) (*Buser, Debeljak 1997*). As the local presence of this limestone is con-

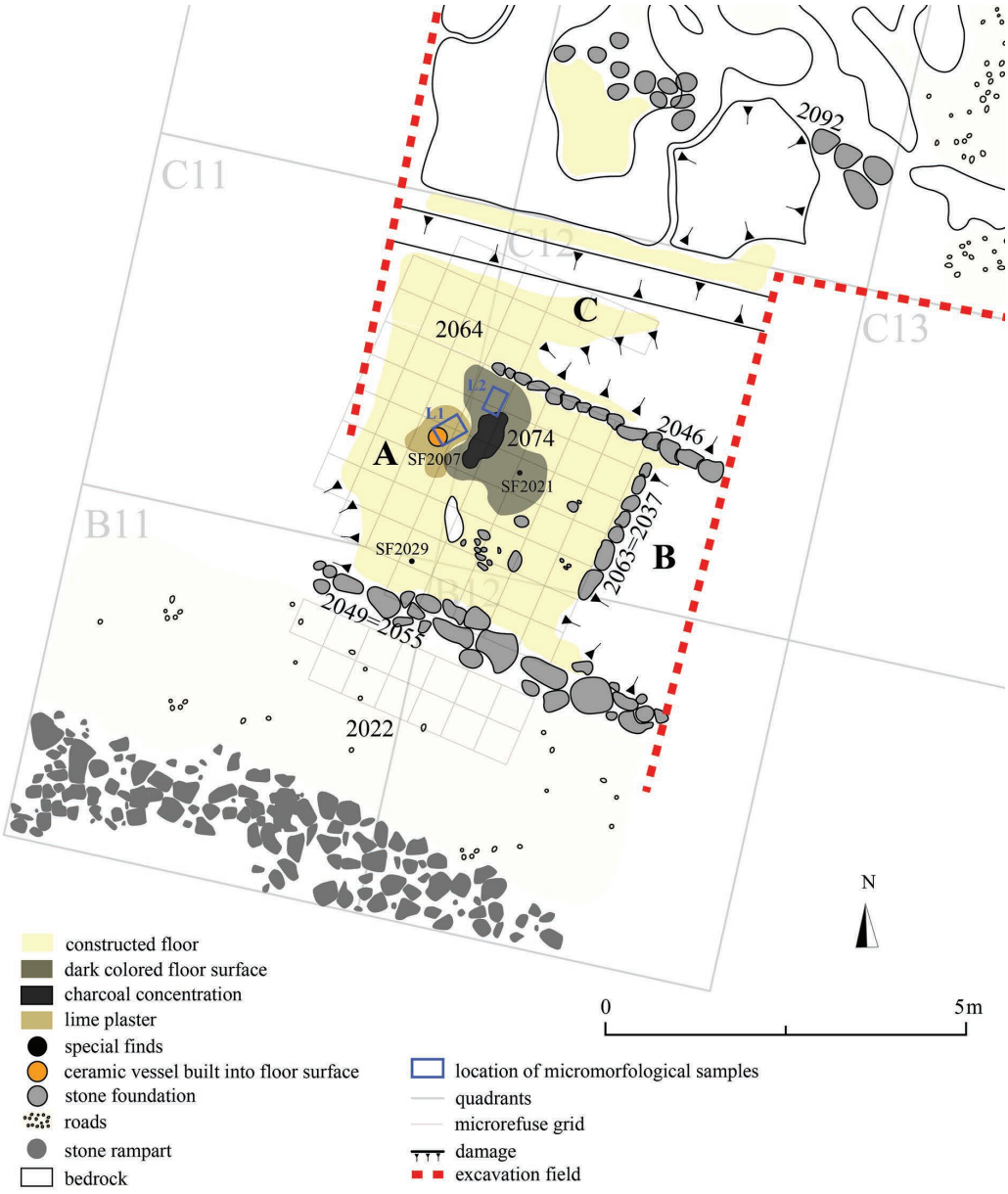

Fig. 2. Pungrt hillfort. Plan of the Late Hallstatt period Building 24 in the IIb2 phase (figure by P. Vojaković).

firmed by a geological map (*Djurić* et al. *2022.Fig. 20*), it is reasonable to assume that the stone blocks used were extracted locally.

The foundation walls were only roughly shaped. The select surfaces of stone blocks would have been worked, as evidenced by their shape, which in several cases had perfectly square chiselled edges. An almost flat surface that has been smoothed with only minor chipping was observed in the outer wall faces. The overall rough shape of the studied limestone blocks indicates that only a low-level of stonemasonry skill was employed in the building's construction.

The interior of the building was divided into three distinct areas, which had been separated by partition walls, again erected on dry-stone foundations (SU 2046, SU 2063=2037/2038), albeit in this instance, only up to 30cm wide and constructed of individual stones up to 40cm in size. The two smaller rooms (*i.e.* Rooms A and B) were located at the southern end of the building, while the third, large room (*i.e.* Room C) occupied the entire northern end. In the south-western Room A, with an excavated area of *c.* 10m^2, the occupation surface was easy to trace due to the presence of a constructed yellowish-brown silty clay floor (SU 2064.1), which was up to 9cm thick. The same floor continued into the largest, northern Room C (*c.* 20m^2), where it was preserved only in traces due to the presence of a rocky outcrop and extensive later disturbances. No floor evidence was preserved or discerned in the smallest, south-eastern Room B (*c.* 3m^2).

Whereas no constructed hearths were recorded in any of the three rooms, an oval patch (1×0.4m) composed of finely comminuted charcoal (SU 2074) was identified in the centre of Room A. To the west of this feature, a ceramic vessel (special find, henceforth SF 2007) was set in a pit (SU 2089/2090) within the floor. The pit and the floor immediately around it were covered with a pinkish-white material of a coarser-grained, silty clay loam texture (SU 2064.3), which micromorphology has shown to be a clay lime plaster (see below). At the contact with the vessel this plaster and pit infill both appeared rubified, indicating that high temperatures were present in the vessel. In addition, the plaster contained aggregates of the same clay lime material, some of them with rubified contact surfaces similar to the *in situ* contact with the vessel (*Gruškovnjak* et al*. 2024.2.2.Ig 94*), indicating a previous episode of removing the vessel and installing it anew.

After the end of the building's life cycle in phase IIb2 it seems to have been immediately followed by the construction of a new building above the previous one (Building 24, Phase IIc1).

Micro-stratigraphic evidence

Four undisturbed block samples for micromorphological analysis were taken at two locations within Room A, targeting the patch of the pinkish-white silty clay loam surrounding the ceramic vessel set into the floor (Location 1) and the dark-coloured part of the floor at the northern end (Location 2), where its surface appeared somewhat drier and harder, suggesting thermal alterations in this area (Fig. 2). In addition, four monoliths for control samples were extracted from the natural subsoil underlying the archaeological sequence on the Terrace 1 (Fig. 1). The sampling and thin section preparation followed the procedures described in Luka Gruškovnjak *et al.* (*2025*) and the micromorphological descriptions followed the terminology used in Georges Stoops (*2021*), with reference to additional texts such as Panagiotis Karkanas and Paul Goldberg (*2019*), and Cristiano Nicosia and Georges Stoops (*2017*). Distinct micro-layers distinguished within the macroscopically documented stratigraphic units were given a number suffix (*e.g.,* SU 2064.3–2064.9) and described separately (see Tab. 1).

Micro-stratigraphic floor sequence

The micromorphological analysis (Tab. 1) of floor samples from the building revealed a combination of a preparation layer (SU 2071) and an overlying constructed, silty clay floor (SU 2064.1) (Figs. 3, 4.A–D; *Gruškovnjak* et al. *2024.2.3.Figs. 2–3*). At the microscopic level, the two differed in their heterogeneity, internal fabric, texture, porosity and inclusions. The examined preparation substrate (SU 2071) consisted of a mixture of loose occupational debris (charcoal, bone, pottery), remnants of old floors, their plasters, finishing coats and other construction materials, as well as coarser carbonate clasts, all chaotically distributed within the layer. Compared to the constructed floor, the matrix of the construction fill was coarser-grained (silty clay loam) and more carbonate-, organic- and phosphate-rich due to the larger quantity of carbonate grains, charcoal, humified plant material and post-depositionally formed phosphate nodules. The nature of the material suggests that SU 2071 was a mixture of indoor and outdoor, occupational and demolition debris. This heterogeneous material would have been employed as a levelling substrate for the overlying

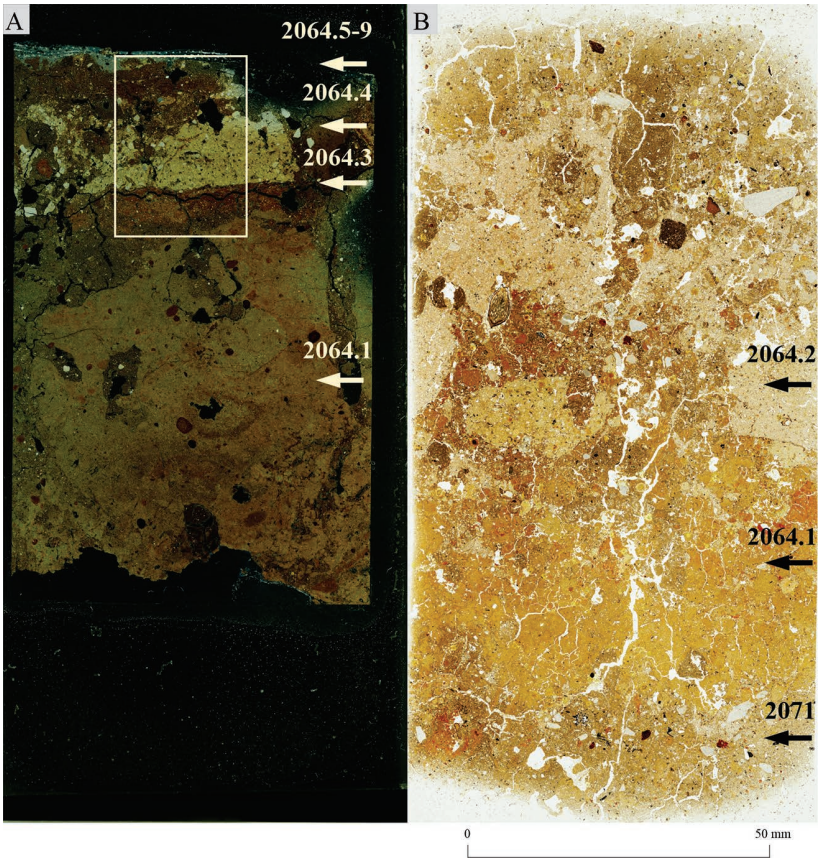

Fig. 3. Pungrt hillfort. A couple of floor (micro)stratigraphic sequences captured in micromorphological blocks Ig 3 at Location 2 and Ig 5 at Location 1 within Building 24, which are associated with its IIb2 phase. The sequence in Ig 3 (A, in XPL) includes (from bottom to top): a constructed, silty clay floor (SU 2064.1), and a series of alternating earthen and lime-based floor coats and washes (SUs 2064.3 – 2064.9), with the higher magnification image of the latter provided in Figure 5. The sequence in Ig 5 (B, in PPL) includes (from bottom to top): a preparation layer (SU 2071), a constructed, silty clay floor (SU 2064.1), and a lime plaster (SU 2064.2) (figure by A. Prijatelj).

constructed floor (SU 2064.1). In contrast to the latter, it exhibited greater porosity and no signs of wetting, kneading and pugging, suggesting that it was deposited across the construction area in a dry state.

A combination of macro- and micro-characteristics, including its field geometry, the compacted nature of the matrix, the homogeneity of the fabric and the sharp upper and lower contacts of SU 2064.1 were consistent with a constructed floor. A comparison between control soil samples (Ig 1811, 1813) and the analysed deposit demonstrated a similarity between the two types of groundmass identified within SU 2064.1 and B horizons at the site, which, at the microscopic scale, vary in their clay content (Tab. 1; *Gruškovnjak* et al. *2024.2.3.Fig. 1*). The raw material for the silty clay floor would have been procured locally from the carbonate-free, clay-rich B horizons, located in the areas with deeper and more developed soil types (*i.e.* Eutric Chromic Cambisols and Luvisols). As the naturally existing differences between clay-rich and clay-poorer areas within the local B horizons continued to be present also within the groundmass of the constructed floor, it appears that the wetted material would have been kneaded and pugged, without being thoroughly homogenized, thus preserving the naturally occurring variations in clay content of the local subsoils within the floor itself (Fig. 4.C–D; *Gruškovnjak* et al. *2024.2.3.Fig. 3.A–D*). When applied across the levelling fill in a wet state, parallel arrays of vesicles and smooth vughs (*Gruškovnjak* et al. *2024.2.3.Fig. 3.E–F*) would have been produced by water or air escaping from the construction material during the drying stage, which would have probably taken place over the course of several days (*Karkanas 2018; Goldberg 2019.129; García-Suárez* et al. *2021*).

The yellowish-brown silty clay floor (SU 2064.1) was treated differently in different areas of Room A. The three types of floor covering – plasters, finishing coats and washes – were distinguished based on their thickness, as observed in thin sections (Tab. 1, Figs. 3.A,5,6). More specifically, the clay lime plaster (SU 2064.2) was some 65mm thick, finishing coats (SUs 2064.3–2064.7, 2064.9) ranged from 3.5 to 14mm in their thickness, and the single lime wash (SU 2064.8) was, at 0.5mm, the thinnest among the identified floor coverings.

The thick clay lime plaster (SU 2064.2) covered the yellowish-brown silty clay floor in the area surrounding the ceramic vessel (SF 2007) built into the floor in Room A (Location 1, Figs. 3.B, 4.E–F; *Gruškovnjak* et al. *2024.2.3.Fig. 4*). The deposit was identified as containing lime due to the nature of its binding matrix and

Location	(Micro) Stratigr. Unit	Monoliths	Micromorphological Description	Interpretation
Terrace 1	Control subsoil samples	lg 1808, 1811, 1813, 1815	Yellow to reddish yellow silty clay with moderate porosity (5-10%) and no carbonate grains. Trace amounts of silt-sized microcharcoal (< 1%), occasional iron-manganese nodules (2-5%), and occasional intact and fragmented clay coatings (2-5%), the quantity of which increases with depth.	Subsoil horizons of the Eutric Chromic Camibisols underlying the archaeological deposits on Terrace 1. Carbonates are leached from the groundmass, which exhibits signs of intense illuviation processes. While the quantity of clay fraction increases with depth, it also varies laterally, leading to the microscopically heterogenous appearence of the groundmass.
Building 24, Room A, Location 1	2064.2	lg 5, 94	A dense layer of pinkish white to pink silty clay loam, which is progressiviely rubefied to reddish yellow towards the top. The micromass is composed of a mixture of micrite and clay. Carbonate aggregate within the micromass consists of moderately sorted subangular, subrounded and rounded grains in fine and medium sand fractions (40%). Few lime lumps (5%), few humified plant fragments (2%), trace amount of charcoal (< 1%), rare Fe-Mn (hydr)oxide coatings (< 2%) and clayey phosphate nodules (< 2%) are all present within the deposit.	A 65 mm thick clay lime plaster, produced with dry slaking, applied across the floor area associated with the in-built ceramic vessel.The horizontal sample of floor plaster (lg 94) has older, rubefied clay lime aggregates embedded in its matrix, suggesting the recycling of material and periodical renovations of plastered surfaces. The rubefaction of the material towards the top of the layer suggests that this floor area would have been exposed to high temperatures.This area of Room C would have been the site of distinct smithing activities, most likely the quenching of the iron.
	2064.1	lg 5	Reddish yellow silty clay with occasional relict iron-manganese (hydr)oxide nodules (2%) and trace amounts of silt-sized microcharcoal (< 1%), evenly dispersed through the matrix. Within the dense groundmass, commonly disrupted by channels and chambers (15-20%), are embedded very few clay lime plaster aggregates (3%), rubified silty clay aggregates (< 2%), and clayey phosphate nodules and infillings (< 2%).	A reddish yellow, constructed, silty clay floor, with the raw material procured from the local, silty clay subsoils. The wetted material was kneaded and pugged, without being thoroughly homogenised, then applied across the preparation substrate in a 9 cm thick layer.The presence of clay lime, burnt silty clay aggregates and phosphatic features within the floor is associated with the bioturbation of deposits in this area.
	2071	lg 5	Moderately to very porous (16-30%), aggregated, organic-rich, yellowish brown to dark brown silty clay loam with few gravel-sized carbonate clasts (5-15%) and common anthropogenic inclusions (16-25%): macro and micro charred plant remains, bone and pottery fragments, fragments of old floors, their plasters, finishing coats, burnt and unburnt aggregates of pure clay, and phosphate nodules and vivianite.	A preparation layer for the overlying constructed floor consisting of a mixture of loose occupational debris (charcoal, bone, pottery), remnants of various construction materials, as well as coarser carbonate clasts, all chaotically distributed within the organic-rich, silty clay loam.
	2064.9	lg 3	Yellowish red to red silty clay loam with few relict iron-manganese (hydr)oxide nodules (5%). Sub-horizontal planar voids in the upper part of the layer.	A 2 mm thick ertahen floor coat with silty clay loam texture, applied across the floor surface in the N section of Room A. The rubefaction of the coat suggests increased temperatures on the floor surface. Regular traffic and trampling in the area damaged the coat in its upper section and produced sub-horizontal planar voids.
	2064.8	lg 3	A thin, pinkish white lense of carbonate-rich aggregates and quartz sand.	A 0,5 mm thick clay lime wash, applied across the floor in the N section of Room A.
	2064.7	lg 3	Yellowish red to red silty clay loam with few relict iron-manganese (hydr)oxide nodules (5%).	A 3,5 mm thick earthen floor coat with silty clay loam texture, applied across the floor in the N section of Room A. The rubefaction of the coat suggests increased temperatures on the floor surface.

Tab. 1. Pungrt hillfort. Summary micromorphological description of deposits from Building 24 in its IIb2 phase (figure by A. Prijatelj).

Building 24, Room A, Location 2		lg 3, 4	Carbonate-rich reddish yellow lamina with texture, fabric, microstructure and individual components similar to SU 2064.4.	A 5,5mm thick clay lime floor coat, produced with dry slaking, and applied across the floor surface in the N section of Room A. The rubefaction of the coat suggests increased temperatures on the floor surface.
	2064.5	lg 3, 4	Yellowish red to red silty clay loam with few relict iron-manganese (hydr)oxide nodules (5%), evenly dispersed trace amounts of silt-sized microcharcoal (< 1%) and charred fibrous plant fragments (< 1%), as well as few aggregates of rip-up clasts from the underlying SU 2064.4 (2%) and aggregates of other, clay-based construction materials (1%).	A 14mm thick earthen floor coat with silty clay loam texture, and (probably unintentional) addition of rare plant fibers, applied across the floor in the N section of Room C. The rubefaction of the coat suggests increased temperatures on the floor surface.
	2064.4	lg 3, 4	A dense layer of pink to yellow silty clay loam, with the micromass composed of a mixture of micrite and clay. Carbonate aggregate within the micromass consists of moderately sorted subangular, subrounded and rounded grains in fine and medium sand fractions (40%). Few lime lumps (5%), few humified plant fragments (2%), trace amount of charcoal (< 1%), and occasional clayey phosphate nodules and infillings (3%) all present within the deposit.	A 12.5mm thick clay lime floor coat, produced with dry slaking, and applied across the floor area in the N section of Room C.
	2064.3	lg 3, 4	Pure red clay, rich in quartz sand (15–25%). A dense, poreless microstructure post-depositionally disturbed by channels and vughs. The clay groundmass has a random-striated birefringence fabric. On the upper surface is a thin lense (0,01mm) of comminuted, horizontally oriented charred plant remains.	A 11mm thick, earthen floor coat made of pure red clay mixed with quartz sand. Applied across the silty clay floor in the N section of Room A. Its ritual significance perhaps associated with the inauguration of the smithy. A thin layer of soot on the surface suggests a proximity of a combustion feature.
	2064.1	lg 3, 4	See description for the SU at Location 1. Notably, at Location 2, no inclusions of clay lime plaster and rubified silty clay aggregates, nor clayey phosphate nodules and infillings were identified in the layer.	See description for the SU at Location 1. At location 2, the reddish yellow silty clay floor appears to be less damaged by the bioturbation compared to Location 1.
	2071	lg 4	See description for the SU at Location 1.	See description for the SU at Location 1.

Tab. 1. Continued

the presence of half-burnt carbonate clasts and lime lumps (see also *Karkanas 2007*). Within the plaster, the heated carbonate clasts appeared to become progressively brown, developing complex shrinkage fracture patterns and rims of a reacted lime (*Gruškovnjak* et al. *2024.2.3.Fig. 4.C*). Having several possible origins, including unreacted, half-reacted and overburnt quicklime, as well as crudely slaked lime (*Leslie, Hughes 2002*), lime lumps represented one of the defining features of the analysed lime plaster. In thin sections, they were recognized as grey, sand-sized carbonized lime aggregates of micrite with a diffuse halo gradually blending into the matrix (*Gruškovnjak* et al. *2024.2.3.Fig. 4.D*). The latter had a hazy, pixelated appearance, with calcite crystallites sharing interconnected boundaries and forming a continuum within the matrix (*Gruškovnjak* et al. *2024.2.3.Fig. 4.E–F*). This characteristic of lime micromass is, in fact, a fundamental property that allows discerning between the lime and the carbonate-rich, clayey materials, in which micrite grains are, as a rule, individually embedded within the clayey matrix (*Karkanas 2007.786–787*). Rather than pure lime, the material employed for SU 2064.3 was clay lime: the presence of clay, quartz and mica grains and iron-manganese (hydr)oxide nodules within the matrix suggests that the damp mineral subsoil was mixed with the carbonate aggregate and lime binder in the process of hot mixing or dry slaking (see also *Prijatelj, Gruškovnjak 2023*). The progressive reddening of the material towards the top of the layer (*Gruškovnjak* et al. *2024.2.3.Fig. 4.A–B*) indicates that this floor area would have been exposed to high temperatures.

At Location 2, the silty clay floor was periodically coated with alternating thin, earth- and lime-based finishing coats and washes, which created an intricate microstratigraphic sequence of seven micro-layers (SUs 2064.3–2064.9) on top of the constructed floor (Tab. 1, Figs. 3.A, 5, 6). Three different types of raw materials were employed for skimming the floor surface: while the earliest, some 11mm thick SU 2064.3 consisted of pure red clay mixed with quartz sand, the subsequent, progressively thinner coats SUs 2064.4–2064.9 were

alternately made of coarser textured, silty clay loam, and clay lime. In one particular instance (SU 2064.5), the earth-based finishing coat also contained a probably unintentional addition of a few plant fibres that were charred (Fig. 6.C). Rotational features identified in the same micro-stratigraphic unit might have been associated with the kneading, pugging or the directional pressure in the application of this finishing coat (*Gruškovnjak* et al. *2024.2.3.*Fig. 5.E–F; see also *Karkanas 2018*). Sub-horizontal planar voids in SU 2064.7,

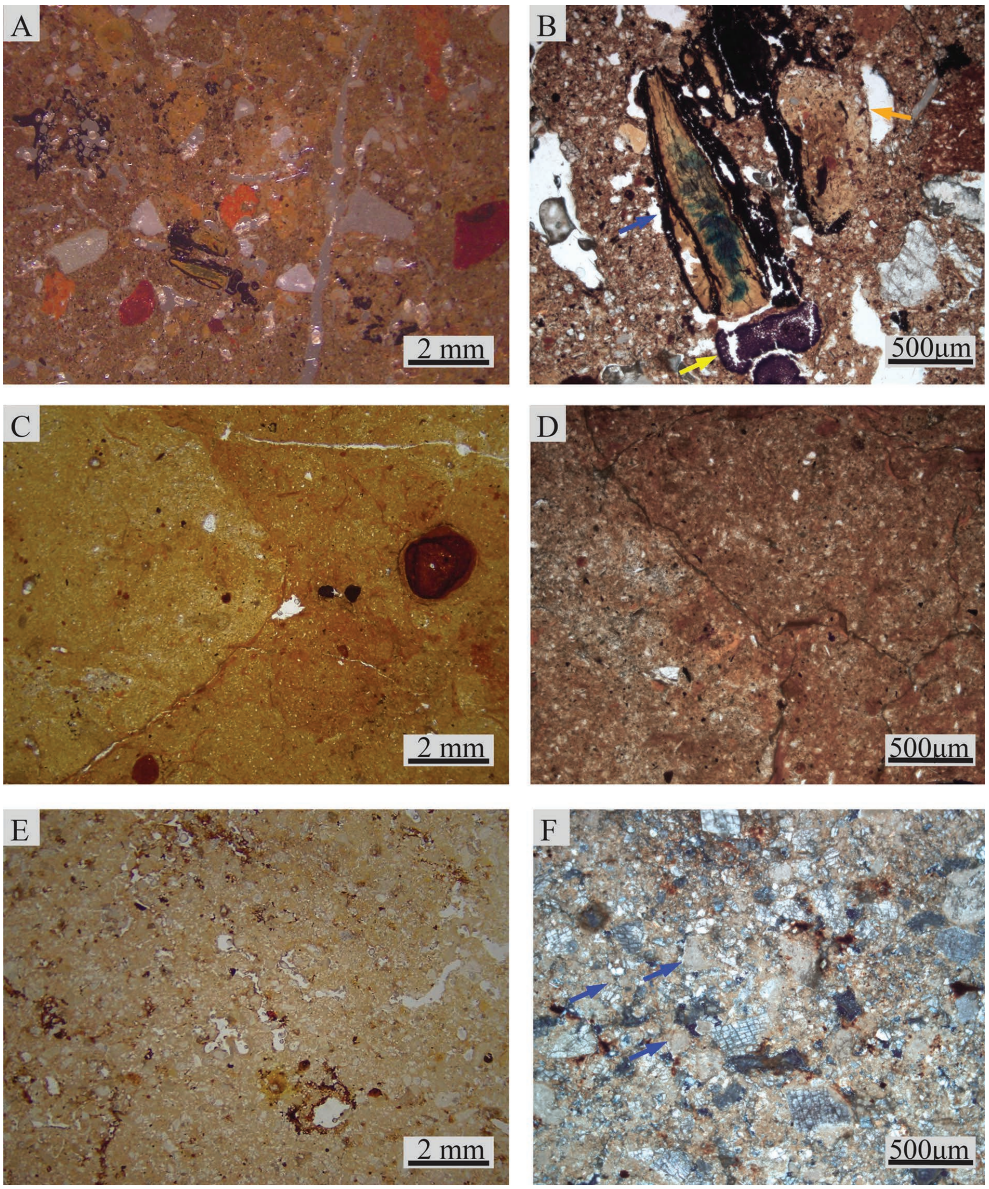

Fig. 4. Pungrt hillfort. Photomicrographs of stratigraphic units within Building 24 in its IIb2 phase:* A *a preparation layer SU 2071 consisting of the silty clay loam with heterogenous anthropogenic inclusions, such as charcoal, aggregates of various construction materials, and pure clay (Ig 5, OIL);* B *the presence of sclerotia (yellow arrow, bottom of the image), and vivianite (blue arrow, centre left) and phosphate nodules (orange arrow, centre right), frequently associated with the in situ decay of charred and humified plant material indicates that the preparation layer SU 2071 is organic-rich (Ig 5, PPL);* C-D *constructed, silty clay floor (SU 2064.1) with variations in clay content within its groundmass (compare left and right side of the image), which suggest that the material procured from the local subsoils was not thoroughly homogenized during the preparation process (Ig 3, PPL);* E *lime plaster (SU 2064.2) with a silty clay loam texture and rare Fe-Mn (hydr)oxide coatings and clayey phosphate nodules (Ig 5, PPL);* F *the micromass of the lime plaster (SU 2064.2) is composed of a mixture of micrite and clay; note the carbonate aggregate in fine and medium sand fractions, and few lime lumps (blue arrows), recognizable due to their diffuse boundaries with the surrounding matrix (Ig 5, XPL) (figure by A. Prijatelj).

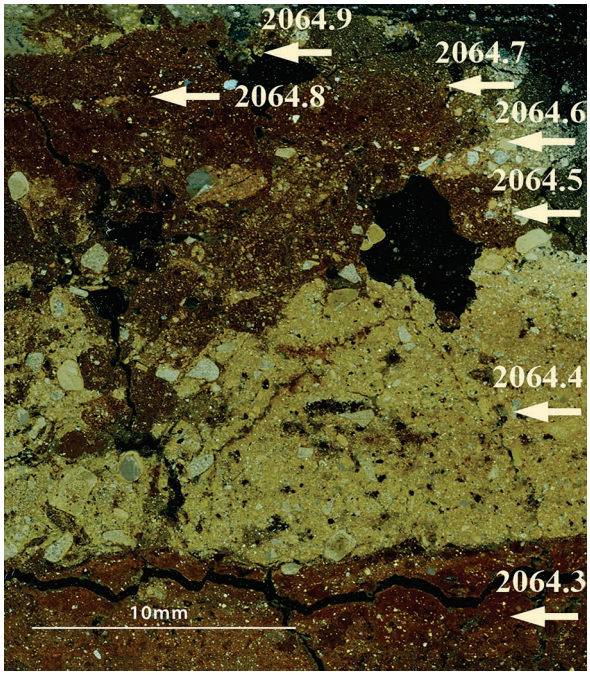

Fig. 5. Pungrt hillfort. A series of alternating earthen- and lime-based floor coats and washes (SUs 2064.3 – 2064.9) overlying the constructed, silty clay floor (SU 2064.1) at Location 2 (Ig 3, XPL) within Building 24 (phase IIb2). The sequence includes (from bottom to top): a 11mm thick earthen coat made of pure red clay mixed with quartz sand (SU 2064.3), a 12.5mm thick lime coat (SU 2064.4), a 14mm thick, earthen, silty clay loam coat with addition of plant stabilisers (SU 2064.5), a 5.5mm thick lime coat (SU 2064.6), a 3.5mm thick earthen, silty clay loam coat (SU 2064.7), a 0.5mm thick lime wash (SU 2064.8), and a 2mm thick, earthen, silty clay loam coat (SU 2064.9) (figure by A. Prijatelj).

on the other hand, suggested intense trampling in the area that caused cracking of the material. Significantly, all of the identified finishing coats in this area appeared rubified, which suggests they were altered by high temperatures (Tab. 2, Fig. 6).

Macro-artefact evidence

Altogether, 320 ceramic, metal, and bone macro-finds were recovered from Phase IIb2 occupation surfaces within Building 24 and from Road 1 in front of it (Tab. 2). The area of 50m² was spread over 6 quadrants, 5×5m in size (Fig. 2). The finds were recovered from two different stratigraphic units, including the floor within the building (SU 2064) and the muddy deposits on Road 1 (SU 2022) (see *Gruškovnjak* et al. *2024.3.*).

Macro-artefact chronology

Of 174 macro-artefacts recovered from Phase IIb2 occupation surfaces within Building 24, only a few (n=16) could be typologically classified. The most numerous were pots (Fig. 7.1 and 3–4), followed by tripods (Fig. 7.8) and baking lids (Fig. 7.5–6 and 9). A situla and a ciborium (high-legged vessels) (Fig. 7.2 and 7) as well as the bottom of the vessel, which has a knob inside (Fig. 7.11) were represented by one specimen each.

The dating of the pottery assemblage is difficult due to the temporal insensitivity of the forms and the lack of decoration. The most precisely datable pieces are the fragments of a situla and a ciborium found in Room A. The fragment of the situla (Fig. 7.2) was classified as a footless situla of version Ib1 according to Snežana Tecco Hvala (*2014.329,Fig. 2.9–10*). This type of situla has been known only from a few graves at Križna gora in the Notranjska region, dated to the 9th–8th century BC (*Urleb 1974.Tab. 1:1–3, 3:17–26, 8:1–7; Guštin 1973. 469,Fig. 2; 1979.25,Fig. 9*). The ciborium leg fragment (Fig. 7.2 and 7) is more difficult to identify, but the oxidising atmosphere during firing suggests that it is a younger form. They appear relatively early (8th century BC) in the Dolenjska region. However, such vessels increased in number in the following phases (7th–6th century BC) and continued to be used throughout the Early Iron Age. The shapes of the ciboria are very varied and have no parallel outside the Dolenjska region, which indicates that the vessels were made based on local designs in local workshops (*Dular 1982.54*).

A narrower and more secure *post quem* date was provided by the two fibulae recovered from the levelling deposit (SU 2071). The first fragment of a bronze three-knobbed fibula (SF 2030; Fig. 7.15) belonged to Type

MATERIAL GROUPS	FUNCTIONAL GROUPS		FORMS
CERAMIC	Pottery	Cooking ware	Pot
			Tripod
		Table ware	Ciborium
			Situla
		Cooking utensils	Lid
			Baking lid
			Ceramic ring
			Platter
			Portable oven
			Firedog
	Tools		Tuyere
	Building material		Burnt clay
METAL	Bronze		Unidentified

Tab. 2. Pungrt hillfort. A representation of material groups, functional groups and forms of macro-artefacts discovered within Building 24 and on Road 1 in the IIb2 phase (figure by P. Vojaković).

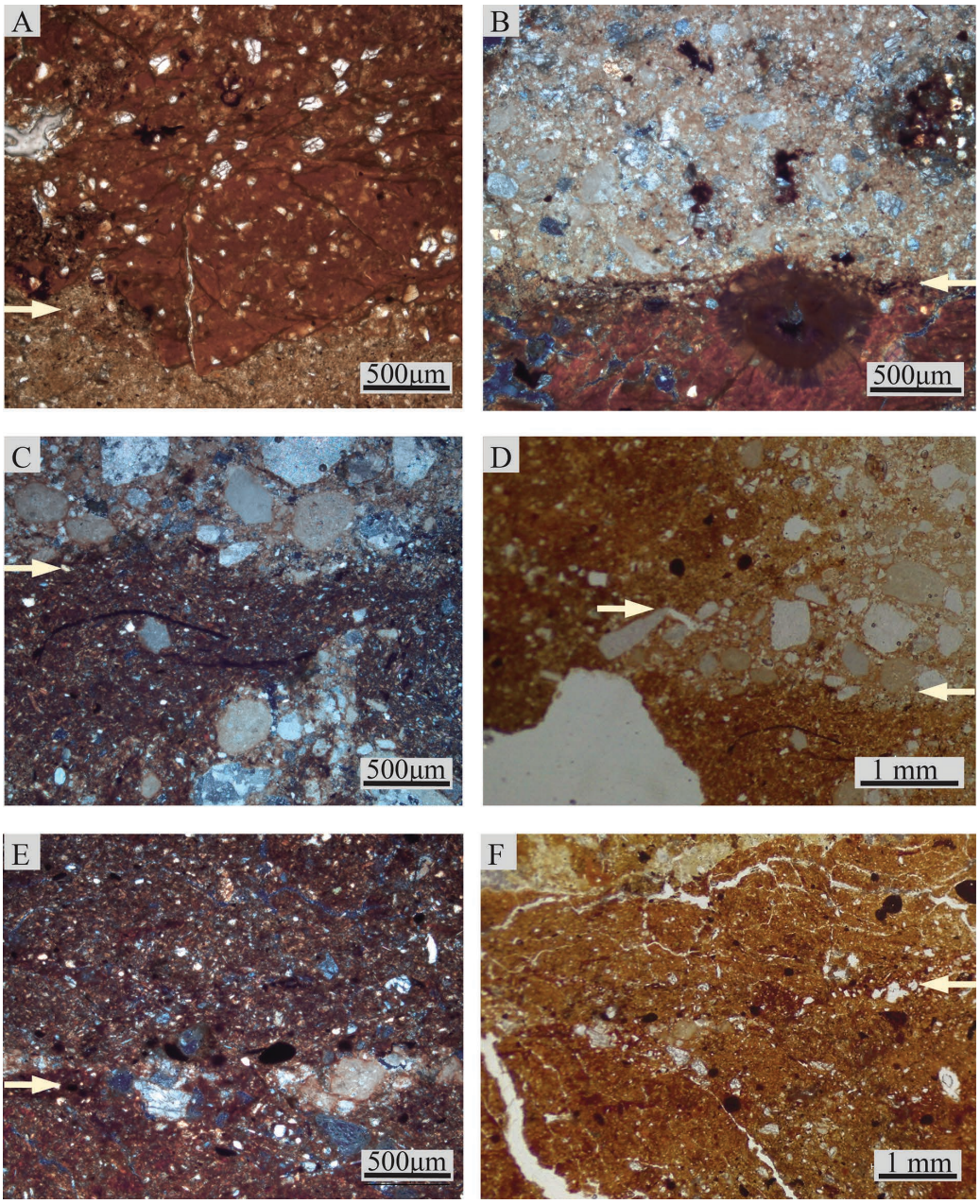

Fig. 6. Pungrt hillfort. Photomicrographs of microstratigraphic units captured at Location 2 (Ig 3) within Building 24 in its IIb2 phase:* A *a sharp and undulating contact between the constructed, silty clay floor (SU 2064.1) and the overlying pure red clay floor coat with quartz sand mixed in (SU 2064.3); the non-linear contact suggests the application of the red clay coat at the time when the silty clay floor was constructed (PPL);* B *a sharp and linear contact between the red clay floor coat (SU 2064.3) and the overlying lime floor coat (SU 2064.4); note a thin layer of soot on top of the clay coat, suggesting the proximity of the combustion feature and the passage of time prior to the application of the overlying lime coat (XPL);* C *a sharp and sub-horizontal contact between the earthen floor coat (SU 2064.5) and the overlying lime coat (SU 2064.6); the earthen floor coat (SU 2064.5) with silty clay loam texture has a probably unintentional addition of few plant fragments, and a few aggregates of rip-up lime clasts from the underlying SU 2064.4 (bottom of the image) (XPL);* D *a sharp and sub-horizontal contact between the earthen floor coat (SU 2064.5) and the lime floor coat (SU 2064.6) (lower arrow), and a clear and sub-horizontal contact between the lime floor coat (SU 2064.6) and earthen floor coat (SU 2064.7) (upper arrow, PPL);* E *a 0.5mm thick lime wash (SU 2064.8) applied across the earthen floor coat (SU 2064.7); note a few microcharcoal fragments on the surface of the lime wash, suggesting the proximity of the combustion feature and the passage of time prior to the application of the overlying earthen floor coat (XPL);* F *the earthen floor coat with a network of sub-horizontal planar voids, suggesting regular traffic and trampling in the area (PPL) (figure by A. Prijatelj).

VII after *Ogrin* (*1998.113,115,Fig. 15*). Such fibulae were mainly characteristic for 6th–mid-4th century BC. They often appeared together with small long-footed fibulae with a reticular decorated bow (*Teržan, Trampuž 1973.429–430,Fig. 4. 2*). A fragment of such a fibula (SF 2032; Fig. 7.16) was also found on the same levelling deposit (SU 2071). This suggests that the IIb2 phase of building 24 can hardly be older than the late 6th century BC.

Macro-artefact patterning

Comparing the density of macro finds per m^2 between the building's interior and the adjacent road showed significantly higher densities on the road compared to the building (Fig. 8.A). Cooking ware and burnt clay were the most abundant both inside and outside the building, but their numbers were significantly higher on the road surface. There they are followed by cooking utensils and animal bones, which were again more abundant on the road compared to the building. On the contrary, tableware was poorly represented on the road but was relatively abundant in the building. Similarly, there were also more bronze fragments discovered in the building's interior.

The significantly higher densities of most finds on the road in front of the building could, on the one hand, be mainly related to removing waste produced within the building and depositing it on the road in front of it (see *Hayden, Cannon 1983.125,139–140; Deal 1985.260–261; Tani 1995.237; Sherwood* et al. *1995.453; LaMotta, Schiffer 1999.21–22*). However, it might also (partly) represent deliberate addition of coarse material to aid runoff (*Rosen 1989.566, 573; Raja, Sindbæk 2020.179*). Tableware perhaps represents a more valuable type of pottery which was treated and disposed of differently, perhaps as provisional refuse intended for reuse (see *Hayden, Cannon 1983. 130–131; Tani 1995.240*), while bronze fragments (Fig. 7.12) most likely represent remains of small unintentionally lost objects (see *Fehon, Scholtz 1978; Hayden, Cannon 1983.160*).

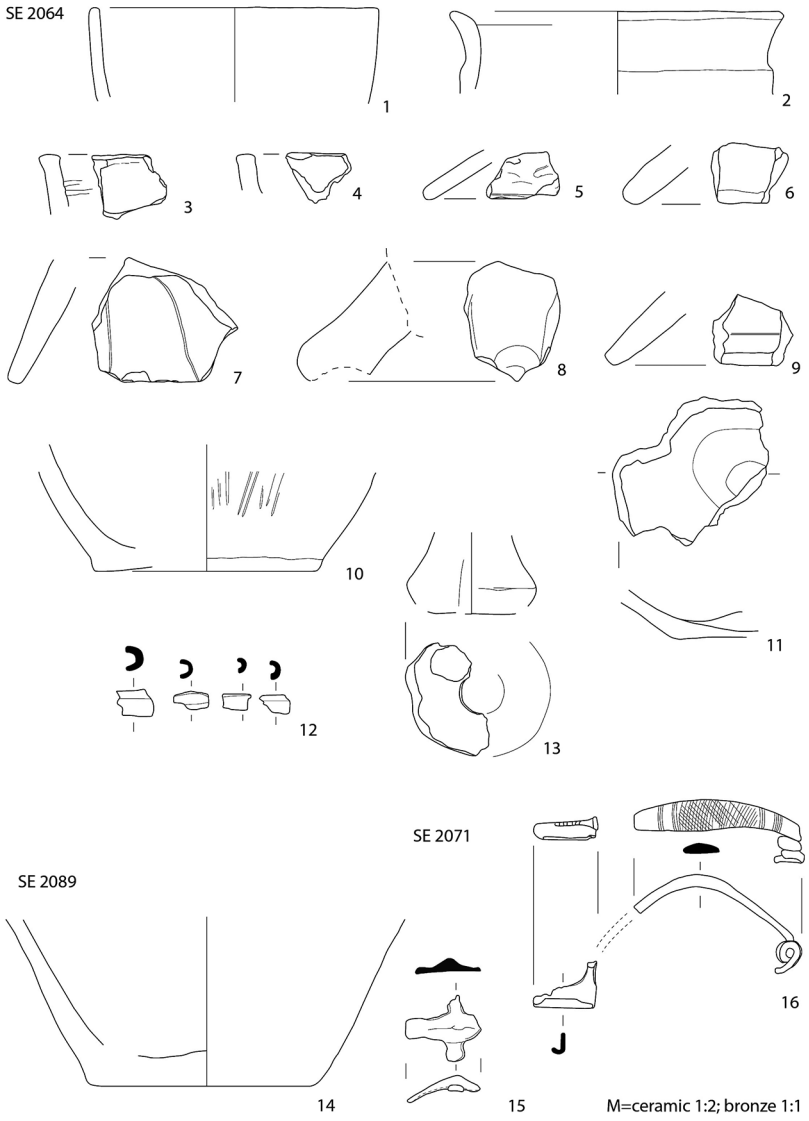

Fig. 7. Pungrt hillfort. Representative macro-finds from Building 24 in the IIb2 phase (figure by P. Vojaković).

The coarse excavation grid (5× 5m)used for basic spatial reference of finds during fieldwork does not allow for any detailed observations of artefact patterning across the building's interior. Virtually all finds were documented in the western area of the building (in quadrant C11; Fig. 8.B), where the passageway between Rooms A and C was located. In this area within Room A, the vessel built into the floor (SF 2007=SU 2089; n=84; Fig. 7.14) was located. Compared to the reddish-brown colour of the vessel the base in its interior was very dark brown. This colour is not the result of charred food remains but instead indicates the storage of some substance, which has caused the colouring of the base and lower part of the vessel.

A concentration of burnt clay was discovered between the vessel and the charcoal layer (SU 2074). Not a single specimen of burnt clay displayed any wood impressions, which would (undoubtedly) identify them as the remains of burnt daub. Therefore, we assume that the fragments likely belonged to a portable hearth, oven or furnace used in this area. The predominance of cooking ware, cooking utensils and tableware among the macro-artefacts in the building would lead us – without the additional microarchaeological methods employed – to the conclusion that domestic activities of food preparation and serving were dominant in its interior.

However, the high density of burnt clay along with a putative tuyere (SF 2029; Fig. 7.13) could be related to remains of a high-temperature fire installation such as a smelting furnace or a forge hearth (*e.g., Eliyahu-Behar* et al. *2012; Workman* et al. *2021*). In this case, they could suggest that some metallurgy-related craft activities have taken place in Room A. In addition, the 5 small fragments of a bronze tubular object (SF 2021; Fig. 7.12) might be attributed to an accidental loss of an object that would have been part of a personal attire or equipment. In light of the possible craft activities in the building (see below), it is important to note that the tiny artefact (Fig. 7.12) might have already been lost during its manufacturing stage (see *Fehon, Scholtz 1978.272*).

Similarly to the cooking ware, animal bones were also represented in much higher densities on the road compared to the building's interior. In terms of species (Fig. 9.A), cattle (*Bos taurus*) bones are the most abundant in both assemblages, followed by sheep or goat (*Ovis aries / Capra hircus*) bones on the road. Interestingly, the domestic pig (*Sus* cf. *domesticus*) is poorly represented only in the road assemblage while the probable wild boar (*Sus* cf. *scrofa*), possibly the only wild species represented, was discovered in the building. It was the above-average size of the specimen that suggested a wild (rather than domestic) pig, although in principle, it could also be an atypically large male domestic pig or a hybrid.

From the meat quality perspective (after *Uerpmann 1973*; Fig. 9.B), bones from medium-quality and low-quality meat body parts dominate the assemblage on the road, while high-quality and low-quality parts dominate the building's interior. However, the assemblage from the building is too small to draw conclusions. In general, the analysed bone assemblages, show no clear signs of selection in favour of certain parts of the carcass and, in this sense, no specialized activities associated with the particular phase of the meat processing *chaîne opératoire* (see *e.g., Seetah 2019*). Nevertheless, the pattern of fragmentation of the long bones suggests that fresh bones would have been broken to access marrow (*e.g.,* bovine humerus and metatarsus). Exceptionally, a macro bone fragment showed irregular fractures with a roughened surface of the compact at the fracture site, a feature usually associated with the breaking of old, largely dried bone (*Outram 2002*). It is also important to note that the size fractions of the bones collected in the open areas were larger than those in the house, once again emphasising the idea of waste disposal from the house to the street.

On the road, two fragmented horn cores were found, showing cut marks made during the removal of the keratinous horn sheath and, therefore, a culinary uninteresting example of craft waste (the horn was used as a raw material) (see *e.g., Prummel 1978; Binford 1981; Lisowski 2014; Saliari, Felgenhauer-Schmiedt 2017*). A bovine tibia, gnawed at both ends, was also found. The latter was thought to have been gnawed on by (probably) dogs. Lying in the open, such organic waste was clearly accessible to animals (see *e.g., Walters 1984; Pokines 2021*).

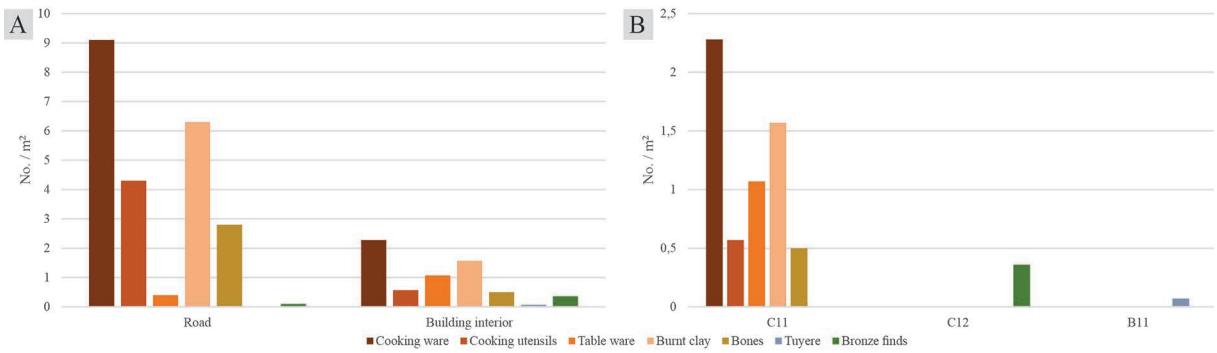

Fig. 8. Pungrt hillfort. Comparison of macro-artefact densities between Building 24 interior and Road 1 and (B) between quadrants within the Building 24 in the IIb2 phase (figure by P. Vojaković).

Micro-artefact evidence

The sampling for the micro-refuse within Building 24 was carried out in Room A and the southern part of Room C, where the floors were well preserved, as well as also on a part of Road 1 adjacent to the building. The sampling, sample processing and examination followed procedures described in Luka Gruškovnjak *et al.* (*2025*).

Excluding numerous natural neoformations (*e.g.,* iron-manganese (hydr)oxide nodules), the heavy fraction assemblage comprised 19 843 identified fragments in 2mm to >8mm size fractions and additional 599 magnetic pieces in 1–2mm size fraction. They were divided into five material groups (lithics, ceramics, lime, metallic, and faunal remains) (Tab. 3), further subdivided into 33 (sub)types. We separately examined the light fraction assemblage, acquired by flotation, which is comprised of charred botanical remains, representing the sixth material group (see *Gruškovnjak et al. 2024.4.4*).

Micro-artefact SEM-EDS analysis

Several types or subtypes (see Tab. 3) have been analysed and defined using scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) analysis (see *Gruškovnjak* et al. *2025*), including fragments of metallurgical materials, lime and a lithic grain of graphite schist.

Metallurgical materials combine two main by-products of metallurgical processes: hammerscale and slag (*Gruškovnjak* et al. *2024.4*). Both were further subdivided according to magnetism and various visual characteristics. Their interpretation and typology were established using SEM-EDS analysis. The subtypes of hammerscale include flakes of iron oxides produced during forging and welding (Fig. 10.A–B); spheroids formed during welding or purifying the bloom (Fig. 10.C–D); and miscellaneous pieces with quartz sand flux produced during welding (Fig. 10.E–F). Hammerscale is related to blacksmithing (see *e.g., Dungworth, Wilkes 2007; 2009*), while slag could also be related to iron smelting or copper metallurgy. Most slag pieces display black, greyish, and reddish colours; they have a porous structure and a typical solidification dendritic microstructure (Fig. 10.G–H). They are related to ferrous metallurgy, either smelting or the accumulation of clinker (mixture of inorganic impurities such as hammerscale, flux, ash, vitrified clay) in the smithing hearth (see *e.g., Crew 1996; Serneels, Perret 2003; Miller, Killick 2004; Dunster, Dungworth 2012; Workman* et al. *2021*). In addition, two fragments display greenish to bluish colours, suggesting copper metallurgy, confirmed by the presence of Cu and Pb (Fig. 10.I) (see *e.g., Eliyahu-Behar* et al. *2012; Nerantzis* et al. *2017*).

Two types of lime were identified and analysed with SEM-EDS (*Gruškovnjak* et al. *2024.4.6.3*). The EDS spectra (Fig. 11.A–B) corresponded with those reported for ancient calcitic mortars and lime plasters (*e.g., Borsoi* et al. *2019; Mignardi* et al. *2021*), confirming their identification. The first type had a pure white porous lime fabric with numerous medium to coarse sand sized rounded limestone or dolomite grains as aggregate. The second had an off-white, less- or non-porous fabric with numerous fine to medium sand sized angular and rare rounded limestone or dolomite grains. The comparison with floor sequences captured in thin sections (Ig 3–5, 94) suggests that the second type represent aggregates of either clay-lime plaster (SU 2064.2) or clay lime finishing coats and washes, such as those identified at Location 2 (SUs 2064.4, 2064.6, 2064.8). The higher values of Si and Al also

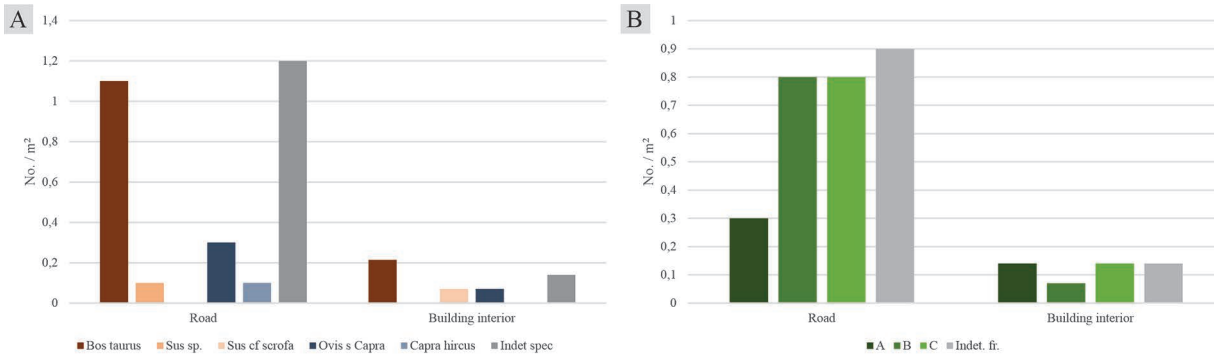

Fig. 9. Pungrt hillfort. Comparison of macrofaunal remains from Building 24 and Road 1 in the IIb2 phase from the perspective of (A) species representation and (B) quality of meat (A: high, B: medium, C: low quality, after* Uerpmann 1973*) (figure by P. Vojaković).

MATERIAL GROUP	TYPE	SUBTYPES		POSSIBLE INTERPRETATION
LITHIC	Limestone and dolomite	Angular grains		Building material (roads, floors, lime etc.), environmental (backgroung geology)
		Rounded grains		Building material (lime, roads)
	Sandstone and conglomerate	Lithic sandstone		Tools, implements, utensils
		Micaceous sandstone with sericite-quartz matrix		
		Micaceous sandstone with calcite matrix		
		Quartz conglomerate		
		Chert pebbles		
	Other	Quartz crystals and grains		Raw material (metallurgy, pottery, floors)
		Graphite schist		Raw material (pigment?)
CERAMIC	Coarse pottery			Cooking ware, storage ware (?)
	Fine pottery			Table ware, cooking utensils, tools and implements, building material
	Daub			Building material (daub), burnt pottery
	Burnt clay			Building material (floors, fire installations)
	Vitrified and sintered clay	Red to black vitrified		Building material (fire installations), metallurgical tools
		Yellow to brown vitrified		
		Sintered		
LIME	Lime type 1			Building material
	Lime type 2			Building material (floors)
METAL	Hammerscale	Magnetic / weakly-magnetic / non-magnetic		Blacksmithing (iron forging, welding, burning)
		Flakes / spheroids / miscellaneous		
	Slag	Magnetic / weakly-magnetic / non-magnetic		Blacksmithing (clinker), iron smelting, copper metalurgy
		Glassy / non-glassy		
		Iron / copper		
FAUNAL	Bone (mammals)	Unburnt		Food processing, raw material
		Burnt	Carbonised	Fuel, casual burning (refuse), intentional burning (raw material)
			Calcined	
	Bone (micromammals)			Environmental
	Bone (reptiles)			Environmental
	Bone (fish)			Food processing
	Molluscs			Environmental
	Insects			Environmental
BOTANICAL	Charcoal			Fuel
	Fruits and seeds			Food processing, cooking accidents, casual burning (refuse)
	Cereal food			Cooking accidents, casual burning (refuse)

Tab. 3. Pungrt hillfort. A representation of material groups, types and subtypes of micro-artefacts discovered within Building 24 and on Road 1 in the IIb2 phase (figure by L. Gruškovnjak ; for detailed descriptions see Gruškovnjak* et al. *(2024)).

point to the mixing of lime with clay. On the other hand, the first type has no parallels in any material discovered in a context that would allow for its functional interpretation.

The lithic grain of graphite schist was black to dark grey in colour with very well-developed discontinuity planes (Fig. 11.C) and fine (< 2mm) spacing between cleavage planes. SEM-EDS analysis was used to further determine its structure and composition. In some cases, we observed 0.2mm wide openings filled with secondary minerals. Phaneritic grains of graphite up to 75µm in size were also observed (Fig. 11.D). The aphanitic groundmass consists of inosilicates (probably amphiboles), while the phaneritic mineral grains were identified as graphite (Fig. 11.E). The rock was named as graphite schist in accordance with the Systematics of Metamorphic Rocks (*Fettes, Desmons 2007*).

Micro-artefact radiocarbon dating

Two radiocarbon samples were selected from among archaeobotanical material in micro-artefact assemblage to establish its absolute chronology (see *Gruškovnjak* et al. *2024; 2025*). A fragment of carbonized wheat seed (*Triticum* sp.) was dated to between 766 and 480 calBC (95.4%; 2473±23 BP; SUERC-123528), therefore falling within the so-called 'Hallstatt plateau' (see *e.g., Teržan, Črešnar 2014. 703*), while a fragment of charred cereal food was dated to between 550 and 405 cal BC (76.8%; 2425±24 BP; SUERC-123527) (Fig. 12). The two dates thus narrow the Late Hallstatt Phase IIb2 of Building 24 to the second half of the 6th century BC and the early 5th century BC.

Micro-artefact patterning

Micro-artefact assemblages can be studied using various statistical and spatial analyses (*e.g., Sherwood*

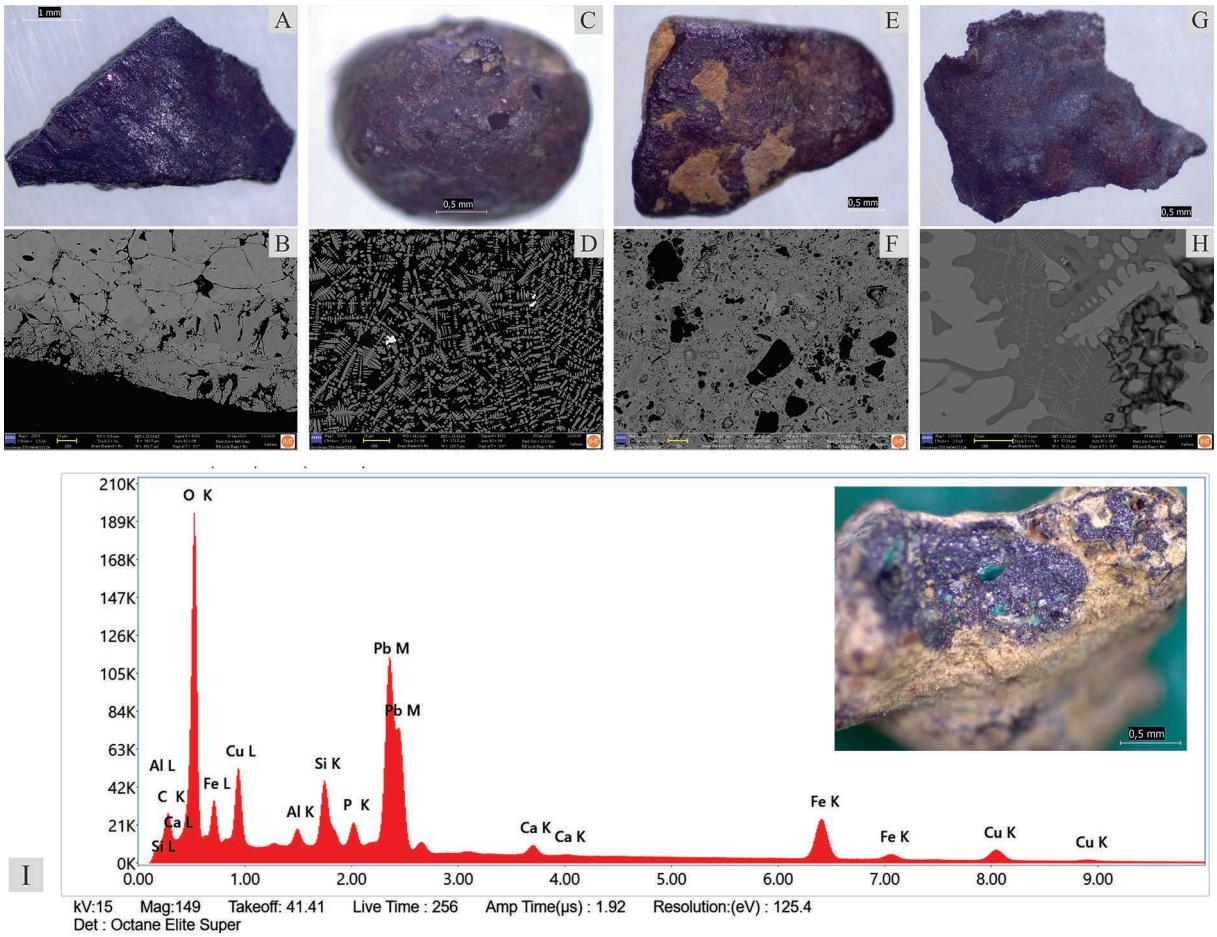

Fig. 10. Pungrt hillfort. SEM-EDS analysis of micro-refuse from Building 24 in IIb2 phase. Flake hammerscale (A) photograph and (B) SEM image showing hammerscale with various ferrous oxides. Spheroid hammerscale (C) photograph and (D) SEM image showing dendritic microstructure typical for solidification. Miscellaneous hammerscale (E) photograph and (F) SEM image showing hammerscale, different ferrous oxides with flux. Slag (G) photograph and (H) SEM image showing solidification microstructure of slag. (I) Photograph of slag and EDS spectra showing presence of Pb and Cu, typical for copper smelting (figure by L. Gruškovnjak, J. Burja, B. Šetina Batič).

2001; Kontogiorgos 2012; Ullah 2012; Milek, Roberts 2013; Ullah et al. *2014; Parker* et al. *2018*). Here, we primarily rely on a characterization study, the most straightforward analysis (see *Parker* et al. *2018*), appropriate for gaining first insights into the micro-artefact assemblage and comparing it to the macro-artefact assemblage. To achieve this objective, we analyse the data mainly through densities[2] and concentrations[3] of individual categories of micro-refuse (see *Gruškovnjak* et al. *2025*). Densities were chosen for comparability to the macro-artefact data (Fig. 8) and concentrations for comparability between samples and different size fractions (Figs. 14.B, 15–17). In contrast to the macro-artefacts data, the high sampling resolution of micro-artefacts enables various meaningful spatial divisions of the building's interior, the most obvious being the distinction between Rooms A and C. Furthermore, it allows for a spatial distribution analysis,[4] offering a de-

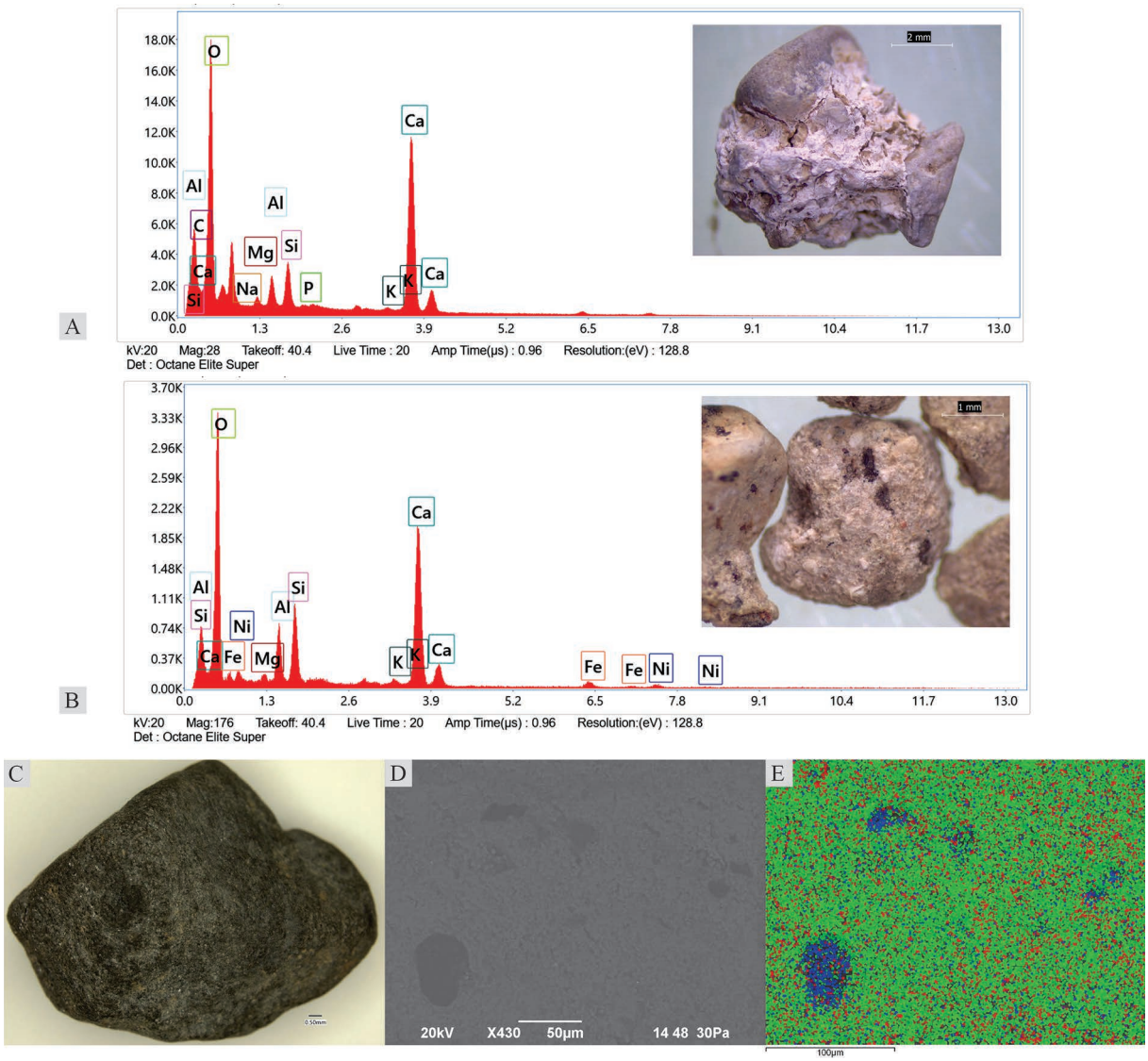

Fig. 11. Pungrt hillfort. SEM-EDS analysis of micro-refuse from Building 24 in IIb2 phase.* A *a photograph and EDS spectra of lime type 1.* B *a photograph and EDS spectra of lime type 2.* C *macroscopic photograph of graphite schist,* D *SEM-EDS microphotograph showing phaneritic minerals of graphite and* E *element distribution of the sample (blue – carbon, green – silicon, red – aluminium), additionally containing also trace amounts of calcium, potassium and chlorine in aphanitic groundmass (figure by L. Gruškovnjak, B. Šetina Batič, R. Brajkovič).

2 The fragment counts from all size fractions of individual material types were added and calculated into the density per square metre.

3 Concentrations per litre of sediment were calculated by dividing the fragment counts in each sample and size fraction by the bulk sample volume to ensure comparability between samples.

4 To obtain high-resolution density plots we employed the kriging interpolation method in the Surfer software using concentrations of individual types of material.

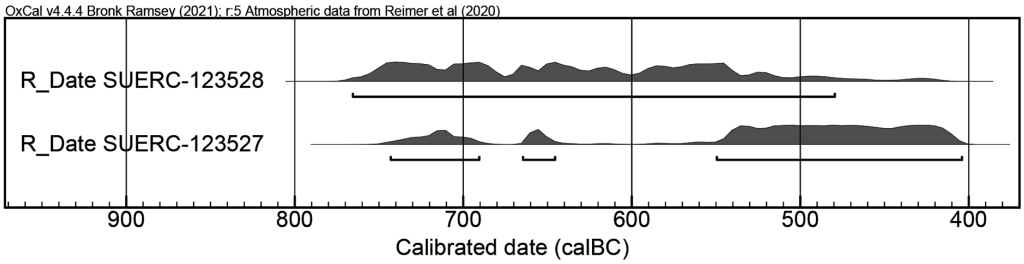

Fig. 12. Pungrt hillfort. The cumulative diagram of micro-refuse radiocarbon dates from Building 24. SUERC-123528: carbonized wheat seed (*Triticum *sp.). SUERC-123527: carbonized cereal food (figure by T. Leskovar).

tailed insight into the spatial structure of activities within the sampled area. Because a detailed spatial analysis of all documented materials in all size fractions goes beyond the scope of this paper, we focus only on three types, which are most relevant for the present discussion: hammerscale and both types of lime in the 2–4mm fraction (Fig. 18).

Based on previous research conducted on refuse behaviour, artefact fragmentation and micro-refuse, the interpretation of micro-artefacts patterning in the contexts of Building 24 and Road 1 in front of it was based on the following assumptions:

❶ In the case of intensive cleaning within the building, less material can be expected in its interior, especially in the case of larger size fractions. Only the finer size fractions will represent primary refuse and reflect long-term patterns of activities and their spatial structure within the building. In comparison, the larger size fractions will more likely reflect processes at the time of abandonment. We can therefore expect a poor match between small and large size fractions (*Hayden, Cannon 1983.156; Deal 1985.260,269; Dunnell, Stein 1989.37; Nielsen 1991.497,501; Tani 1995.234,244, 246,247; Sherwood* et al. *1995.453; LaMotta, Schiffer 1999.21–22*).

❷ In the case of intensive cleaning within the building, an increased amount of daily non-hazardous refuse can be expected on the adjacent road due to frequent floor sweeping and hearth cleaning. In such secondary refuse contexts we can expect a better match between small and large size fractions (*Hayden, Cannon 1983.126–130; Deal 1985.261–262; Rosen 1989. 566,573; Metcalfe, Heath 1990.782; Tani 1995.237, 239–240,244,247; Sherwood* et al. *1995.453; LaMotta, Schiffer 1999.21–22*).

❸ For materials only or mainly represented in the building's interior, we can assume they are specific types of refuse (hazardous or valuable) associated with

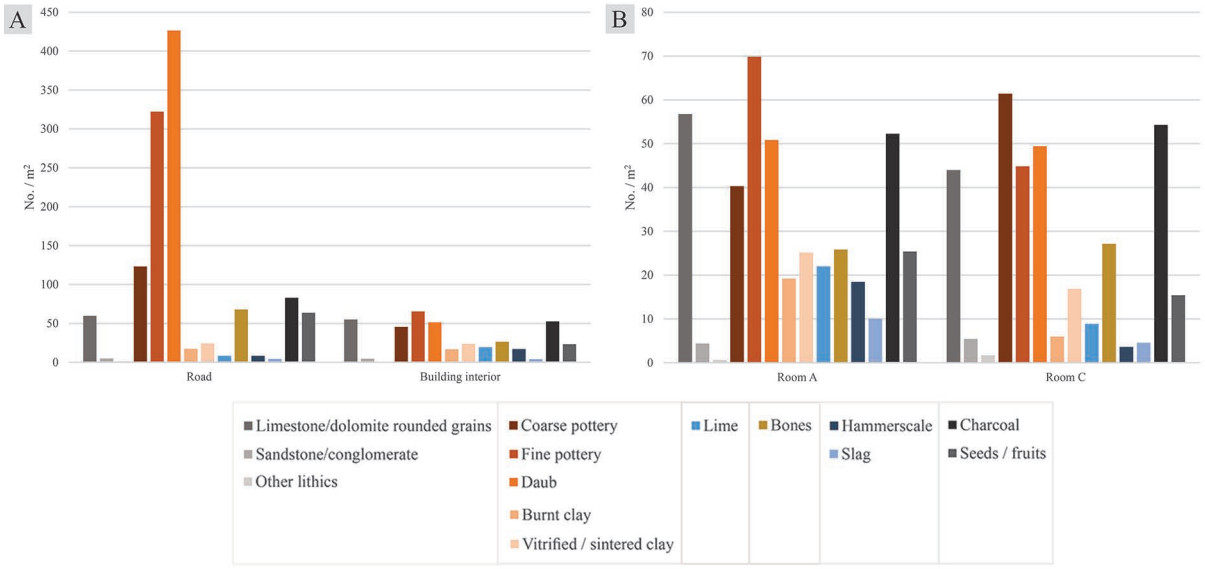

Fig. 13. Pungrt hillfort. Comparison of micro-refuse densities (A) between the interior of Building 24 and Road 1 in the IIb2 phase and (B) between Rooms A and C within Building 24 in the IIb2 phase (figure by L. Gruškovnjak).

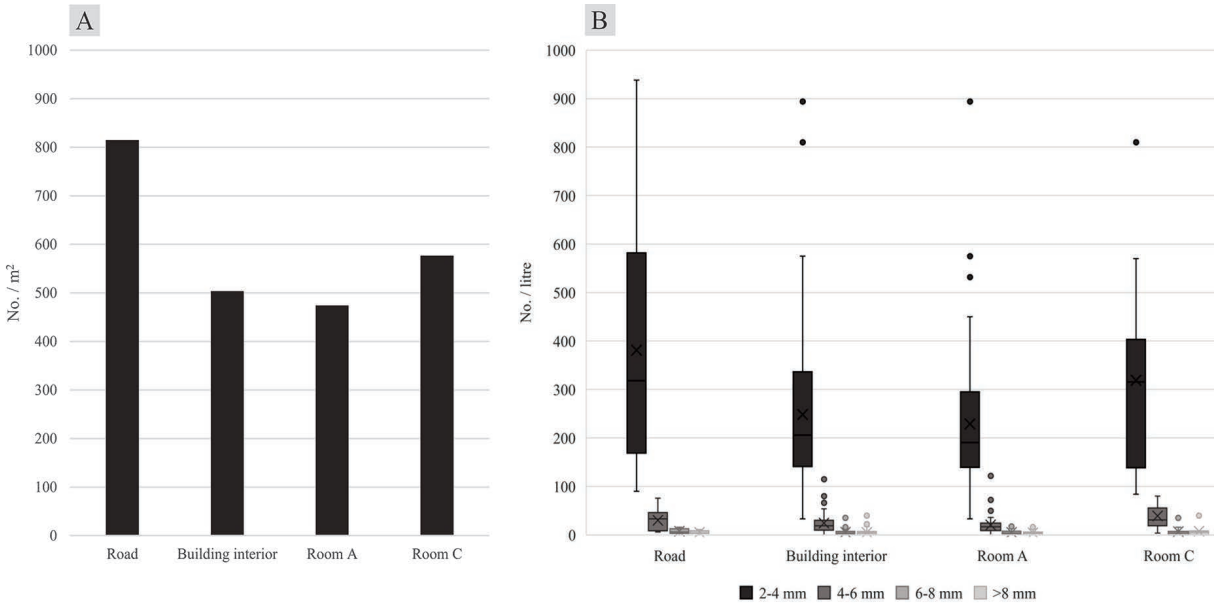

Fig. 14. Pungrt hillfort. Comparison of (A) densities and (B) the distribution of concentration values of limestone/dolomite angular grains between the interior of Building 24 and Road 1 and between Rooms A and C within Building 24 in the IIb2 phase (figure by L. Gruškovnjak).

activities within the building that require different management than ordinary refuse (*Tani 1995.240; LaMotta, Schiffer 1999.21–22; Parker* et al*. 2018.69–70*).

❹ For materials only or mainly represented on the road, we can assume they were not related to the disposal of refuse from cleaning within the building but to activities and processes specific to the road (*Parker* et al*. 2018.69–70*) or other adjacent areas.

The regular cleaning of the building's interior was indicated by much higher densities and concentrations of various materials on the road compared to the building. Furthermore, we could observe the expected discrepancies between the size fractions within the building. Most of the material was represented as primary micro-refuse smaller than 6.3mm, and any larger fragments were present only as outliers (Figs. 13.A; 15).

The higher densities on the road could, on the one hand, indicate a secondary refuse context. The significantly higher densities of bones, charcoal, and burnt plant seeds and fruits can be interpreted mainly as domestic secondary refuse resulting from cleaning the building's interior and dumping the sweepings onto the road. A similar interpretation might be suggested for coarse pottery, fine pottery and daub, whose densities were exceptionally high. Compared to other materials, their concentrations on the road were high in all size fractions, probably indicating the disposal of larger fragments on the road and their subsequent fragmentation due to road traffic (see *Gifford-Gonzalez* et al. *1985; Nielsen 1991*). On the other hand, the exceptionally high densities and concentrations of these three types of material, among which daub stands out in particular, could also be related to activities and processes specific to the road. As noted in the macro-artefact patterning, they were probably mainly related to the intentional deposition of these materials on the road to aid runoff (*Rosen 1989.566,573; Raja, Sindbæk 2020.179*).

Another type of material related to road maintenance is angular limestone and dolomite grains (Fig. 14). Compared to pottery and daub, their grain size distribution shows that they are not associated with fragmentation of larger clasts but with the intentional use of granule gravel (2–4mm; after *Wentworth 1922*) for metalling and maintaining the road, which was evident in the macro-stratigraphic observations. Interestingly, the granule gravel is also present in very high densities and concentrations in the building, where it could have been unintentionally transported on the soles of people entering from the road into the building. However, its density in the interior is more than four orders higher than the rest of the identified materials, and is similarly high in both the room facing the road (Room A) and the room further in the interior (Room C). This could suggest intentional use in floor maintenance, perhaps to improve friction and prevent slippery floors or more likely as aggregate in the two identified types of lime.

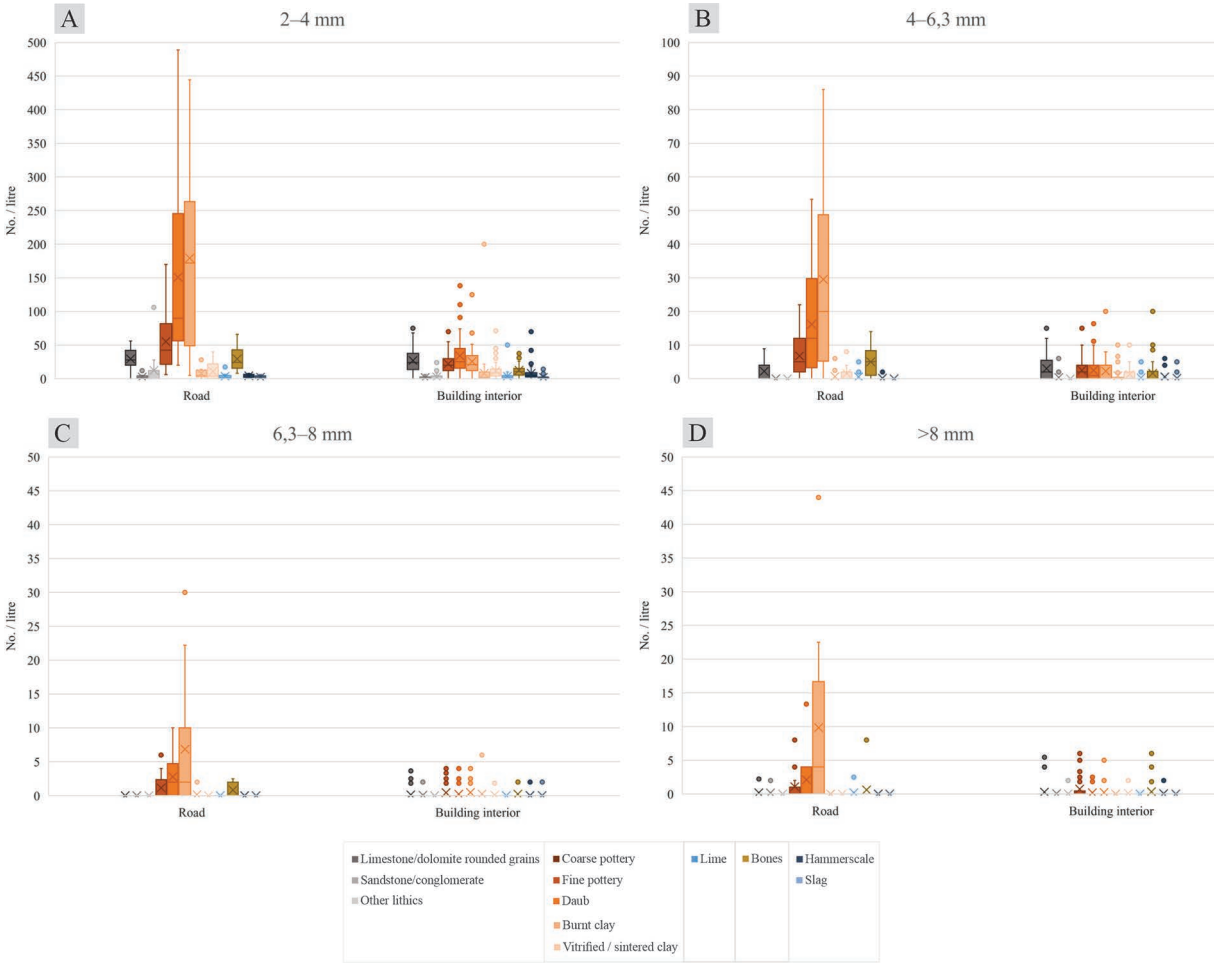

Fig. 15. Pungrt hillfort. Comparison of micro-refuse concentrations between the interior of Building 24 and Road 1 in the IIb2 phase and between 2–4mm, 4–6.3mm, 6.3–8mm, >8mm size fractions by showing in detail the distribution of the concentration values (figure by L. Gruškovnjak).

Lime and hammerscale represent materials particular to the building's interior, as evidenced by their distinctly higher densities and concentrations in the building (Figs. 13,15). Lime suggests a building material typical of building interiors, mainly floors, as demonstrated by the micromorphological analysis (see above), while hammerscale suggests blacksmithing (*Starley 1995; Dungworth, Wilkes 2007; 2009*) within the building and an activity typical of the interior. On the other hand, the density of slag, which is also related to metallurgical activities, was similar in the building and on the road. However, its concentrations within the building were higher. Burnt clay and vitrified and sintered clay display a similar trend. All three types of materials could be related to metallurgical activities within the building, namely to the use of a clay-lined smithing hearth and metallurgical utensils made of pottery (*e.g.,* tuyeres and crucibles) and the production of clinker within the smithing hearth. Limestone and dolomite rounded grains, sandstone and conglomerate, and other lithics appeared also with similar densities in both contexts but with somewhat higher concentrations within the building. Limestone and dolomite rounded grains are probably related to lime, while the sandstone and conglomerate pieces are probably associated with the use-wear of stone tools within the building. Because quartz is the most abundant material among the other lithics, this category mainly reflects its use as a raw material in the building, probably as flux in iron welding (see Fig. 10.F). The fact that hammerscale is the only activity-produced refuse which is distinctly more concentrated within the building suggests different waste management practices than other materials. It seems to have been collected separately and disposed of at another location, or perhaps even stored and intended for recycling (see *Light 1984.62; Tani 1995.240; Thiele, Török 2022*).

The comparison of micro-artefact patterning between the two rooms within the building revealed differences in their use (Figs. 13.B,16,17). The much higher densities and concentrations of hammerscale and slag in

Room A indicate that it would have functioned as a blacksmith's workshop where some bronze casting also took place (see Fig. 10.I). Among these materials, the interpretation of processes in which hammerscale is produced is the most straightforward, as this is a typical by-product of blacksmithing (iron forging, welding and burning) mainly produced in the 1–3mm size fraction (*Starley 1995; Dungworth, Wilkes 2007; 2009*). Indeed, it is the most abundant in the 1–2mm size fraction (Fig. 17) examined only for magnetic pieces, particularly for this reason. The grain size distribution showed that many pieces were also produced in the 2–4mm size fraction, but there were only a few larger pieces. Its spatial distribution shows two distinct concentrations in Room A (Fig. 18.A). Hammerscale generally falls within 2m around the anvil (*Dungworth, Wilkes 2009.37*), and where the anvil or the blacksmith stood, the concentrations should be lower than immediately around it (*Light 1984.59; Jouttijärvi 2009.980,Fig. 14*). Therefore, we can reconstruct that the anvil and the blacksmith working it stood in between the two distinct concentrations in Room A (Fig. 18).

The higher densities and concentrations of fine pottery, burnt clay and vitrified and sintered clay in Room A suggest a relation to the blacksmithing, probably due to the use of clay-lined blacksmithing hearth and metallurgical pottery utensils. On the other hand, coarse pottery was present with much higher densities and concentrations in Room C. Because this type of primary refuse was related to the use of various cooking and storage ware, it suggests that the activities in Room C were more domestic. Somewhat higher concentrations of bone fragments would also point in this direction. The similar densities of charcoal in both rooms suggest the presence of hearths in both rooms, presumably a smithing hearth in Room A and a cooking hearth in Room C. Similarly, we may presume that the use of stone tools indicated by the presence of sandstone and conglomerate is related to the use of craft-related stone tools in Room A (*e.g.,* anvil, polishers, whetstones) and

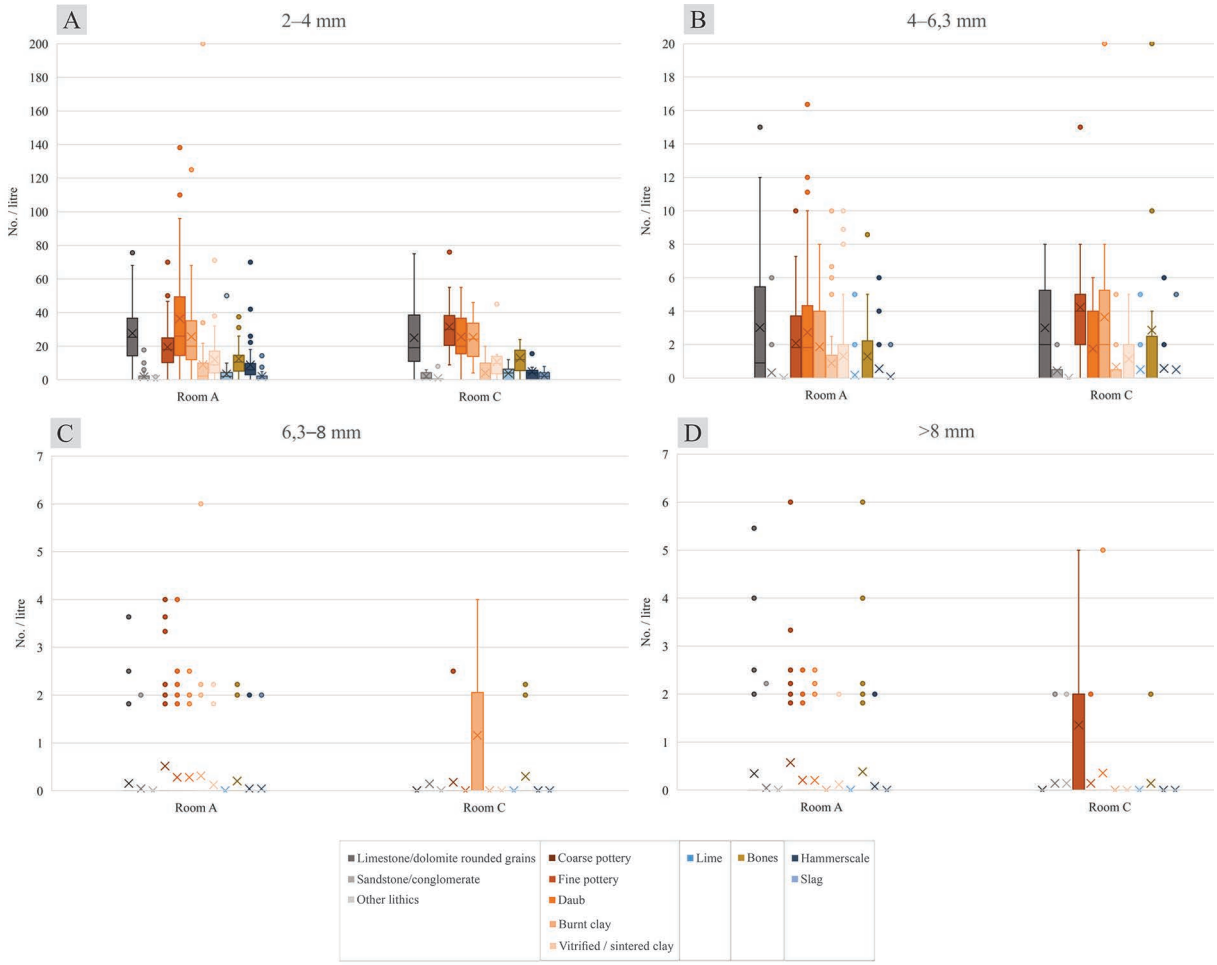

Fig. 16. Pungrt hillfort. Comparison of concentrations between Rooms A and C within Building 24 in the IIb2 phase and between 2–4mm, 4–6.3mm, 6.3–8mm, >8mm size fractions by showing in detail the distribution of the concentration values (figure by L. Gruškovnjak).

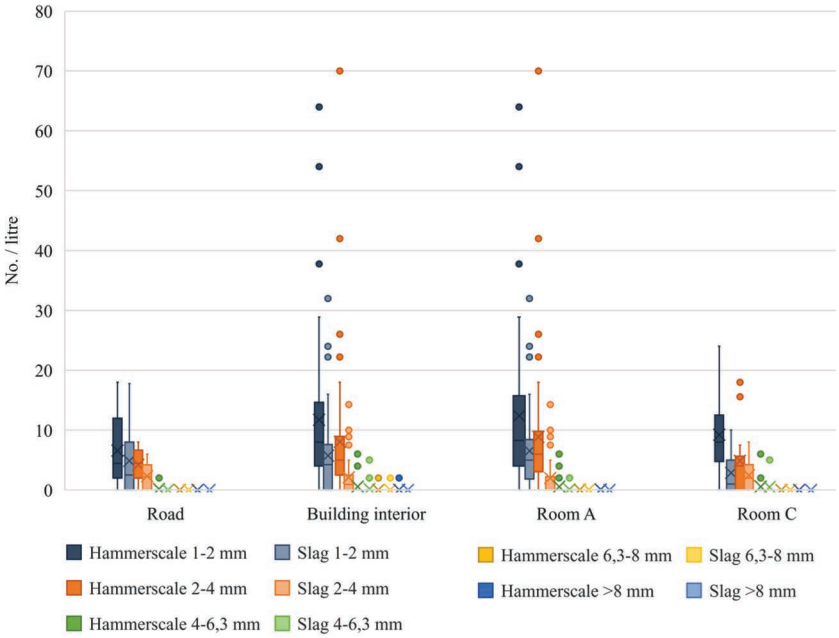

Fig. 17. Pungrt hillfort. Comparison of concentrations of metallurgical remains between 1–2mm, 2–4mm, 4–6.3mm, 6.3–8mm, >8mm size fractions within Building 24 and on Road 1 in the IIb2 phase (figure by L. Gruškovnjak).

more domestic related tools in Room C (*e.g.,* querns, pounders, whetstones). However, some activities related to food processing and preparation seem to have been performed in both rooms, as higher densities of charred seeds and fruits and relatively high densities and concentrations of coarse pottery and bone in Room A would suggest.

Lime as a building or floor maintenance material seems to have been used in a more considerable amount in the blacksmith's workshop in Room A. There, the distribution of lime type 2 (Fig. 11.B, 18. B) shows a distinct concentration around the vessel set into the floor, which corresponds to the lime plaster floors observed in the field and in thin section Ig 5 (SU 2064.2; Figs 3, 5; Tab. 1). The low-density areas may, on the one hand, be related to the unintentional spreading of this material across the room. On the other hand, they may be associated with the use of thin lime coats documented in thin sections Ig 3 and 4 (SU 2064.4,6,8; Figs 3, 5; Tab. 1). The generally low-density spread of lime type 1 (Fig. 11.A, 18. C) across the entire building could, therefore, be related to similar floor maintenance practices. However, these have been documented neither in the field nor in thin sections.

To conclude, the study of micro-refuse revealed functional differences between the two rooms examined in Building 24. Room A was used as a smithy, while Room C was used for domestic activities. The interior of the building was regularly cleaned, leaving behind only micro-refuse, which escaped cleaning. This is evidenced by the grain size distribution of material, which suggests that activities are mainly reflected in the smallest size fractions examined while the information about activities diminishes with increasing size. The relationship between the information potential of individual size fractions is further demonstrated by summarising the number of material types and the number of fragments in individual size fractions (Tab. 4). The numbers of identified types and fragments are the highest in the 2–4mm size fraction, which therefore holds most of the information about activities. The number of types in the 4–6.3mm size fraction drops slightly, but the number of fragments is significantly lower and considerably less informative for evaluating differences in activities between contexts. Moving to larger size fractions, the numbers of types and fragments drop substantially. In both 6.3–8mm and >8mm size fractions, around half of all identified types are not present anymore, and their numbers are negligible compared to smaller size fractions.

Discussion

The life cycle of Building 24

The integrated data, obtained at the macro- and the microscopic scales, provide detailed insights into the Late Hallstatt phase IIb2 of the Building 24 (Fig. 2). Based on the chronology of the macro-artefacts (Fig. 7) and radiocarbon dating of micro-artefacts (Fig. 12), the building was dated to the late 6th century and early 5th century BC. When the house was built, the architectural remains of the preceding phase were levelled and employed, together with a mixture of various outdoor waste materials, as a preparation deposit, on which the new building was erected (SU 2071; Fig. 3.B). A low outer dry-stone foundation wall of roughly shaped limestone was laid down, and a timber building made in a cross-jointing technique was built upon it. Earthen material was used to fill the spaces between the beams,

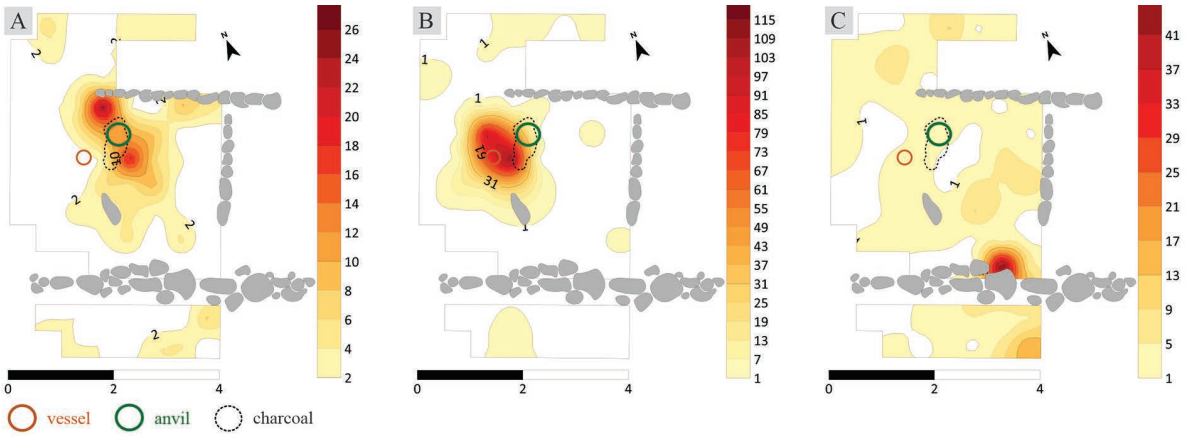

Fig. 18. Pungrt hillfort. Distribution of hammerscale (A), lime type 2 (B) and lime type 1 (C) in 2–4mm size fraction within Building 24 and on Road 1 in the IIb2 phase (figure by L. Gruškovnjak).

as indicated by the fragments of daub with beam impressions discovered across the site. The floor in the interior was constructed as some 9cm thick layer of yellowish-brown silty clay (SU 2064.1, Figs. 3,4,6). The foundations for thinner and lighter partition walls (*e.g.,* wooden plank or wattle and daub construction), dividing the interior into three rooms, were laid down only after the floor was constructed.

Room A, facing Road 1, was used as a blacksmith's workshop, as evidenced by the concentration of hammerscale and slag in the micro-refuse (Figs. 13.B,16–17,18.A). The function of the adjacent Room B, where the floors were not preserved, remains unknown, while the northern Room C would have been mainly used for domestic purposes, as suggested by the higher concentrations of coarse pottery in the micro-refuse. The latter would have been related mainly to the cooking ware and, therefore, possibly food preparation (Figs. 13.B,16). Densities of charcoal and carbonized seeds and fruits in the micro-refuse light fraction (Fig. 13.B) suggest that fire installations, which were not uncovered during the excavation, would have probably been utilized as a smithing hearth in Room A, and as a domestic hearth in Room C.

Size Fraction		(Sub)types	Pieces
Macro-artefacts		7	320
Micro- artefacts	> 8 mm	17	321
	6,3–8 mm	15	341
	4–6,3 mm	26	1734
	2–4 mm	33	17447

Tab. 4. Pungrt Hillfort. Comparison of the numbers of pieces and types or subtypes of materials discovered in various size fractions within Building 24 and on Road 1 in the IIb2 phase (figure by L. Gruškovnjak).

In the blacksmith's workshop (Room A), a vessel (SF 2007; Fig. 7.14), probably serving as a quenching tub (see below), was set into the constructed floor (SU 2064.1), and the area surrounding it was plastered with clay lime (SU 2064.2; Figs. 3,5,18.B). The floor in the vicinity, where the anvil would have stood (Fig. 18.A), received a different treatment. Initially covered with a red clay coat (SU 2064.3; Figs. 3,5,6), it was subsequently cyclically maintained by skimming of its surface with alternating thin, earth- or lime-based coats and washes (SU 2064.4–9; Figs. 5,6).

During its use, the interior of the building was regularly cleaned and maintained, leaving behind only tiny pieces of primary refuse associated with a number of distinct activities within the building. These included various processes and activities associated with blacksmithing, as well as domestic activities primarily related to food processing and preparation. The waste materials produced in the process were mostly dumped on the road in front of the building with only a few notable exceptions. (Figs. 8.A,14.A,15). Hammerscale appears to be the main one, considering that it seems to have been collected separately from the remainder of the refuse, in order to be either recycled or disposed of at a different location. Furthermore, some types of refuse on the road, namely pottery and daub fragments, are possibly not only related to the dumping of waste from the building but, at the same time, also to road maintenance.

The end of the building's use-life might have been associated with the end of the life span of the building's construction materials and architectural elements, such as its timber frame, and constructed floors. We can assume a planned abandonment, as evidenced by the facts that its interior was thoroughly emptied ex-

cept for the vessel (SF 2007; Fig. 7.14) set into the floor in Room A, and some macro waste materials (pottery, burnt clay and bone), left behind in the same room (Figs. 7, 8.B). The area was then levelled again to prepare it for the rebuilding that followed, during the next phase IIc1.

Identification of floor construction and maintenance practices

The on-site observation of floors provided the initial distinction between two different floor construction materials, which informed the subsequent micromorphological sampling; however, it failed to offer a more specific characterization of these or to detect any thinner and finer floor coats and washes. Micromorphology has proved, therefore, particularly important in examining the floor construction and maintenance practices, which reflected the temporal rhythms in the entangled life-cycles of the house and its inhabitants (see *Boivin 2000; 2004; Prijatelj* et al. *in prep.*).

Using micromorphological analysis, we identified two floor construction materials and four distinct floor skimming techniques employed in Building 24, during its Late Hallstatt phase IIb2. While the use of the first material – earth – has already been known from other Iron Age settlements in the region (*e.g., Vojaković 2013; Svoljšak, Dular 2016*), its microscale analysis has been lacking. Employing micromorphological analysis at Pungrt allowed for the identification of raw material provenance and distinct preparation techniques used in floor construction at the site. It was established that the yellowish-brown floor (SU 2064.1; Figs. 3,5) was made from the locally available, carbonate-free, and finely textured silty clay subsoils. These would have been wetted, kneaded, and pugged before being carefully packed, on top of the heterogeneous levelling fill, to form some 9cm thick layer, which would have been left to dry for several days.

In different areas of the house, the floor surfaces were skimmed with either plaster or various finishing coats and washes. The 6.5cm thick floor plaster (SU 2064.2; Figs. 3,4,18.B), identified exclusively in the wider area of the ceramic vessel (SF 2007; Fig. 7.14), was manufactured using lime-based technology. The stratigraphic observations at the macro- and micro-scales have revealed this to be a general pattern in the houses on the lowest terrace of the hillfort, with clay lime typically plastered across the constructed floors where the ceramic vessels were built-in. Pending the results of the micro-residue analysis of the vessels, it is possible that the plastered areas required both a greater mechanical strength and a better heat and liquid resistivity compared to the constructed earthen floors. This was probably due to the distinct activities that occurred in these areas of the house. The micro-refuse data from Building 24 indicates that the plastered floor section was located near the anvil (Fig. 18.A–B), where all the blacksmithing processes that required the use of heavy tools and equipment, such as heating, forging and welding, were carried out. Significantly, a quenching tub would have been placed somewhere in the immediate vicinity of the anvil. Considering that these were typically simple containers, which may have been set into a pit (*Light 1984.57–58*), the ceramic vessel (SF 2007) built into the lime-plastered floor appears to have served such a function. Had the vessel indeed been employed as a container for the quenching liquid, the regular spillage of this may have necessitated the plastering of the earthen floor in this area with the material that was less susceptible to damage caused by the liquids. The thermal alterations of plaster, most intensively at its contact with the vessel and within the vessel's interior itself, further indicate a type of process associated with the high temperatures – possibly the process of quenching.

In contrast to constructed earthen floors, the manufacturing technology for various types of lime skim would have been more complex. The production of quicklime involved heating of calcareous rocks at temperatures ranging from 800 to 900° C for several hours or longer. Rather than preparing a putty (*i.e.* slaked lime) that would have matured for months, the unslaked lime was mixed with varying amounts of mineral subsoil, carbonate aggregate and a limited amount of water, which triggered the dry slaking of the quicklime (see also *Henry, Stewart 2012; Hunnisett Snow 2016; Karkanas 2007; Prijatelj, Gruškovnjak 2024*). In the following step, the dry ingredients were mixed with enough water to obtain a viscous mixture, which was applied across the constructed floor surrounding the built-in vessel (SF 2007) in Room A and allowed to set. Rendering tools were likely used in the process, due to the caustic and alkaline nature of hydrated lime.

The striking microstratigraphic sequence of seven finishing coats and washes on top of the constructed floor in the northern section of Room A (SUs 2064.3–9; Tab. 1, Figs. 3,5,6) suggests that the floor surfaces in this part of the building were scrupulously maintained. The renovations were undertaken using both earth- and lime-based construction materials, with a distinct

temporal rhythm in the use of different skims evidenced throughout the sequence. The earliest, some 11mm thick finishing coat was made of pure red clay mixed with quartz sand (SU 2064.3; Figs. 3.A,5), with the layer in question representing a single use of this construction material throughout the entire IIb2 microstratigraphic floor sequence. The subsequent, progressively thinner coats and washes (SU 2064.4–2064.9; Fig. 5) consisted of either clay lime or silty clay loam.

The evidence for the cyclical skimming of the floor surface correlates with the area where the anvil would have stood (Figs. 2,18.A). This plastering routine may have been dictated by the wear and tear of the floor surface in this focal area of the blacksmith's workshop. However, the cyclical alteration between the earth- and lime-based skims could suggest additional ritual and symbolic significance as similar practices related to cyclically occurring festivities have been documented in ethnoarchaeological studies (*e.g., Boivin 2000; 2004*). In fact, ritual practices related to blacksmithing, a transformative, socially embedded, and symbolically charged activity (see *e.g., Njoku 1991; Budd, Taylor 1995; Bergstøl 2002; Haaland* et al*. 2002; Haaland 2004; 2007/2008; Barndon 2005; Giles 2007; Wright 2019; Nión-Álvarez 2022*), should probably be expected, especially in the area of the anvil, one of the most important and emblematic of the blacksmith's tools (*e.g., Njoku 1991.207; Giles 2007.406; Haaland 2008. 92*).

Significantly, establishing the proximity of the micromorphological blocks to the probable location of the anvil and interpreting this micro-stratigraphic sequence in relation to blacksmithing was only possible by integrating the results of micromorphological and micro-artefact analyses. While the microscopic analysis of the vertical floor sequence is highly informative about the floor construction and maintenance practices on its own, it provides, in the particular case of the Pungrt site, only limited information about distinct activities, which leave an imprint across the floor surface (compare *Milek, Roberts 2013.1863* for a contrasting conclusion on a site in a different environmental setting). In general, various types of micro-refuse, which are present in significant quantities across the horizontal floor plane, are rarely captured in vertical thin sections. Perhaps the most striking example of the disparity between these two micro-archaeological methods is provided in the case of micromorphological samples Ig 3 and 4. They were located in the area of Room A with the highest concentration of hammerscale (Figs. 2,18.A), which was absent in thin sections. Notwithstanding the occasional occurrence of soot (*e.g.,* SU 2064.3; *Gruškovnjak* et al*. 2024.Fig. 5.B*), suggesting the proximity of the fire installation, the floor surfaces appear 'clean' as so often observed in micromorphological analyses of house floors (*e.g., Karkanas, Efstratiou 2009; Matarazzo* et al*. 2010; Milek 2012*). This is due to two reasons. On the one hand, various effective cleaning techniques and refuse management strategies employed within the buildings tend to keep the floor surfaces clean. Even more importantly, however, the lack of micro-refuse material within thin sections tends to reflect the significantly different effectiveness in capturing micro-artefacts distributed across a surface with discrete versus continuous sampling, a methodological issue more commonly discussed in survey archaeology (*e.g., Miller 1989; Gruškovnjak 2017.53–55*).

To elaborate, each micromorphological sample represents a discrete point within a continuous horizontal plane of the examined floor surface and has, as such, a very low probability of capturing micro-artefacts distributed across that plane, while the horizontally continuous micro-refuse sampling is well suited for this purpose. Therefore, the absence of micro-refuse trampled into the floor surfaces in thin sections should not be interpreted as evidence of the absence of such remains or as an indication of a limited range of activities within the building (*e.g., Matarazzo* et al. *2010. 462*).

At the same time, it is important to note that the micromorphological sampling in the vertical plane offers in-depth information on the spatial and temporal relationships between the individual floor (micro) layers, which micro-refuse analysis cannot provide on its own. In the particular example of Building 24, micromorphology demonstrated the presence of (at least) seven consecutive (sub)millimetre-thick skims, which coated the silty clay floor in Room A. With such microlayers regularly going undetected in the field (as was also the case at Pungrt), and with currently available field methods unable to provide for the continuous micro-refuse sampling of thin finishing coats and washes, the micro-refuse assemblages inadvertently tend to provide information on various distinct activities within much coarser temporal frame, which homogenises the micro-artefact data across a number of the subsequent floor microlayers. Despite this currently unresolved methodological issue and

despite the discrepancy in the temporal resolution of the two analytical methods, we strongly advocate for the continuous sampling of the entire floor surfaces (in contrast to *Hodder, Cessford 2004*), in order to gain a distinct set of data which would have been unobtainable through the micromorphological sampling alone. In fact, we contend here that the integration of micromorphological (*i.e.* vertical) and micro-refuse (*i.e.* horizontal) sampling is necessary within the household and settlement archaeology, in order to obtain the optimal set of micro-archaeological data.

Interpretations of household activities and the use of space

A comparison of the macro- and micro-artefact assemblages has shown that the only *in situ* piece of the household inventory left within the building, *i.e.* the only piece of *de facto* refuse (*Schiffer 1996.89–97; LaMotta, Schiffer 1999.22*), was the ceramic vessel (SF 2007, Fig. 7.14) set into the floor in Room A (Fig. 2). Apart from this, the building's interior was practically devoid of any large artefacts or large pieces of refuse. Most of the discovered and identified materials in the building were smaller than 6.3mm, with the majority falling into the 2–4mm size fraction (Tab. 4), which is clear evidence of the regular cleaning of the building's interior. With all the larger pieces of refuse related to activities within it intentionally removed, only tiny fragments that escaped cleaning techniques and became trampled into the floor were left behind (*LaMotta, Schiffer 1999.21*). These tiny pieces represent residual primary refuse (see *Tani 1995.236*) produced by daily or regularly recurring activities within the building throughout its use life.

At the end of the building's use life, all large artefacts and pieces of equipment, except for the vessel set into the floor, would have been taken out of the house, as demonstrated, for example, by the comparison between the lithic macro- and micro-assemblages. Not a single stone artefact was present in the macro-assemblage (Fig. 8), while all the main types of stone tool raw materials documented elsewhere across the settlement were identified within the analysed micro-assemblage (Tab. 3), indicating that all the typical stone tool types were regularly used inside the building throughout its use-life.

In a similar vein, recurrently used materials and regularly occurring activities were reflected only in the micro-assemblage, while the macro-assemblage represented only refuse related to the very end of the building's use when previously regular cleaning practices were no longer maintained and its interior was systematically emptied. The two temporal scales associated with the micro- and macro-assemblage are, therefore, very different, with the first reflecting the entire use-life of the building, and the second encapsulating only a short period related to its abandonment. This clearly demonstrates that using macro-artefact assemblages to identify activities within buildings and functionally evaluate them is highly problematic and may lead to erroneous interpretations (see *Tani 1995.244,247; LaMotta, Schiffer 1999*). It also points to the fact that macro-artefact and micro-artefact data are not as complementary as often suggested (see *Dunnell, Stein 1989.31; Sherwood* et al. *1995.431; Sherwood 2001.328*).

In the present case, for example, the building would have been interpreted as purely domestic based on the macro-assemblage, when, in fact, a blacksmith's workshop operated within it. A sole piece of pottery, a fragment of a tuyere (Fig. 7.13) might have suggested blacksmithing. Regardless, a single artefact would not have sufficed on its own to unambiguously identify Room A as a blacksmith's workshop. On the one hand, tuyeres may have been used in either smithing or smelting and are therefore broadly related to both types of metallurgical activities (*e.g., Tylecote 1981*). On the other, the object suffers the same drawback as all other macro-artefacts recovered by reflecting only a short and atypical time at the end of the building's use.

Even in the rare case when the macro-artefact assemblage would have represented the primary refuse reflecting regularly recurring activities (*e.g.,* the ceramic vessel SF 2007), they would have provided information only about a limited range of these, given that some produce material traces only in the micro-artefact size range (see also *Dunnell, Stein 1989.33–34*). Hammerscale, fish scales, and archaeobotanical remains, for example, represent distinct finds produced by anthropogenic activities only at the micro-scale. Furthermore, the majority of environmental data, including micromammal, mollusc and insect remains, is also accessible only at the micro-level.

Further differences exist between the two datasets. The present analysis demonstrated that with the decreasing scale, the number of material types increases (Tab. 4). The increased heterogeneity can be attributed to at least two different factors. First, as larger heterogeneous materials break down into increasingly smaller

pieces, the variability within the original material causes its fragments to become progressively different (see *Dunell, Stein 1989.35*). At the micro-scale, they can no longer be recognized as belonging to the same heterogeneous material but become so different that they are identified and classified as discrete types. A distinct example of such fragmentation principle in Building 24 would have been provided by the clinker formed at the bottom of a smithing hearth, which could have potentially broken down into different types of slag and burnt, vitrified or sintered clay or even fine pottery and daub (see *e.g., Crew 1996; Serneels, Perret 2003; Miller, Killick 2004; Dunster, Dungworth 2012; Workman* et al. *2021*). Further examples of heterogenous materials, which may regularly be classified into several discrete micro-refuse types, include pottery with temper in its fabric, which could break down into both pieces with or without evidence of temper. If the original vessel was secondarily burnt, some fragments might also display properties (lighter hues, chalky feel) used to define daub in the present assemblage. Another example would be an unthoroughly and unevenly burnt bone that could break into calcined, burnt and unburnt pieces within the micro-refuse assemblage.

Related to this challenge is the fact that artefact types, which are clearly recognizable at the macro-scale, are no longer identifiable at the micro-level. For example, the ceramic vessels, at the macro-scale, can be easily classified into discrete forms and types with distinct functions. At the micro-scale, however, their fragments can no longer be correlated to certain forms or types (see also *Dunell, Stein 1989.35*). With most types of pottery micro-refuse identified at the micro-scale, it is not even possible to know whether they originated from a vessel, tool, or utensil or whether they were related to some construction material (compare Tabs. 2 and 3). Similarly, bones at the macro-level are easily taxonomically and anatomically identified, while at the micro-scale, such identification is mostly impossible. Other finds, which are produced only at the micro-scale (*e.g.,* hammerscale, fish scales and archaeobotanical remains in the particular case of Building 24), however, do not face the same challenge and consequently allow for straightforward identification. This is especially true of archaeobotanical remains, which can be very efficiently identified regarding plant taxonomy and anatomy (see *Andrič* et al. *2016. 70–72; Gruškovnjak* et al. *in prep.*).

The third group of materials is preserved only at the micro-scale. Despite the challenges with relating them to the macro-scale, they have the advantage of providing information on activities and processes which would have otherwise gone unnoticed. Take two types of lime identified at the micro-scale, for example. With only one of them identified at a macro-scale (Figs. 11.A–B,18.B–C), the microrefuse data provides evidence of at least two different lime-plaster recipes, as well as two different types of use of this material.

Due to the broader range of materials preserved at the micro-scale, the chances of discovering rare materials are higher. This is illustrated by a single piece of graphite schist (Fig. 11.C–E) identified in the micro-assemblage, a material entirely absent from the macro finds assemblage at the site. Consequently, the micro-evidence becomes even more significant, as it reveals the presence of an exotic raw material not available within the territory of modern Slovenia. A graphite-rich formation has been identified in the Tauern Window in the Austrian Central Eastern Alps and in the Ultrahelvetic Grestener Klippenzone along the northern edge of the Alps, outcropping north of Salzburg. This facies also extends into the Moravian Zone of the Bohemian Massif and is widespread in the Europe-derived Tisza and Dacia Mega-Units in the Pannonian region (*Schmid* et al. *2020*). It is found closest to the Pungrt hillfort in Austrian Central Eastern Alps, south of Salzburg (*Pestal* et al. *2009*), and in eastern Croatia (*Šinkovec, Krkalo 1994*). Therefore, the fragment of graphite schist discovered in Building 24 indicates long-distance trade with one of these areas. Given that the only currently known use of this raw material in the Early Iron Age in Slovenia was as a painting pigment in pottery production (see *e.g., Grahek, Košir 2018*), it appears that the inhabitants of the Pungrt hillfort, specifically those in Building 24, would have possessed working knowledge of pigment preparation and its subsequent application. This evidence suggests that the black and red coated ware, discovered at the site, may be of local production rather than imported (see *Vojaković* et al. *2024.Fig. 12.2*), or that the pigment may have been used for other, as yet undocumented purposes, such as painting on perishable materials. Alternatively, it might have served as a refractory material in metalworking contexts (*e.g., Bayley, Rehren 2007.47*), though there is currently no direct evidence for such a practice. As a valuable consumable, graphite schist would have been treated differently from more common materials, which were intentionally discarded and make up the bulk of the

settlement's macro-artefact assemblage (*Hayden, Cannon 1983.130–131; Tani 1995.239–240*). Consequently, the likelihood of its preservation in the macro-record is slim.

Nevertheless, most types of micro-refuse are represented in much higher quantities than the graphite schist. Combined with the high-resolution sampling grid, it is precisely this quality that gives them a significant advantage against the macro-assemblage data (see *Dunnell, Stein 1989.36–37*). As illustrated by this paper, even a simple characterization study comparing the densities and concentrations of various micro-refuse types provides an important insight into the behaviour related to waste management practices, road maintenance and the differences in activities between the road, building interior and the two rooms. Most notably, it allowed us to identify Room A as a blacksmith's workshop (Figs. 13,15–17). On the other hand, the kriging analysis of the hammerscale distribution, which helped us to identify the location of the anvil within the workshop (Fig. 18.A), demonstrates the micro-refuse potential for providing further detailed insights into the spatial structuring of activities within the building when more advanced analytical techniques are employed. In the next phase of our research, we will therefore seek to focus on reconstructing the structured use of space within Building 24, especially within the blacksmith's workshop, and deciphering the metallurgical processes and the technological knowledge used by the Early Iron Age blacksmiths at the Pungrt hillfort.

Conclusions

The analysis and comparison of evidence preserved at the macro- and micro-scales in phase IIb2 of Building 24 at the Pungrt hillfort provided crucial insights into the distinct strengths and weaknesses of different scales of observation, as well as the two micro-archaeological methods employed.

The macro-stratigraphic observations offered the context for understanding the household on a human scale, enabling us to identify the building's construction techniques and its internal division into three rooms. These macro-scale observations also highlighted variations in colour and texture across the floor in Room A, which informed the design of micro-archaeological sampling techniques and provided a framework for contextualising their results.

The multiscalar analysis of stratigraphic and artefactual data revealed that the building's abandonment was planned and related to the need for rebuilding. During the abandonment, the building's interior was thoroughly emptied, except for the vessel built into the floor of Room A and some pieces of pottery, burnt clay and animal bone. The macro-artefact assemblage from the building, therefore, correlated to the very short abandonment period and was not informative about the structured activities during its use-life. Data about these were, on the other hand, preserved in the micro-artefact assemblage. While neither macro-stratigraphic nor macro-artefactual evidence would have allowed us to suggest anything else but basic domestic activities within the building, micro-refuse analysis clearly showed that Room A was used as a blacksmith's workshop, and Room C mainly for domestic activities. Furthermore, the spatial distribution of hammerscale within the building allowed us to pinpoint where the anvil, one of the most important pieces of blacksmith's equipment, would have stood. The blacksmithing, as well as other aspects of activities, were completely invisible and undetectable at the macro-scale. These findings have important implications for studying activities in ancient households in general, and particularly in houses with their abandonment and rebuilding planned, which seems to be the case for most buildings at the Pungrt hillfort. Importantly, they also revealed that the macro- and micro-artefact data sets, which tend to be associated with different stages in the life cycles of the examined buildings, are not as complementary as often suggested.

The micromorphological analysis of the building's floors correlated and explained distinct variations observed during the macro-stratigraphic observations, revealing different floor construction materials, manufacturing techniques, and maintenance strategies. Significantly, it exposed the micro-stratigraphic floor sequence of (at least) seven subsequent coats and washes on top of the constructed, silty clay floor that were undetectable during excavation. The rhythmic alterations of contrasting, white and red skims located near the anvil in the area that experienced the heaviest wear, and also held symbolic significance within the smithy, suggest a combination of practical and possibly symbolically driven choices in the selection of floor renovation materials.

The spatial correlation between the described micro-stratigraphic sequence and the anvil, however, could only be achieved through the integration of micromor-

phological and micro-refuse analyses. Micromorphology alone was insufficient to detect distinct daily activities within the building. This highlights a significant drawback of this micro-archaeological method, one that is not often discussed. A similar gap in such discussions was observed regarding the much coarser temporal resolution of micro-refuse data compared to the floor sequences captured in thin sections. By demonstrating the complementary nature of both micro-archaeological methods in the study of the Early Iron Age smithy at the Pungrt hillfort, we strongly advocate for the integration of these methods within settlement archaeology in general, and household archaeology in particular.

Using such an integrated approach at Pungrt revealed that two distinct types of lime were used within Building 24. One type was employed as a floor plaster and floor coat, while the use of the second remains unclear at present. The discovery of lime at the hillfort was arguably one of the most significant findings of this study, especially considering that prior to the geoarchaeological research at Pungrt, lime plaster technology had not been identified at any prehistoric site in Slovenia. Although traditionally associated with Roman colonization, the integrated micromorphological and micro-refuse data from Pungrt demonstrated that lime technology was already in use in the core area of the south-eastern Alpine region – in what is now Slovenia – during the Early Iron Age.

In summary, integrating interdisciplinary data at multiple scales has significantly enhanced our understanding of distinct floor sequences, and household activities in Building 24. However, the value of this evidence extends beyond providing insights into the precise nature of building and manufacturing technologies, floor maintenance strategies and blacksmithing processes, as it also deepens our understanding of how symbolic and ritual aspects of one smithy (and its associated household) may be manifested at the material level. Thinking about Building 24 and the numerous processes associated with its life-cycle as multi-scalar allowed for different themes to come into focus, depending upon the analytical lens applied. In doing so we gained access to both ephemeral acts – such as the possible ritual spreading of bright red clay coat across part of the floor surface, which would have occurred within the experiential time of one day or less – and processes spanning much lengthier timescales, such as repetitive heating, forging, welding and quenching that left material traces on the floor surface and that may have been ongoing throughout the building's use-life. As cogently argued by John Robb and Timothy R. Pauketat (*2013*) in their discussion on scale and change in archaeological narratives about the past, history – in this case, the history of one Late Hallstatt smithy at the urban hillfort of Pungrt – was a multi-layered process that unfolded through different temporalities and relations.

Data availability
*The data used in the study is available online in the Repository of the University of Ljubljana (*Gruškovnjak *et al.* 2024*).*

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Recent wadi surveys shed additional light on the prehistoric occupation of the central Azraq Basin, Jordan

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ABSTRACT – *The Azraq Basin in Jordan's eastern desert features Qa' Azraq, a seasonally flooded mudflat, and a spring-fed wetland complex that was vital for hominin populations in prehistory. A recent survey focused on prehistoric lithic artefacts along wadis draining into Qa' Azraq, yielding over 900 artefacts. The chronologically diagnostic materials mainly originate from four Levantine prehistoric periods: the Lower, Middle, and Upper Palaeolithic, and Neolithic. While many artefact locations align with past findings, new discoveries alter our understanding of the basin's prehistory. The study concludes with an updated prehistoric overview and recommendations for future fieldwork.*

KEY WORDS – *Pleistocene; Palaeolithic; Acheulean; Levallois; wetlands; desert archaeology*

Nove raziskave v vadijih pojasnjujejo prazgodovinsko poselitev v osrednjem delu kotline Azraq v Jordaniji

IZVLEČEK – *Azraška kotlina v jordanski vzhodni puščavi obsega Qa' Azraq, sezonsko poplavno blatno ravnico, ter z izviri napajani močvirni kompleks, ki je bil v prazgodovini ključnega pomena za človeške populacije. Med nedavnim terenskim pregledom, osredotočenim na razporeditev prazgodovinskih kamnitih orodij vzdolž vadijev, ki se iztekajo v Qa' Azraq, je bilo dokumentiranih več kot 900 najdb. Artefakte lahko kronološko umestimo v štiri prazgodovinska obdobja v Levanti: zgodnji, srednji in pozni paleolitik ter neolitik. Čeprav se številna nova najdišča prekrivajo z že znanimi lokacijami, pa nova odkritja pomembno dopolnjujejo in ponekod spreminjajo dosedanje razumevanje prazgodovinske poselitve. Študijo zaključimo s posodobljenim pregledom prazgodovine območja in s priporočili za nadaljnje terensko raziskovanje.*

KLJUČNE BESEDE – *pleistocen; paleolitik; Acheulean; Levallois; močvirja; arheologija puščav*

Introduction

This paper reports the preliminary results of an archaeological survey project focused on hominin occupation of the central part of Jordan's Azraq Basin. The Azraq Basin is an endorheic depression of approximately 13 000km^2 (Fig. 1). More than 90% of the basin lies within the borders of Jordan, but it extends into south-

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ern Syria and northwest Saudi Arabia. At the centre of the basin is a large mudflat of roughly 75km^2, known locally as Qa' Azraq, which collects water during the rainy season. On the northeast edge of Qa' Azraq is a relatively small area of spring-fed wetlands. Beyond the wetlands and mudflat, the basin is a nearly barren desert.

The prehistory of the central Azraq Basin has been a focus of archaeological research for about a century (*Rollefson* et al. *2022*). For instance, in the 1920s, pilots of the Royal Air Force of the British Army, Group-Captain Lionel W. B. Rees and Flight-Lieutenant Peter E. Maitland, independently took photographs and made sketches of stacked stone structures that they saw from the air. These were described by the local Bedouin as *"the works of the old men"* (*Maitland 1927.197*), as they were thought to be ancient. Pedestrian reconnaissance among the features led to the observation that *"[f]lints of various ages are found near them, but no connection with the walls can be affirmed"* (*Rees 1929.398*). In 1937, John Waechter and Veronica Seton-Williams were made aware of potential prehistoric sites along Wadi Dhobai (now called Wadi Jilat) and undertook pedestrian surveys and small-scale excavations. They found several sites containing Epipalaeolithic materials (*Waechter* et al. *1938; Waechter 1947*). Archaeological research in the basin halted during World War 2 and did not restart until the 1950s.

Incidental discoveries were made in the 1950s in connection with an irrigation project (*Zeuner* et al. *1957; Kirkbride 1989*). Systematic archaeological research began in the 1970s with pedestrian surveys (*Stanley Price, Garrard 1977; Rollefson 1984*), and expanded in the 1980s with larger surveys and excavations (*Rollefson 1983; Betts 1988; Copeland, Hours 1988; 1989b; Garrard* et al. *1988a; Hunt, Garrard 1989*). Further survey and excavation work has been carried out on and off since then by a number of different teams (*Rollefson* et al. *1997a; 1997b; 2001; Cordova* et al. *2013; Ames, Cordova 2015; Akkermans, Brüning 2020; Smith 2020; Ames* et al. *2022*).

Artefacts recovered to date indicate that the basin was occupied during the Lower Palaeolithic, Middle Palaeolithic, Upper Palaeolithic, Epipalaeolithic, and Neolithic (*Stanley Price, Garrard 1977; Copeland 1988; Garrard* et al. *1988b; 1994a; Copeland, Hours 1989a; Jones, Richter 2011; Garrard, Byrd 2013; Richter, Maher 2013*). So far, there is limited evidence that humans lived in the centre of the basin during the final two periods of prehistory in the Levant, the Chalcolithic and Early Bronze Age (*Garrard* et al. *1994a; Garrard 2013*).

Research has traditionally focused on the Azraq wetlands and areas to their west, highlighting long-term reliance on this water source. Less attention has been given to the possibility of occupation in other areas, especially to the northeast. To explore this, we initiated a survey of wadis (seasonal streambeds) in the central Azraq Basin to collect lithic artefacts. We also noted the presence of stone tools among wadis in other areas, and suspected that these artefacts were at risk of damage or loss due to encroaching urban development unless there was an intervention. The project was thus expanded to include other wadis. Currently the project has four aims:

(1) To collate and analyse existing data pertaining to the prehistoric occupation of the basin, with particular emphasis on diachronic changes in behaviour in response to environmental change.
(2) To survey portions of the major wadis to identify and recover prehistoric lithic artefacts.
(3) To type and coarsely geolocate any such artefacts.
(4) To integrate the new survey data with existing data pertaining to the prehistory of the basin.

In this paper, we summarise the results of the first two field seasons of the project with a focus on how the chronologically diagnostic artefact types augment our understanding of the geographic distribution of evidence of occupation through time.

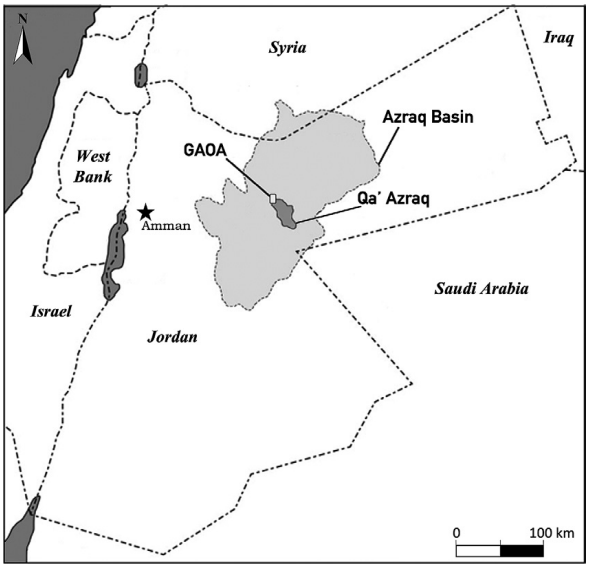

Fig. 1. Location of the Azraq Basin and other geographic features discussed in this paper. Figure redrawn and modified after Lisa A. Maher (2017.679). Figure created with Inkscape.

Background

The environmental setting

There is general agreement that geohydrological conditions have played a key role in the history of the occupation of the Azraq Basin by hominins (*e.g., Copeland 1988; Copeland, Hours 1989a; Garrard* et al. *1994a; Rollefson* et al. *1997b; Jones, Richter 2011; Cordova* et al. *2013; Richter, Maher 2013; Abed 2018; Ames* et al. *2022*). The basin is a distinct hydrological catchment that spans Jordan's Central and Northern Basalt plateaus and extends into southern Syria and, to a lesser extent, northwest Saudi Arabia (Fig. 1).

The geology of the Azraq Basin is a patchwork of igneous and sedimentary rocks (*Bender 1974; Abed 2018*). In multiple places, surficial alluvium is absent and the underlying formations of the Belqa Group, most notably the Muwaqqar Chalk-Marl, Umm Rijam Chert-Limestone, and Wadi Shallala Chalk, are exposed. Across the northern half of the basin, these formations are overlain by the large (*c.* 11 000 km^2) intracontinental Harrat Ash-Shaam basaltic field which is of Oligocene-Pleistocene age (*Al-Malabeh 1994; Ilani* et al. *2001; Cordova 2007*). Its local source is known as Jabal al-Druze.

At the centre of the Azraq Basin lies a mudflat, or *sabkha*, Qa' Azraq (Fig. 2). Qa' Azraq floods during the wet season, which typically starts in late November and finishes at the end of March (*Ames, Cordova 2015; Abed 2018*). In addition to the water that falls directly onto it, Qa' Azraq receives water from a number of wadis that drain the Azraq Basin (Fig. 3). The most notable of these wadis are Butm, Enoqiyya, Ghadaf, Hayat, Jilat, Kharanah, al-Masayil, Rattama, Rajil, and Usaykhim. The northern and western portions of the Azraq Basin receive more precipitation than the southern and eastern areas due to the influence of the Mediterranean Westerlies (*Cordova 2007*). Water percolates through fissures in the basalt and limestone and keeps the water table higher in the northwest. Because of these two factors, the wadis located to the north and west of Qa' Azraq have a longer duration of seasonal flow (*Enzel* et al. *2008; Abed 2018*).

The Greater Azraq Oasis Area (GAOA) is located along the northwestern edge of Qa' Azraq (Fig. 2). Considered a single geographic unit, it comprises the wetlands of the historic Druze Marsh and the recently rehabilitated Shishan Marsh (*Cordova* et al. *2013; Ames, Cordova 2015*). The Shishan Marsh is part of the modern

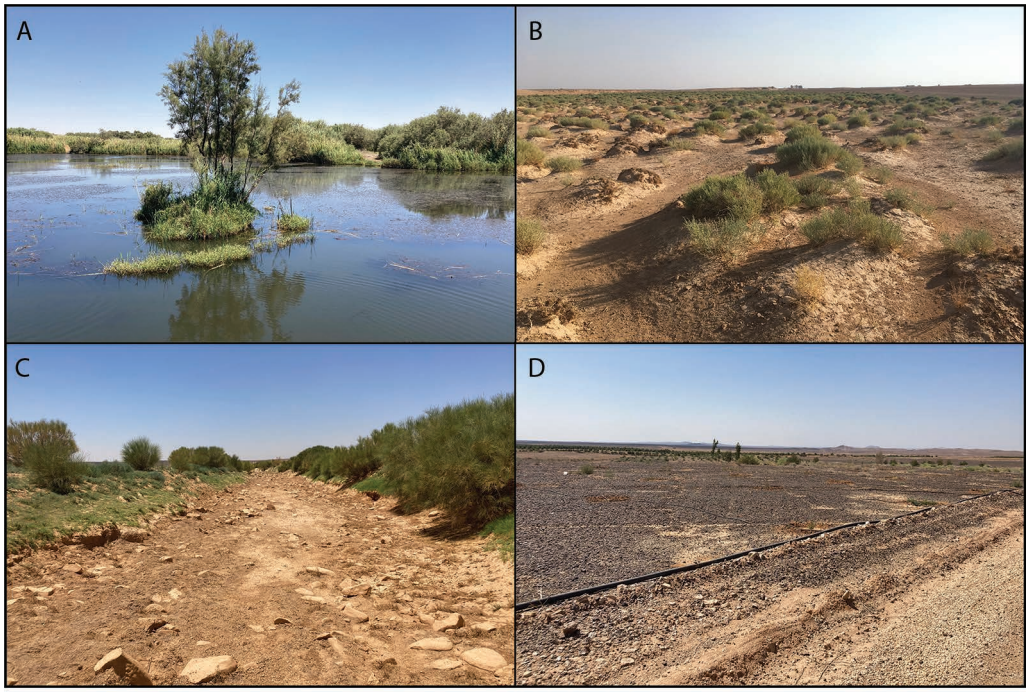

Fig. 2. The four main types of environment found in the central Azraq Basin. **A** ***Marshland. Shown is a restored portion of the Shishan Marsh, which is part of the Greater Azraq Oasis Area (GAOA).*** **B** ***salty mudflat. At the centre of the basin lies a mudflat known as Qa' Azraq. The photograph shows Qa' Azraq in the dry season. In the wet season, which typically starts in late November and finishes at the end of March, Qa' Azraq usually floods.*** **C** ***Wadi. The photograph shows part of Wadi Usaykhim, which is located to the southwest of the GAOA.*** **D** ***gravelly desert. Away from the GAOA, Qa' Azraq, and the wadis, the landscape is barren. This photograph was taken near the community of al-Masayil, northeast of the GAOA (photographs by JAB).***

Azraq Wetland Reserve, which was established in 1978 by the Royal Society for the Conservation of Nature. The marshes of the GAOA are fed by freshwater springs associated with an aquifer system contained in the Tertiary limestones and basalt (*Dottridge 1998; El-Naqa 2010*). In the wet season, the marshes occasionally receive water from the spillover of Qa' Azraq, which increases their size and salinity (*Al-Kharabsheh 2000; Cordova* et al. *2013*). In the dry season, the process reverses: the water of Qa' Azraq evaporates and recedes, and this reduces the amount and salinity of water in the marshes. The size and salinity levels of the marshes of the GAOA thus vary seasonally and in response to longer-term changes in regional climate.

The aquifer system that feeds the marshes of the GAOA is a key source of fresh water for the modern population of Jordan (*Nelson 1973; El-Naqa* et al. *2007; Abed 2018*). Large amounts of water began to be pumped from the Azraq Basin aquifer in the early 1960s to supply the rapidly growing cities of Amman and Irbid (*Fariz, Hatough-Bouran 1998*). The pumping led to a substantial drop in the water table and a rapid draining of the two marshes. They were both completely dry by the mid-1990s (*Fariz, Hatough-Bouran 1998*). A restoration effort led by the Royal Society for the Conservation of Nature has rehabilitated about 10% of the Shishan Marsh (*Fariz, Hatough-Bouran 1998*). There has been no attempt to do the same for the Druze Marshand it remains completely dry (*Cordova* et al. *2013*).

The plant and animal species one encounters in the centre of the Azraq Basin depends on where one is situated (Fig. 2), and extensive data on this have been collected over the last century (*Hemsley, George 1966; Nelson 1973; 1985; Hatough-Bouran, Disi 1991; Garrard, Byrd 2013*). The GAOA, especially the rehabilitated portion of the Shishan Marsh, supports a variety of aquatic plants, including reeds (*Phragmites australis, Arundo donax*), rushes (*Juncus* spp.), and cattails (*Typha angustata* and *Typha domingensis*) (*Al-Eisawi 1996; Woolfenden, Ababneh 2011*). The GAOA also supports more than 400 bird species. Among these are reed warblers (*Acrocephalus scirpaceus*), grey herons (*Ardea cinerea*), and numerous species of duck, which use the wetlands year-round. The GAOA is also utilised by several migratory species, the most noteworthy of which are white storks (*Ciconia ciconia*), European honey-buzzards (*Pernis apivorus*), great white pelicans (*Pelecanus onocrotalus*), and multiple species of gulls (*Nelson 1985*). In addition, a few mammal species can be found in the GAOA, most notably water buffalo (*Bubalus bubalis*), which were introduced in the 1990s in connection with the aforementioned restoration project. The nearby Shaumari Wildlife Reserve contains small populations of Arabian oryx (*Orynx*

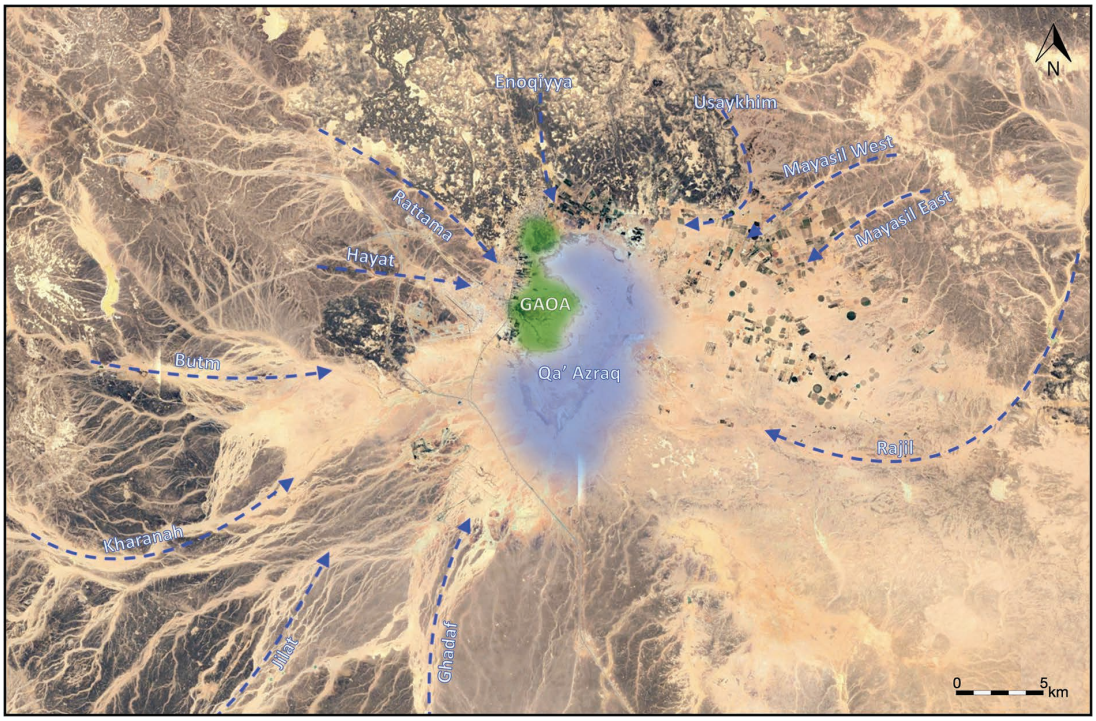

Fig. 3. Major wadi channels in the central Azraq Basin. Figure created with Inkscape with Google Earth as the base map.

leucoryx) and Arabian gazelle (*Gazella arabica*). These species likely would have roamed throughout the central Azraq Basin prior to the 20th century CE (*Clark 1978; Nelson 1985*).

Qa' Azraq and the wadis that empty into it support fewer plant and animal species than the GAOA. With regard to plants, Qa' Azraq and the wadis are dominated by halophytes, mainly *Ruppia* spp. and *Tamarix* spp. Some desert-adapted birds, such as larks (*e.g., Ammonmanes*), bustards (*e.g., Chlamydotis*), shrikes (*e.g., Lanius*), and warblers (*e.g., Acrocephalus*), are occasionally observed, as are some reptiles, most notably lizards (*e.g., Agama*, *Acanthodactylus*) and snakes (*e.g., Cerastes*, *Natrix*, *Malpolon*) (*Nelson 1985*). However, wild mammals are generally scarce, save for the occasional rat (*Psammomys obesus terraesanctae*), fox (*Vulpes vulpes arabica*), or golden jackal (*Canis aureus*) (*Nelson 1985; Pokines* et al. *2019*).

Away from the GAOA, Qa' Azraq, and the wadis, the central Azraq Basin is nearly barren (Fig. 2). What little flora and fauna exist is of the Saharo-Arabian type. Shrubs belonging to the Amaranthaceae family are the most abundant plants (*Cordova 2007*). Wild animals, especially those in the medium and large body size categories, are very rarely encountered. It is important to note that this barrenness is thought to be at least partly a consequence of human activity in the historic period, especially over-grazing and agricultural practices (*Long 1957; Nelson 1973; 1985*). As such, the whole of the central Azraq Basin was probably more hospitable in prehistory than it is today.

Prehistoric occupation of the central Azraq Basin

As noted earlier, there is evidence that the central Azraq Basin was occupied during the seven main periods of Levantine prehistory (Fig. 4). Due to the vast area and range of time periods involved, the distribution of occupation for each period can only be briefly summarised (Tabs. 1 and 2). It is important to note that the region is hydrologically dynamic and both surface and buried materials can be exposed, transported, and covered by flooding events. Therefore, the absence of evidence is not assumed to be evidence of absence.

The Lower Palaeolithic (LP) is well represented in the central Azraq Basin. So far, no Lomekwian or Oldowan material has been recovered, but plenty of evidence

Site/survey location	Period represented	Type of recovery	Key references
'Ain el-Beidha (White Spring)	LP, MP, UP, EP, Neolithic	Survey	*Copeland 1989d; Garrard, Byrd 2013*
'Ain Soda and 'Ain Qasiyya	LP, MP, EP, Neolithic	Survey and excavation	*Rollefson* et al. *1997a; 1997b; 2006*
C-Spring	LP, EP, Neolithic	Excavation	*Garrard* et al. *1987; Copeland 1989a; 1989e; 1991; 1988b; Hunt, Garrard 1989*
Druze Marsh (2, 3, 8, 11)	LP, MP, UP, EP, Neolithic	Excavation	*Cordova* et al. *2013; Ames* et al. *2014; Ames, Cordova 2014; 2015*
D-Spring	LP	Excavation	*Copeland 1989e*
E-Spring	LP	Excavation	*Copeland 1989e*
Lion Spring ('Ain el-Assad)	LP, Neolithic	Excavation	*Harding 1967; Rollefson 1980; Copeland 1989c; Turnbull 1989*
Shishan Marsh 1	LP	Excavation	*Nowell* et al. *2016; Pokines* et al. *2019; Beller* et al. *2020; Ames* et al. *2022; Beller 2023; Beller* et al. *2024*
Wadi Butm	LP, MP, EP	Survey	*Copeland, Hours 1989b*
Wadi Enoqiyya	LP, MP, UP, EP, Neolithic	Survey	*Hours 1989; Bisson et al. 2014*
Wadi Jilat	MP, UP, EP, Neolithic, Ch/EBA	Survey	*Garrard* et al. *1988a, 1988b*
Wadi Kharanah	LP, MP, EP, Neolithic, Chalcolithic	Survey	*Stanley Price, Garrard 1977; Copeland, Hours 1989b*
Wadi Rajil	LP, Neolithic, Ch/EBA	Survey	*Copeland 1989d; Akkermans, Brüning 2020*
Wadi Rattama	LP, MP, UP, EP, Neolithic	Survey	*Copeland, Hours 1989b*
Wadi Usaykhim	LP, MP, UP, EP, Ch/EBA	Survey	*Garrard, Byrd 2013; Smith 2020*
Wadi Uweinid	LP, MP, UP, EP, Neolithic, Ch/EBA	Survey	*Garrard* et al. *1977; Rollefson 1984; Copeland, Hours 1989b*

Tab. 1. Previously documented archaeological occurrences in the central Azraq Basin that are discussed in the text.

of Acheulean occupation has been found in and around Qa' Azraq and the GAOA (*Beller, Richardson in press*). In the 1950s, an irrigation project on the southern margin of the GAOA inadvertently uncovered a number of dense concentrations of Acheulean artefacts. Subsequent salvage excavations and later formal excavations in the 1970s and 1980s identified a cluster of sites in the vicinity. Surveys in the 1970s and 1980s identified Acheulean artefacts in wadis Butm, Enoqiya, Kharanah, Rajil, Rattama, and Uweinid (Fig. 3).

During the 1990s and subsequent decades, further excavations in the GAOA, in both Druze and Shishan marshes, identified *in situ* layers containing Acheulean artefacts. Diagnostic artefacts recovered include handaxes, cleavers, choppers, and thick blades (*Rollefson 1980; 1984; Copeland 1989a; 1989b; Copeland, Hours 1989b; Hours 1989; Rollefson* et al. *1997a; Ames, Cordova 2015; Nowell* et al. *2016*). These are reminiscent of the Late Acheulean elsewhere in the Levant. Radiometric dates obtained at Shishan Marsh 1 have provid-

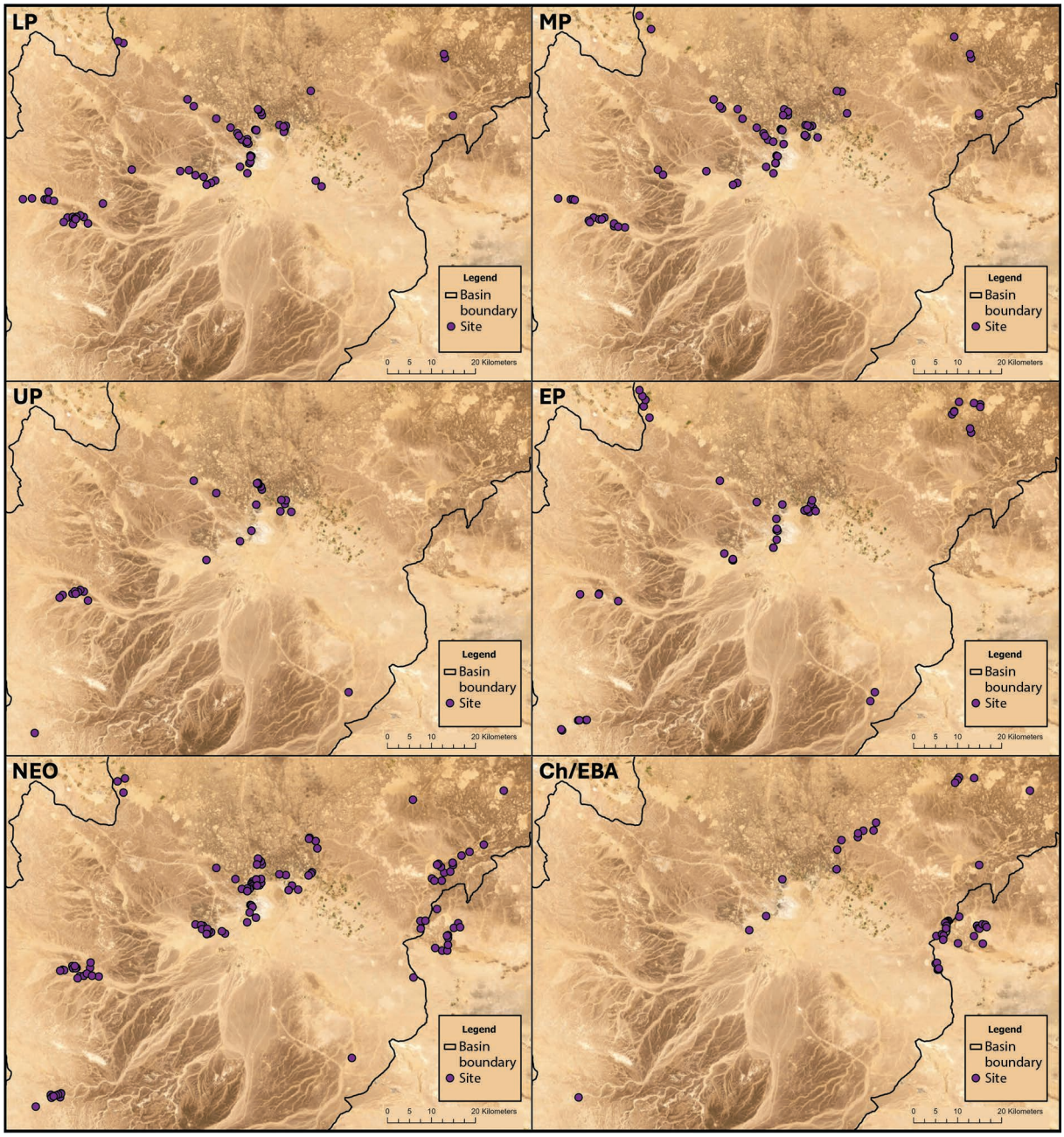

Fig. 4. Distribution of sites in the central Azraq Basin. Site locations are based on codes and coordinates in the publicly available literature and MEGAJordan.org. Sites vary in that a dot may represent a small surface scatter or an excavated in situ locality. Basin boundaries georeferenced and modelled after Ali El-Naqa (2010.45). Figure produced with ArcGIS.

ed a time range of *c.* 300–120 ka BP for the Acheulean in the GAOA (*Nowell* et al. *2016; Ames* et al. *2022*), but it is possible that Acheulean assemblages elsewhere in the basin extend back as far as 700 ka BP (*Rollefson 1984*).

The Middle Palaeolithic (MP) is not as well represented as the LP in the central Azraq Basin. MP artefacts have been discovered in some buried contexts in the GAOA, in both the Druze and Shishan marshes (*Rollefson* et al. *1997a; 1997b; Ames* et al. *2014; Ames, Cordova 2015*). They have also been recovered as surface finds in, and along the banks of, several of the larger wadis, including wadis Butm, Enoqiyya, Jilat, Kharanah, Rattama, and Uweinid (*Copeland 1988; Garrard* et al. *1988b; Copeland, Hours 1989b; Byrd, Garrard 2013*). Wadi Enoqiyya is particularly noteworthy in this regard, as it has yielded in excess of 6000 artefacts that have been assigned to the MP (*Hours 1989; Bisson* et al. *2014*). Diagnostic MP artefact types that have been found in the central Azraq Basin include Mousterian points, Levallois points and flakes, denticulates, sidescrapers, and endscrapers (*Copeland, Hours 1988; 1989b; Hours 1989; Bisson* et al. *2014*). These are thought to mostly belong to the classic Levantine Mousterian, which is currently dated to *c.* 100–50 ka BP (*Copeland 1988*). The recovery of a few large, elongated MP artefacts may indicate that the region was occasionally occupied during the early MP.

The Upper Palaeolithic (UP) is poorly represented in the centre of the basin. In comparison to the preceding two periods of prehistory, very few diagnostic UP stone tools have been recovered, and most of those that are known were recovered as surface finds. The artefacts include endscrapers, burins, bladelets, and microliths (*Garrard* et al. *1988b; Copeland 1989d; Hours 1989; Garrard, Byrd 2013*). It is generally assumed that the UP of the central Azraq Basin may be of similar age to the UP elsewhere in the Levant, which is *c.* 50–20 ka BP (*Belfer-Cohen, Goring-Morris 2017*), based on the morphological characteristics of the surface finds. However, the earliest radiometric dates for intact layers in the centre of the basin are 30–24 ka BP (*Garrard* et al. *1994b; Byrd, Garrard 2017*) and 43–23 ka BP (*Ames, Cordova 2015*), suggesting slightly later occupation, generally accepted as younger than 40 ka BP. So far, diagnostic artefacts have been found mostly to the north of Qa' Azraq and the GAOA. Specifically, they have been discovered in, and along the banks of, wadis Enoqiyya and Uweinid, and around an isolated spring called 'Ain el-Beidha (*Garrard* et al. *1988b; Copeland 1989d; Hours 1989; Garrard, Byrd 2013*). Small numbers of UP artefacts have also been found along the wadis Jilat and Kharanah (*Stanley Price, Garrard 1977; Copeland, Hours 1989b*). To date, no diagnostic UP artefacts have been reported from Wadis Butm or Wadi Rajil. The extent of occupation in certain areas by UP groups is thus unclear.

The Epipalaeolithic (EP) is better evidenced than the UP, and the sites in the central Azraq Basin have been dated to 23–12 ka BP (*Richter* et al. *2013; Byrd, Garrard 2017*). Diagnostic EP artefacts include nongeometric blades and bladelets, single-platform bladelet cores, and Geometric Kebaran lithics (*Byrd 1988; Garrard, Byrd 1992; Maher* et al. *2012*). A number of buried sites in and around the GAOA have yielded such artefacts. For instance, a sitting burial dating to the EP has been found at 'Ain Qasiyya in the Shishan Marsh

Period	Chronology	Developments in lithic technology
Lower Palaeolithic	Middle Acheulean: 700-400 ka BP Late Acheulean: 400-250 ka BP	Azraq cleaver, 'heavy-duty' types
Middle Palaeolithic	Early MP: 250-100 ka BP Late MP: 100-50 ka BP	Elongated Levallois elements, Mousterian points, prepared-cores
Upper Palaeolithic	30-23 ka BP	Burins, microliths, bladelets, prismatic blades
Epipalaeolithic	23-12 ka BP	Geometric blades, lunates, microburins; regular backing, truncation, basal modification, Ouchtata retouch
Neolithic	8000-5500 BCE	Celts/axes, sickle inserts, large projectile points, drill bits, burins
Chalcolithic/Early Bronze Age	4500-2000 BCE	Tabular scrapers, Canaanean blades, basalt vessels

Tab. 2. Summary of the date ranges for, and technological developments associated with, the main periods of prehistory in the central Azraq Basin. The date ranges are synthesised from multiple sources, including Christopher J. H. Ames* et al. *(2022), Christopher J. H. Ames, Carlos E. Cordova (2015), Bernard Müller-Neuhof (2014), Andrew N. Garrard* et al. *(1994b), Tobias Richter* et al. *(2013), and Gary Rollefson (2019). It is important to keep in mind that the beginning and end dates for the periods may differ from their equivalents elsewhere in the Levant.

(*Richter* et al. *2010*), and a further two sites have been excavated on the periphery of the wetlands, Ayn Saratan (Azraq 18) and Bawwab al-Ghazal. Ayn Saratan yielded a substantial faunal assemblage, secondary human burials, ground stone tools, and Helwan lunate tools (*Garrard 1991*). Bawwab al-Ghazal has been described as a 'Natufian camp' (*Rollefson* et al. *1999.3*), as hearths have been found at the site. Clusters of buried EP sites are found upstream Wadi Kharanah, where non-lithic evidence includes activity areas and the remains of structures and hearths, such as at Kharanah IV (*Maher* et al. *2012*). Dense surface scatters of diagnostic EP artefacts have been found around 'Ain el-Beidha and the mouth of Wadi Usaykhim, northeast of the GAOA and southwest of it, upstream along wadis Jilat and Kharanah. Surficial evidence of ephemeral occupation has also been found along the wadis Butm, Rattama, Enoqiyya, and Uweinid (Fig. 3) (*Copeland, Hours 1989b; Garrard, Byrd 1992*).

Evidence of Neolithic occupation of the central Azraq Basin is plentiful. The spatial distribution of the sites is similar to that of EP sites. Surveys have found diagnostic Neolithic artefacts along the southern margins of the wetlands, the southern channels of Wadi Jilat and Wadi Kharanah, the northeastern channel of Wadi Rajil, and the northern channel of Wadi Enoqiyya (*Garrard* et al. *1994a; MEGAJordan.org 2024*). These artefacts include blades and bladelets, which tend to dominate the assemblages, and naviform cores (*Garrard* et al. *1994a*). Smaller specialised tools, such as truncation burins and drill bits on burin spalls continue throughout the Neolithic (*Garrard* et al. *1994a*). Excavations within the GAOA have found intact layers with Neolithic material and have revealed many small Neolithic sites along Wadi Jilat (*Garrard* et al. *1994a*). These sites have yielded ground stone tools, figurines, and the remains of domesticated fauna, as well as evidence consistent with the presence of curvilinear, semi-subterranean dwellings (*Garrard* et al. *1986; Wright 1993; Garrard, Byrd 2013*). The few Neolithic sites that have been radiometrically dated occur on the perimeter of the central Azraq Basin, such as among the Wadi Jilat cluster at 7600–5600 BCE (*Garrard* et al. *1994b*).

The Chalcolithic and Early Bronze Age are the last two prehistoric periods in the southern Levant (*Rowan, Golden 2009; Regev* et al. *2012; Fall* et al. *2022*). To date, only a few indications of occupation during these periods have been found in the central Azraq Basin. Due to the many similarities in the material culture associated with these two periods, particularly the lithics, previous work has usually discussed them together. We will follow this precedent and refer to the two together as the Ch/EBA. Most of the evidence of Ch/EBA occupation is stacked stone structures, particularly along Wadi Usaykhim and across the southern Black Desert (*Betts 1986; 1988; Smith 2020*). These are locally known as the 'works of the old men' or commonly in the literature as 'desert kites' (*Maitland 1927; Kirkbride 1946*), and functioned as hunting traps (*Holzer* et al. *2010; Betts, Burke 2015*). Overlapping Ch/EBA occupation is found to the east by Wadi Rajil, where cortical tools, burials, and small dwellings were discovered among Jebel Qurma (*Akkermans, Brüning 2020*). In the south, artefactual evidence is sparse. A few sites along Wadi Jilat yielded lithics and potsherds indicative of Ch/EBA occupation (*Garrard, Byrd 2013*). Currently, the date range for the Ch/EBA in the central Azraq Basin is 4500–2000 BCE (*Müller-Neuhof 2014*).

Methods

The survey was conducted over two weeks in 2022 and one week in 2023. Portions of Wadi Enoqiyya, Wadi Hayat, and Wadi Rattama were surveyed in 2022, while sections of Wadi Butm, Wadi al-Masayil East, Wadi al-Masayil West, and Wadi Usaykhim were surveyed in 2023.

We surveyed a total lenght of 3550m across the seven wadis during the two field seasons. The portions of the wadis we targeted were divided into 50m sections with the aid of a retractable measuring tape and stakes. The latitude and longitude of each stake were recorded with a Garmin inReach SE+ handheld GPS (WGS84 system). Each section was walked for 30 minutes, and every stone object suspected of being an artefact was collected in a pail.

The artefacts were typed according to a combination of widely used general Palaeolithic typology (*Debénath, Dibble 1993*), standard regional typologies specific to the Levant (*Rosen 1997; Shea 2013*), and local typologies of the Azraq Basin (*Rollefson 1984; Copeland 1988; Garrard, Byrd 1992; Byrd, Garrard 2013; 2017*). An emphasis was placed on identifying artefacts that were chronologically diagnostic in the region (Tab. 2). A conservative attitude to period assignment was adopted during the analysis.

In this report, we focus on the broad types and general periodisations of the assemblages, as there is insuffi-

cient space to discuss the minutiae of their techno-typological characteristics. For instance, handaxes are mentioned, but their morphologies (*e.g.*, discoid, lanceolate) are not discussed. However, we do highlight Levallois elements because this technology is diagnostic of the MP. Other reports will focus on the technology of the artefacts and the different phases of each period they may represent (*e.g., Beller* et al*., in press*).

Wadi	LP	LP-MP	MP	Neolithic	UP	UP-EP	EP	Ch/EBA	Unknown	Total	Metres surveyed
Butm	39	17	14	3	2	4			78	157	1000
Enoqiyya		1	30		18	28	1	3	62	143	100
Hayat	24	2	5	2	5				28	66	150
Masayil (east)	17	11	3						26	57	400
Masayil (west)	21	10	14	3	2	2			46	98	400
Rattama	78	19	18	2	7	2	1		141	268	1000
Usaykhim	33	1	33	2	5	2			76	152	500
Total	212	61	117	12	39	38	2	3	457	941	3550

Tab. 3. Summary by wadi and time period of the number of lithic artefacts recovered during the fieldwork reported here.

While prehistoric artefacts are known to be abundant throughout the region, we collected all lithic artefacts, even if they represented historic periods (*e.g.*, large geometric sickles from the Middle-Late Bronze Ages). The artefacts are currently in the care of the Department of Antiquities of Jordan.

Results

We collected a total of 941 lithic artefacts during the fieldwork reported here (Tabs. 3,4; Table 4 see below). Among the artefacts we recovered are types that are diagnostic of single periods (Figs. 5–7). We also found some types that are indicative of one or other of two periods (*e.g.*, LP-MP, UP-EP). Indeterminate UP-EP material has previously been referred to as 'Late Palaeolithic' (*Byrd, Garrard 2013*), but here we will use UP-EP. We did not find any lithic artefacts indicative of any historical period.

Not surprisingly, given that the artefacts were found in and along the banks of wadis, many of show evidence of having been extensively rolled during fluvial transport. The physical weathering has reduced or erased scars and evidence of retouch. In addition, chemical weathering is evidenced by patinas on flatter portions of many artefacts. Detailed descriptions of the raw materials, patinas, origins, and conditions of the artefacts will be provided in future reports.

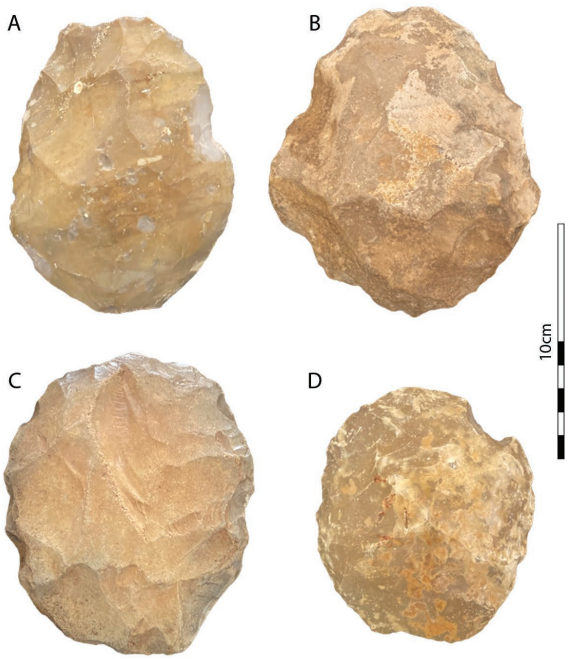

Fig. 5. Examples of Lower Palaeolithic handaxes.* A *Wadi Rattama.* B *Wadi Rattama.* C *Wadi Hayat.* D *Wadi Butm (photographs by JAB).

Wadi Butm

We surveyed a 1000m lenght of Wadi Butm. The survey sections were dispersed along the wadi in an effort to capture the variability in clast size along the wadi's length. The area surveyed spanned from west of the bridge on Highway 40 downstream toward Qa' Azraq. This part of Wadi Butm was last surveyed by archaeologists in the 1980s (*Copeland, Hours 1989b*).

We collected a total of 157 artefacts in Wadi Butm, 58 of which could be assigned to a time period. We assigned the majority of the diagnostic artefacts to the LP (n= 39). These included nine handaxes, two choppers, and four biface preforms. Several large bifacially reduced pieces have similarities with the heavy-duty types outlined by Lorraine Copeland and Francis Hour (*1989b*). Fourteen of the typeable artefacts were assigned to the MP. These were mainly relatively small formal tools, such as various well-made scrapers, and Levallois cores and flakes. Occupation of Wadi Butm during the UP is suggested by two thumbnail scrapers, which are among the diagnostic artefacts of the Levantine UP, al-

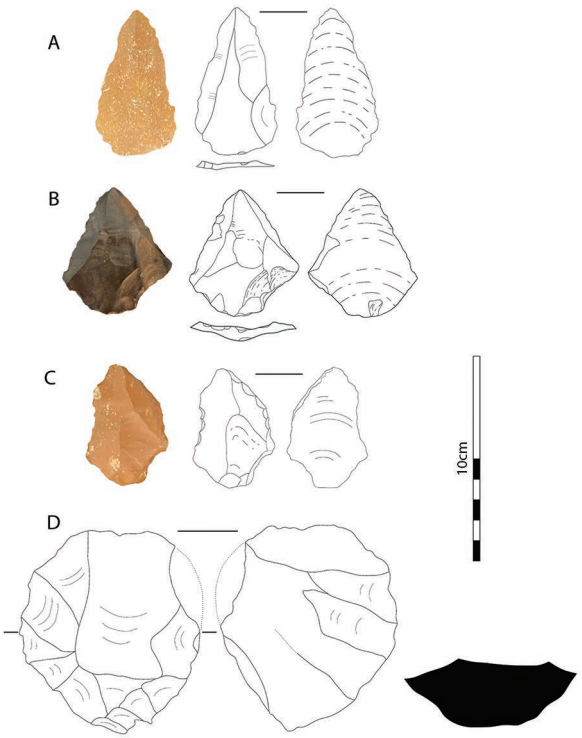

Fig. 6. Examples of Middle Palaeolithic artefacts.* A *Levallois point from Wadi Enoqiyya.* B *Levallois point from Wadi Usaykhim.* C *convex scraper from Wadi Enoqiyya.* D *prepared core from Wadi Rattama (photographs by JAB).

though these are also present during the EP. We also recovered several unretouched prismatic blades that could date to the UP or EP. We found three diagnostic Neolithic artefacts in Wadi Butm. These are two picks/chisels, and are consistent with John J. Shea's (*2013. 235*) description of these artefact types, as they also retain a semi-triangular-trapezoidal cross-section, and an adze. The 78 non-diagnostic artefacts we found in Wadi Butm are mostly flake cores, and primary and secondary flakes, and almost all are unretouched.

Wadi Enoqiyya

Two 50m sections of Wadi Enoqiyya were surveyed. We began at the bridge on Highway 40 that crosses the wadi and moved downstream. This part of Wadi Enoqiyya had previously been surveyed in the late 1980s (*Hours 1989*) and briefly revisited in the late 2000s (*Bisson* et al. *2014*).

We collected a total of 143 artefacts. Fifty-two of these could be assigned to a time period with a reasonable degree of confidence. We assigned most of the diagnostic artefacts to the MP (n=30). The most noteworthy of these are five Levallois points, a Levallois blade, and 14 Levallois flakes. Eighteen artefacts could be assigned as UP, of which three are prismatic blades and two are endscrapers. We also found a number of artefacts that can be assigned to either the UP or the EP. These include fractured unretouched bladelets, flake and bladelet cores, and fractured prismatic blades. In addition, three tabular scrapers, indicative of the Ch/EBA were discovered. The remaining 62 non-diagnostic artefacts are mostly cores and primary and secondary flakes. Many of the flakes are unretouched.

Wadi Hayat

We surveyed three 50m sections of Wadi Hayat. We began where the wadi is interrupted by a modern quarry next to Highway 35 and moved upstream from there. We believe our visit to Wadi Hayat was the first time it had been surveyed by archaeologists.

We collected 66 lithic artefacts in Wadi Hayat and were able to assign 36 of them to time periods. The majority of the typeable artefacts (n=24) were from the LP. Several of them have morphological similarities with the heavy-duty types outlined by Copeland and Hours (*1989b*). These include 13 handaxes, five choppers, and four large bifacially reduced pieces. Among the diagnostic MP artefacts we found were two prepared cores and two points. The five UP types include two burins, a blade core and a bladelet core. Two large points/knives represent the only Neolithic artefacts. The 28 artefacts that could not be assigned to a time period are mostly cores and primary and secondary flakes.

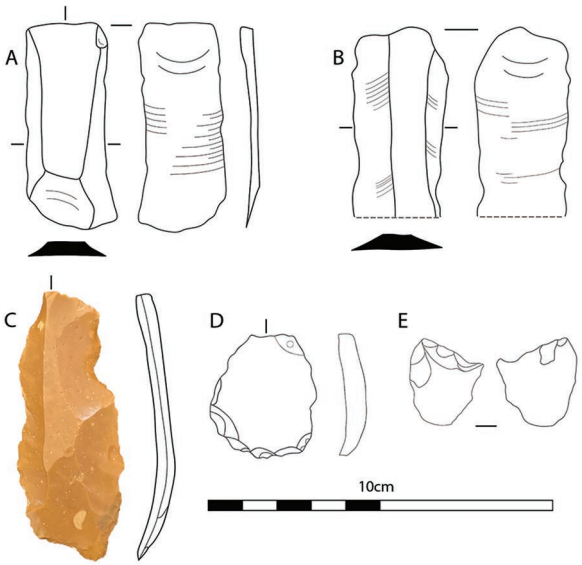

Fig. 7. Examples of Late Palaeolithic artefacts:* A-B *UP-EP prismatic blades from Wadi Usaykhim;* C *EP burin on straight oblique truncation;* D *UP thumbnail scraper from Wadi Butm;* E *EP microburin from Wadi Rattama (photographs by JAB).

Wadi al-Masayil east

We surveyed a 400m lenght of Wadi al-Masayil East. The survey sections were dispersed along the wadi in an effort to capture the variability in clast size along the wadi's length. As far as we have been able to determine, Wadi al-Masayil East had not been surveyed by archaeologists prior to our visit.

A total of 57 lithic artefacts were collected in Wadi al-Masayil East. Twenty of these could be assigned to a time period. We assigned most of the diagnostic artefacts (n=17) to the LP. These artefacts are large and include eight handaxes, three choppers, and three bifacially reduced pieces. An MP presence in Wadi al-Masayil East is best attested by two Levallois flakes. We also recovered a number of artefacts that could be either LP or MP, such as a number of side scrapers and transverse scrapers. The 26 artefacts that could not be assigned to a time period are mostly cores, fractured blades, and primary and secondary flakes.

Wadi al-Masayil west

We surveyed a 400m lenght of Wadi al-Masayil West. Again, the survey sections were dispersed along the wadi in an effort to capture the variability in clast size along the wadi's length. To the best of our knowledge, we are the first archaeologists to have looked for prehistoric artefacts in Wadi al-Masayil West.

We collected a total of 98 lithic artefacts, and were able to assign 26 of them to time periods. We assigned 21 of the diagnostic artefacts to the LP, which makes it the best represented prehistoric period in the wadi. These include seven handaxes, nine large bifacially reduced pieces, and three large notches. We recovered a single Levallois core and several well-made formal tools that are indicative of an MP presence in Wadi al-Masayil West. We found a burin and point/knife from the UP, and two prismatic blades that could be either UP or EP. The Neolithic is evidenced by two point/knifes and an adze. The 46 artefacts that could not be assigned to a period are mainly cores and primary and secondary flakes.

Wadi Rattama

We surveyed 20 sections (1000m in lenght) of Wadi Rattama. We started where the wadi meets Qa' Azraq and moved upstream from there. The last time this part of Wadi Rattama was surveyed by archaeologists was in the 1980s (*Copeland, Hours 1989b*).

We collected a total of 268 lithic artefacts in Wadi Rattama and were able to assign 106 of them to time periods with a reasonable degree of confidence. Once again, the LP is the best-represented period. We assigned 78 artefacts to this period. Many of these are heavy-duty types. These include 21 handaxes, four cleavers, four biface preforms, 11 choppers, and seven picks. We found 18 artefacts that are consistent with the MP, such as seven Levallois flakes and seven Levallois cores. We also identified seven artefacts that are morphologically similar to UP material elsewhere in the Levant, including blade cores, a burin, and a point/knife. A lone microburin is probably best assigned to the EP, while two points/knives are indicative of Neolithic occupation. The remaining 141 undiagnostic artefacts are mostly retouched and unretouched flakes and cores.

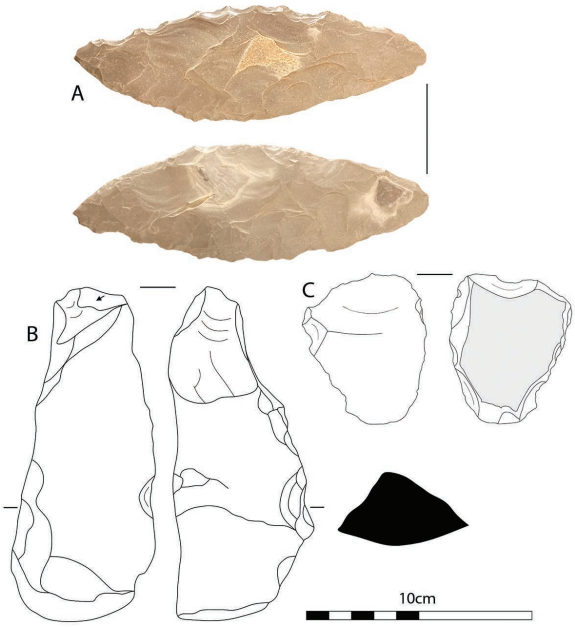

Fig. 8. Examples of Neolithic and Ch/EBA artefacts:* A *large bifacial point/knife from Wadi Usaykhim;* B *pick/chisel with tranchet strike or fracture from Wadi Butm;* C *tabular scraper from Wadi Usaykhim (photographs by JAB).

Wadi Usaykhim

We surveyed ten 50m long sections of Wadi Usaykhim (500m in lenght). These were located near the base of the hill on which the Roman fortlet known as Qasr Usaykhim sits. This upstream portion of Wadi Usaykhim, along with its mouth, had been previously explored by Stefan L. Smith (*2020*) and Nicholas Stanley Price and Andrew N. Garrard (*1977*).

We collected a total of 152 artefacts in and along the banks of Wadi Usaykhim. LP artefacts were among the most common (n=33). The majority of them were

heavy-duty types, such as handaxes, picks, choppers, and large bifacially reduced pieces. We also found 33 MP artefacts. These include various Levallois elements, including points, blades, and cores. Three points/knives with broken tangs and a blade core that we discovered are diagnostic for the UP, and two prismatic blades that could have been made in the UP or the EP. We recovered two Neolithic knife/points in Wadi Usaykhim. One is a well-made foliate bifacial knife. The 76 artefacts that could not be assigned to a time period are mostly cores and primary and secondary flakes.

New perspective on the prehistory of the central Azraq Basin

In this section we consider how the diagnostic artefacts we recovered alter our understanding of the prehistoric occupation of the central Azraq Basin. Because we found so few artefacts that are indicative of the EP and Ch/EBA, the discussion is limited to the LP, MP, UP, and Neolithic.

Previous fieldwork had located LP artefacts in and along the banks of wadis Butm, Enoqiyya, Kharanah, Rattama, Rajil, and Uweinid (Fig. 9). It had also located LP artefacts around the spring known as ʻAin el-Beidha, and in and around the GAOA. We revisited the wadis Butm, Enoqiyya, and Rattama during the fieldwork reported here and found more LP artefacts in each of them. In addition, we surveyed an upstream section of Wadi Usaykhim and found multiple LP artefacts. Lastly, we found LP artefacts in three wadis that had not been previously explored by archaeologists – Wadi Hayat, Wadi al-Masayil East, and Wadi al-Masayil West. The fieldwork reported here thus not only identified further evidence that wadis Butm, Usaykhim, and Rattama were occupied during the LP, but also revealed that more of the central Azraq Basin was occupied by hominins during the LP than previously thought. Most significantly, while the results of previous fieldwork had suggested that only areas to the southeast, southwest, west, northwest, and north of the GAOA were utilised during the LP, the artefacts we recovered indicate that wadis to the northeast of the GAOA were also used by LP hominins.

Initial surveys and excavations identified an MP presence along wadis Butm, Enoqiyya, Kharanah, Rattama, and Uweinid (Fig. 10) (*Copeland, Hours 1989b; Hours 1989*). MP artefacts were also discovered around ʻAin el-Beidha, and within the GAOA (*Copeland 1989d; Bisson* et al. *2014; Ames, Cordova 2015*). Our fieldwork among wadis Butm, Enoqiyya, and Rattama discovered further evidence of the MP, particularly at upstream Wadi Butm. Our survey of the previously unexplored Wadi al-Masayil East, Wadi al-Masayil West, and Wadi Hayat, as well as an upstream section of Wadi Usaykhim, also found MP artefacts. Previous research had indicated that the MP occurred in areas to the north and southwest of the GAOA, as well as within it. Our new results demonstrate that MP occupation in the central Azraq Basin also extended further to the west and northeast of the GAOA.

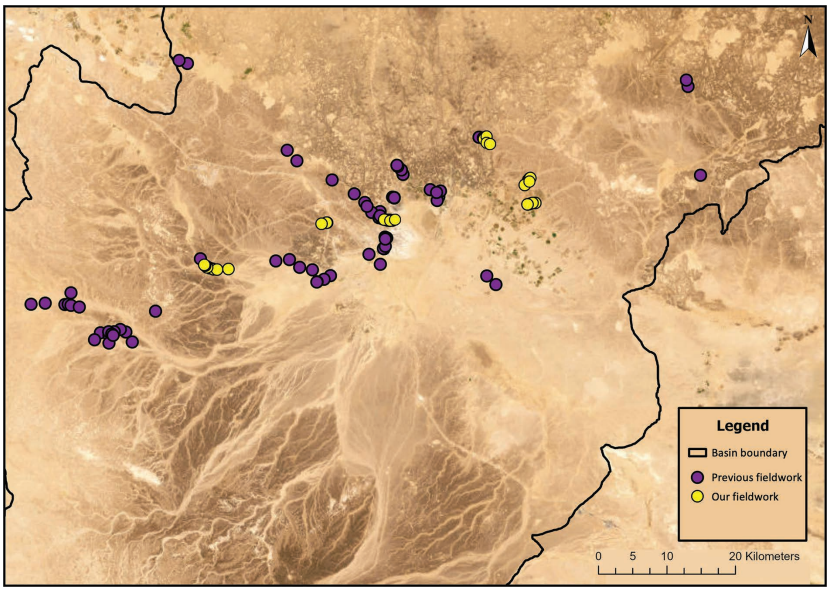

Fig. 9. Areas of the central Azraq Basin in which LP artefacts have been found. Basin boundaries georeferenced and modelled after El-Naqa (*2010. 45*). Figure produced with ArcGIS.

Fieldwork prior to ours had suggested that UP occupation of the central Azraq Basin was concentrated to the north and southwest of the GAOA, with diagnostic artefacts having been recovered along Wadi Enoqiyya and Wadi Uweinid, as well as in the Druze Marsh and around ʻAin el-Beidha (*Copeland 1989d; Bisson* et al*. 2014; Ames, Cordova 2015*). As Figure 11 shows, our survey findings change this picture. Like previous researchers, we located UP types in wadis Enoqiyya and Rattama, but we also discovered them along Wadi Butm, Wadi al-Masayil West, and Wadi Usaykhim. That we recovered UP artefacts from these

wadis demonstrates that UP humans utilised more of the central Azraq Basin than had previously been appreciated. Specifically, it shows that areas to the north, northeast, southwest, and west of the GAOA were used by humans during the UP.

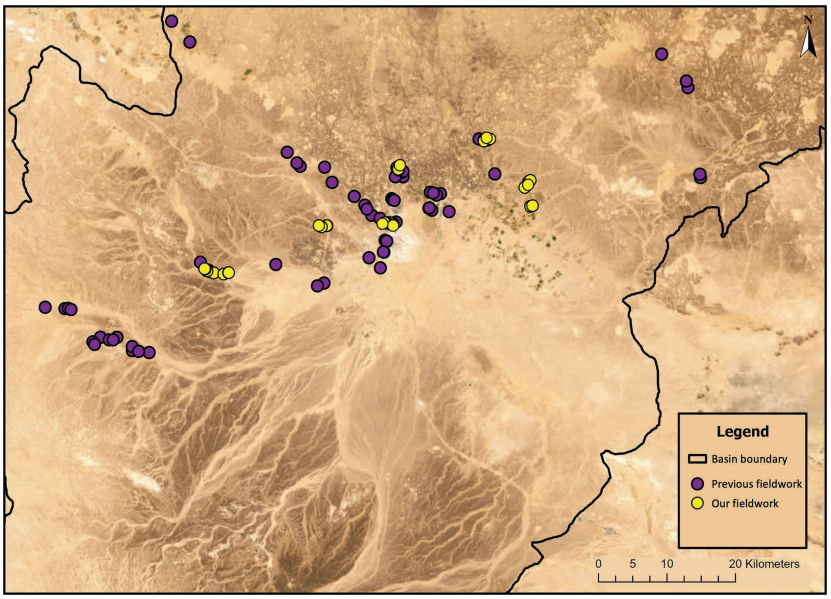

Fig. 10. Areas of the central Azraq Basin in which MP artefacts have been found. Basin boundaries georeferenced and modelled after El-Naqa (*2010. 45*). Figure produced with ArcGIS.

Previous investigations noted the occurrence of Neolithic artefacts in and around the GAOA, as well as at the spring of 'Ain el-Beidha, just northeast of the GAOA (Fig. 12) (*Copeland 1989d; Garrard* et al. *1994a*). A survey at the mouth of Wadi Usaykhim led by Andrew Garrard also found evidence of the Neolithic to the immediate northeast of the GAOA (*Stanley Price, Garrard 1977*). In addition, Neolithic artefacts were discovered directly north of the GAOA, along Wadi Enoqiyya (*Hours 1989*), and to the southwest of the GAOA, along Wadi Uweinid. Wadi Jilat, and Wadi Kharanah (*Copeland, Hours 1989b*). Dense concentrations were also located along upstream Wadi Rajil. The results of our survey also alter this picture. To reiterate, we recovered lithic artefacts that could be confidently assigned to the Neolithic along Wadi Hayat, Wadi al-Masayil West, and Wadi Butm. We also found a bifacial knife some distance north of the GAOA, in Wadi Usaykhim. Our survey thus suggests that more of the central Azraq Basin was utilised during the Neolithic than has previously been appreciated.

A revised overview of occupation of the central Azraq Basin during prehistory

A summary of what is currently known about hominin occupation of the central Azraq Basin during prehistory, based on the combined results of fieldwork carried out prior to our visits and the artefacts we located in the course of our survey, is found in Figures 9–12.

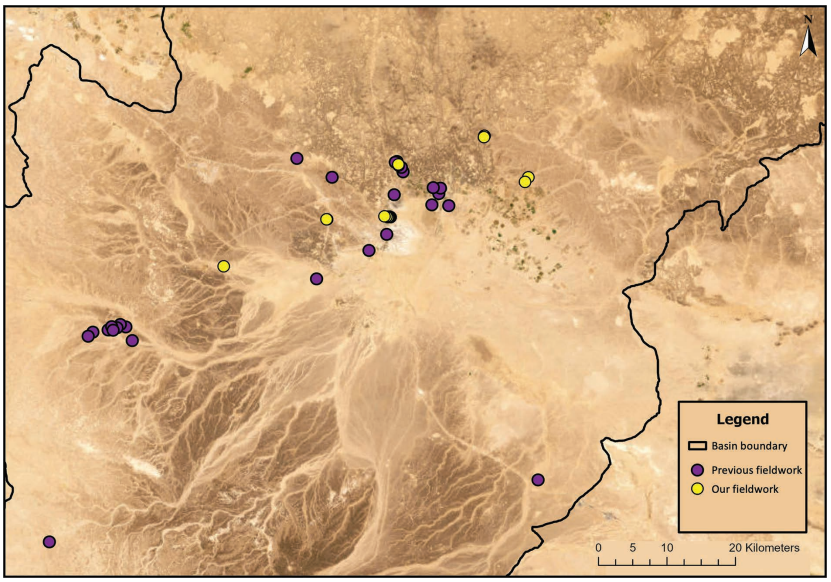

Fig. 11. Areas of the central Azraq Basin in which UP artefacts have been found. Basin boundaries georeferenced and modelled after El-Naqa (*2010. 45*). Figure produced with ArcGIS.

It is important to note at the outset that the meaning of the general absence of finds to the southeast and south of the GAOA in the six distribution maps is unclear. This is typically because no systematic archaeological fieldwork has been carried out in these areas. In the 1980s, LP artefacts were recovered in Wadi Rajil, which is located to the east of the GAOA (*Copeland 1989d*). The same team also collected some EP artefacts in Qa Jashsha, which lies to the southeast of the GAOA (*Copeland 1989d*). However, these artefacts were found incidentally in the course of geomorphological fieldwork rather than

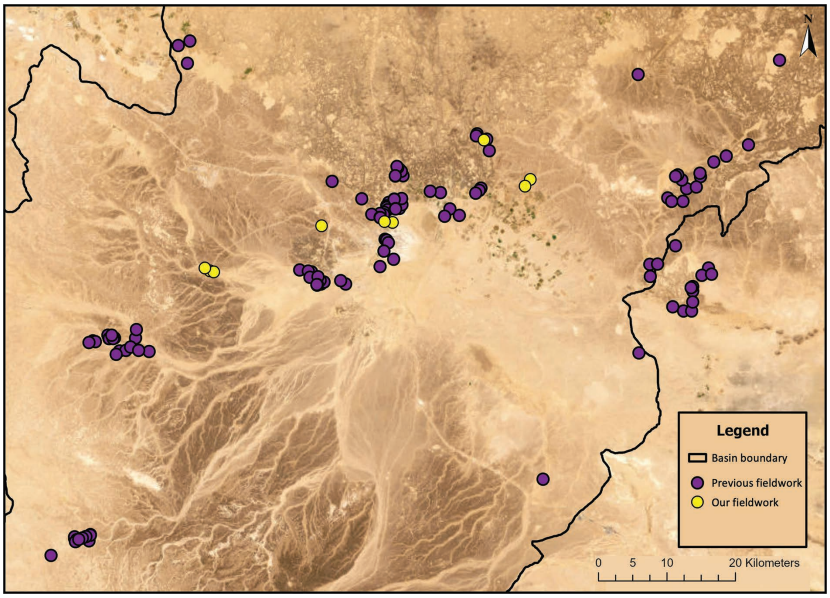

Fig. 12. Areas of the central Azraq Basin in which Neolithic artefacts have been found. Basin boundaries georeferenced and modelled after El-Naqa (2010.45). Figure produced with ArcGIS.

during a dedicated archaeological survey (*Copeland 1989d*). Obviously, the artefacts in question indicate that the area east of the GAOA was used by hominins during the LP and EP, but in the absence of systematic fieldwork we cannot say anything about the absence of artefacts from other time periods in that area or about the lack of any prehistoric artefacts to the south of the GAOA. Given this, in the following discussion of hominin occupation of the central Azraq Basin during prehistory we will focus on the upper left portions of the distribution maps.

The LP is among the best represented prehistoric periods in the central Azraq Basin. It is found within the GAOA, in both Shishan and Druze marshes, and along almost every major wadi. LP occupation of the basin appears to have been concentrated to the southwest, west, and north of the GAOA. The area northeast of the GAOA was also used, but less frequently.

There is little change between the LP and MP in terms of the areas that were occupied. Most of the wadis that have yielded LP artefacts have also produced MP artefacts. However, there is a change with regard to occupation intensity. In general, occupation is much less intensive during the MP than the LP. Wadis to the northeast, west, and southwest of the GAOA have yielded relatively few artefacts, suggesting limited utilisation of these areas. Comparatively sparser evidence of MP occupation has also been discovered within the Shishan Marsh. The exception to this pattern of lower intensity occupation is in the area to the north of the GAOA. In particular, Wadi Enoqiyya has produced abundant evidence of MP occupation.

Artefacts recovered in the central Azraq Basin indicate that both the extent and intensity of occupation were reduced in the UP relative to the MP. UP occupation is found to the southwest, north, and northeast of the GAOA, as well as within it. In none of these areas can occupation be described as intensive. The UP is represented by considerably fewer artefacts than is the case with the MP. Wadis Butm, Uweinid, Rattma, Enoqiyya, and Usaykhim have yielded relatively few artefacts, indicating limited occupation in areas away from the GAOA. Sites in both the Shishan and Druze marshes also contained relatively few artefacts. Due to the indeterminate UP-EP nature of lithics along Wadi al-Masayil East and Wadi al-Masayil West, it is unclear how dense UP occupation is in these more distant areas northeast of the GAOA.

EP finds are more numerous and more widely distributed within the central Azraq Basin than both MP and UP finds. The distribution for the EP is most similar to that of the LP, as its denser areas occur within the GAOA and to its southwest and west. These are often attested by more than lithics, such as architecture and faunal caches. Concentrations are most evident along the wadis Jilat, Kharanah, and Uweinid, and to a lesser extent along Wadi Butm and Rattama. It is also found to the north (*e.g.*, Wadi Enoqiyya) and immediate northeast (*e.g.*, Wadi Usaykhim, ʻAin el-Beidha) of the GAOA, although these areas contain relatively few EP artefacts. The recovery of indeterminate UP-EP artefacts in distant areas to the northeast of the GAOA may indicate possible occupation here.

Neolithic occupation generally occurs in similar areas of the central Azraq Basin to that of the EP, with several shifts in density. For example, dense occupation continues within the GAOA and in areas to the southwest and immediate northeast. Dense occupation is particularly notable within the Shishan Marsh and directly to the northeast of the GAOA, such as around ʻAin el-Bei-

dha and at the mouth of Wadi Usaykhim. Occupation also occurs upstream of Wadi Usaykhim, to the northeast of the GAOA and along the upstream of Wadi Rajil in the northeast.

To date, evidence of occupation of the central Azraq Basin during the final two periods of Levantine prehistory, the Chalcolithic and the EBA, is limited. Across this defined region, relatively few lithics and pottery sherds indicative of the two periods have been identified, especially around the wetlands. The densest area attesting to a Ch/EBA presence are found around Qasr Usaykhim and Jebel Qurum, where stone structures and clustered dwellings suggest temporary hamlets (*Akkermans, Brüning 2020; Smith 2020*).

Possible future directions of research

Several potential directions for future research on the prehistory of the central Azraq Basin suggest themselves. The first concerns the fact that the vast majority of the prehistoric artefacts recovered to date have been found in the GAOA and wadis that drain into it from the southwest, west, northwest, north, and northeast. Copeland (*1988*) suggested that the distribution of artefacts reflects the availability of fresh water because the northwestern portion of the Azraq Basin receives considerably more precipitation than the rest of the basin. However, as mentioned in the last section, there has not been any systematic survey to the southeast and south of the GAOA, so it is not clear whether the northwest-focused distribution is real or a product of research bias. Given this, there is a need to prioritize pedestrian surveys to the southeast and south of the GAOA. To reiterate, LP artefacts were found fortuitously at two spots in Wadi Rajil close to where it empties into Qa' Azraq (*Copeland 1989d*). While Copeland (*ibid.*) was not optimistic about the possibility of the LP continuing south-eastward, it has recently become evident that populations from this period (and later ones) inhabited the Syro-Arabian Desert (*Petraglia 2003; 2011; Shipton* et al. *2014; Petraglia* et al. *2019*). Given this, we suspect that a systematic survey of Wadi Ghadaf and associated tributaries, particularly at upstream locations where clast size is similar to that of Levallois cores or Acheulean bifaces (~10cm), is likely to yield results. The same survey reported finding several small lithic artefact scatters in a sabkha on the southeast edge of the central Azraq Basin called Qa Jashsha (*Copeland 1989b*). The periods of many lithics were unclear, but two sites were assigned to the EP, with Copeland (*1989d*) acknowledging the untapped potential of the area. An extensive concentration of Late Acheulean surface material on the north side of Qa Jashsha was collected by German amateurs in the 1970s and has since disappeared (*Gary Rollefson pers. comms. 2023*). This suggests that there may even be prehistoric artefacts between Qa Azraq and Qa Jashsha that have yet to be discovered.

Second, there is a need to understand the sparsity of occupation of the central Azraq Basin during the Ch/EBA. Currently, it is not clear why humans would have avoided utilising areas around the wetlands during these periods, as the densest occupation occurs to the northeast and east on the fringes of the Black Desert (*Akkermans, Brüning 2020; Smith 2020*). More significantly, occupation occurs beyond the centre of the basin in almost every direction. For example, it is clear that there were thriving communities 60km to the west of the GAOA during the Ch/EBA (*Rowan, Golden 2009; Richard 2014*). Similarly, the site of Jawa, which is located over 50km north of the GAOA, near the border between Jordan and Syria, is thought to be a fortified settlement that was occupied during the EBA (*Helms 1981; Betts 1991*). Ch/EBA occupation is even found about 70km to the southeast of the GAOA, as scatters of lithics were discovered at Jabal Tharwa (*Wasse, Rollefson 2005*). A lack of diagnostic pottery, lithics, and architecture around the wetlands is puzzling, given that the GAOA is generally considered to be stable during the Holocene (*Cordova* et al. *2008; Ames* et al. *2022*). The massive structure of the sediments and the limited radiometric dates do not provide a sufficient basis to identify drastic decreases in spring discharge that may cause the GAOA to dry up for small periods of time. Consequently, further research is needed to establish the nature of the palaeoenvironment during these short periods and to explain the general lack of occupation.

Lastly, at a more general level, there is a need to further connect the prehistory of the Azraq Basin to adjacent regions. For instance, the closest Palaeolithic sites to the west of the Azraq Basin are located within Wadi Zarqa (*Copeland, Hours 1988; Parenti* et al. *1997*), roughly 60km away and across a stretch of stony desert. Copeland and Hours (*1988*) describe typological consistencies between the LP and MP assemblages of two regions. Radiometric dates at recently discovered sites in both regions can assist in establishing a chronological sequence between them. The prehistory of the Azraq Basin can also be connected to regions to its southeast, namely the paleolake basins of northwest-

ern Saudi Arabia. A sequence of (now dry) subcatchments that stretch from the Nefud Desert in northwest Arabia, through the Wadi Sirhan depression, and into eastern Jordan constitute the Azraq Corridor, a potential route of dispersal (*Maher 2009; Breeze* et al. *2016*). The subcatchments (oriented SE-NW) include Al Qutb, Qa' Hazawa, Qurrayat, and finally the Azraq Basin. Increased precipitation during humid periods could cause the basins to fill and maintain freshwater lakes (*Breeze* et al. *2016*). Archaeological investigations in the Nefud Desert over the past decade have identified both surface and buried prehistoric sites with LP and MP assemblages (*Shipton* et al. *2014; Scerri* et al. *2015; Breeze* et al. *2017*). The proximity of these assemblages to the Azraq Basin presents a potential opportunity to explore connections between the two regions.

Conclusion

The Azraq Basin is an important physiogeographic feature and hydrological catchment region in the eastern desert of Jordan. At its centre are a mudflat, Qa' Azraq, and a fragile wetland complex, the GAOA. Archaeological surveys and excavations have demonstrated that the GAOA was an important resource for hominin populations during prehistory.

In the summers of 2022 and 2023, we surveyed portions of seven of the major wadis that empty into Qa' Azraq with a view to recovering prehistoric lithic artefacts. The wadis in question are Wadi Butm, Wadi Enoqiyya, Wadi Hayat, Wadi al-Masayil East, Wadi al-Masayil West, Wadi Rattama, and Wadi Usaykhim.

In total, we collected 941 lithic artefacts. Among these artefacts are types that are diagnostic of several periods of Levantine prehistory. Our results are broadly consistent with the findings of previous surveys and excavations in the centre of the basin. However, our survey also identified occupation in areas of the central Azraq Basin that had not been previously explored. Specifically, areas to the northeast of the GAOA yielded artefact types that are diagnostic of the LP, MP, UP, and Neolithic.

Based on the combined results of fieldwork carried out prior to our visits and the artefacts we located during our survey, it is clear that there were substantial diachronic changes in the occupation of the central Azraq Basin by hominins during prehistory. The region was densely occupied in the first period of Levantine prehistory, the LP, and possibly least densely occupied in the last two periods of Levantine prehistory, the Chalcolithic and EBA. However, this decrease was not linear. Instead, occupation density waned between the LP and the UP, increased in the EP and Neolithic, then declined to the point of near abandonment in the Chalcolithic, and then stayed that way at least until the end of the EBA.

The results of our survey suggest that many surface artefacts and buried sites are yet to be discovered in the central Azraq Basin. Based on previous incidental finds and the results of our survey, we suspect that a systematic survey of upstream wadis where clast size is similar to that of LP bifaces is likely to yield results. We argue that a priority for future research should be to survey to the east, southeast, and south of the GAOA, as these areas have not yet been subject to systematic archaeological fieldwork.

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Tab. 4. Distribution of broad lithic types by wadi.

Type		Butm	Enoqiyya	Hayat	Masayil (East)	Masayil (West)	Rattama	Usaykhim	Total
Adze		1				1			2
Awl								1	1
Biface	Total	13		14	10	8	29	14	88
	Cleaver						4		4
	Handaxe	9		12	8	8	22	12	71
	Preform	4		2	2	-	4	3	13
Bifacially reduced piece		9		4	3	9	13	6	44
Blade		16	37	6	8	8	12	26	113
Bladelet			1						1
Burin	Total		2	2		1	2		7
	Lateral preparation		1	1					2
	Offset dihedral			1			1		2
	Straight dihedral burin		1			1			1
	Straight oblique truncation		1						1
	Microburin						1		1
Chopper		2		5	3	1	11	7	29
Core	Total	33	12	12	4	9	53	22	145
	Bidirectional opposed						1		1
	Blade	1	3	1			3	1	9
	Centripetal	1				1	3	1	6
	Flake (general)	30	8	8	4	8	43	17	118
	Microlithic		1	1					2
	Point?			1			1		2
	Preferential	1		1			1	1	4
	Unidirectional convergent						1	2	3

Continued

Denticulate		1	1	2		2	3	2	11
Denticulate-scraper		1						1	2
End-notched piece		1							1
Endscraper		1	3			6	8		18
Notch		6	2	1	2	5	5		21
Pick		2				2	8	3	15
Point			6	4		1	2	15	28
Polyhedron							1		1
Scraper	Total	22	10	1	10	14	21	7	85
	Convergent		2			3			5
	Double side convex						1		1
	Double side straight		1				1		2
	Round						1		1
	Single side convex	12	1		8	4	17	6	48
	Single side straight	5	1				1	1	8
	Stemmed	1							1
	Tabular		3						3
	Thumbnail	2	2						4
	Transverse convex	2		1	2	7			12
Truncated faceted piece			1						1
Unifacially reduced piece		1		1		1	3		6
Worked chunk				3	4	3	9	6	25
Reduction elements	Core piece	6	10	1	3	6	16	3	45
	Biface thinning flake							1	1
	Chunk		1						1
	Flake	42	55	10	10	21	72	37	247
	Rejuvenation flake		2					1	3
Total		**157**	**143**	**66**	**57**	**98**	**268**	**152**	**941**

A forest-steppe landscape and the settlement Ksizovo-1 in the Don region during the Middle Bronze Age

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ABSTRACT – *Systematic investigations of Bronze Age settlements in different regions of western Eurasia have provided new insights into settlement structures, land use, and past mobile lifestyles. In this paper, we examine the single-layered site of Ksizovo-1 in the Upper Don basin, located in a microregion of the Eastern European forest-steppe. We integrate archaeological, bioarchaeological, and molecular investigations to evaluate if the Middle Bronze Age settlement was a short-lived seasonal site inhabited by a community of mobile pastoralists with distinct land use and economic strategies. Combining the results of the excavations and radiocarbon dating, as well as archaeobotanical, archaeozoological, isotopic, phytolith and organic residue analyses, allows for a more holistic understanding of the character of this site and its environmental and economic contexts. While various features and artefacts were recovered, no remains of architecture or dwellings were found during the excavations, suggesting that the site may have functioned as a temporary camp. The bioarchaeological and molecular data indicate that the community relied primarily on pastoralism, keeping herd animals for meat (mainly cattle), with some reliance on wild animals (*e.g., *wild pig, bear, and elk), and wild plant resources (*e.g., *wild fruits and nuts), indicating the wider exploitation of the forest-steppe landscape surrounding the site.*

KEY WORDS – *pastoral land use; landscape archaeology; bioarchaeology; molecular analyses; Catacomb culture*

Gozdno-stepska pokrajina in naselbina Ksizovo-1 na Donu v srednji bronasti dobi

IZVLEČEK – *Sistematične raziskave naselbin iz bronaste dobe v različnih regijah zahodne Evrazije omogočajo nove poglede na pretekle poselitvene strukture, izrabo prostora in mobilne načine življenja. V prispevku preučujemo enoslojno najdišče Ksizovo-1 v porečju zgornjega Dona v vzhodnoevropski gozdni stepi. Povezujemo arheološke, bioarheološke in molekularne raziskave, da bi ocenili, ali je bila naselbina srednje bronaste dobe kratkotrajno sezonsko naselje mobilnih pastirjev s prilagojeno rabo prostora in posebnimi ekonomskimi strategijami. Povezani rezultati izkopavanj in radiokarbonskega datiranja ter arheobotaničnih, arheozooloških, izotopskih analiz, analiz fitolitov in organskih ostankov omo-*

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gočajo celovito razumevanje najdišča in njegovih okoljskih in gospodarskih kontekstov. Med izkopavanji niso našli ostankov arhitekture ali bivališč, odkrite pa so bile različne strukture in vrsta artefaktov, zato je bilo najdišče morda občasni tabor. Bioarheološki in molekularni podatki kažejo, da je gospodarstvo skupnosti temeljilo na pašništvu in reji goveda za mesno gospodarstvo. Včasih so vključili tudi divje živali (npr. divje prašiče, medvede in lose) ter divje rastline (npr. divje sadje in oreščke) in tako izkoristili tudi gozdno stepo v okolici.

KLJUČNE BESEDE – *pašna izraba prostora; prostorska arheologija; bioarheologija; molekularne analize; kultura katakomb*

Introduction

The Western Eurasian steppe was inhabited by pastoralists for many periods in prehistory, with heavy reliance on domesticated animals providing a way of subsistence in the context of its arid and continental climate. Although archaeologists such as Nikolay Yakovlevich Merpert (*1974*) argued for the early development of mobile pastoralism in this vast area, in Early Bronze Age, only recently has there been a better understanding of the complex ways in which people organized their lives under the challenging conditions of this vegetation zone. In particular, systematic and multidisciplinary studies of Bronze Age settlements in various regions of western Eurasia have provided new insights into settlement structures, land use, and mobility patterns (*Krause, Koryakova 2013; 2014; Anthony* et al. *2016; Gak 2019*). The results of these projects suggest significant differences in steppe subsistence strategies and natural resource use across space and time during this period, although the characteristics of such sites inhabited by pastoralists require further investigation.

Nevertheless, multidisciplinary settlement and landscape archaeological research for Eastern Europe's Bronze Age continues to be underrepresented, and there is still a need for basic research. We conducted joint excavations between 2019 and 2021 at the single layered site of Ksizovo-1, Lipetsk region, district Zadonsk (52°17'32"N, 38°56'35"E). Parallel to the excavations, various scientific methods (radiocarbon dating, archaeobotany, zooarchaeology, isotope, phytolith and organic residue analysis) were used to gain a better understanding of the site's occupational and environmental setting. Ksizovo-1 is situated in a microregion in the forest-steppe zone of European Russia. Excavated pottery fragments at the site are representative of the Catacomb culture in the second half of the 3rd millennium BCE. The Catacomb culture has been based on findings of thousands of burials, most of which were located in grave mounds in the steppe (*Popova 1955; Bratchenko 1976*). To date, only a few settlements have been identified, mainly on the first terraces of larger rivers (*Kaiser 2019.121–128*). The Middle Don region is an exception to this. There, a dense concentration of 67 settlements was first documented by Anatoly Pryakhin (*1982*), while more than 150 settlements were recorded by Maksim Ivashov (*2015*). Only a very small number of these settlements have been excavated using test trenches on a very limited scale, and they were mainly identified by cocentrations of ceramic fragments. As such, their structures remain largely undefined.

Systematic and intensive excavations have only been undertaken at Rykan-3, Novaya Usman, Voronezh region (Fig. 1; *Gak* et al. *2023*), meaning that further, in-depth investigations of Catacomb culture settlements in this region remain necessary. Due to the ephemeral nature of pastoral sites and the lack of stratigraphic sequences, many questions remain unanswered. This study focuses on the results of archaeological, bioarchaeological, and molecular investigations in the forest-steppe, a vegetation zone that is generally considered as more suitable for settlement than the feather grass steppe itself (*Breckle, Rafiqpoor 2019. 380–381*), with trees in the river valleys providing more protection from wind and adverse weather. We provide the results of the excavations at the site of Ksizovo-1, and new data on the land use, subsistence ecology, and economy of the mobile pastoralists occupying the site.

Study area

Located within the East European forest-steppe (Fig. 1), the study area is today part of a transitional ecological zone, characterized by broadleaf forest stands interspersed with grassland steppe (community of fescue (*Festuca* sp.) and feather grass (*Stipa* sp.)) (*Bohn*

et al. *2003; Novenko* et al. *2009*). To the north there are mixed coniferous and deciduous forests, while the south is bounded by the grasslands of the Pontic steppe (*Kremenetski 2003; Anthony 2007*). The present-day topography, in which Ksizovo-1 and its surroundings form a microregion, is mostly flat with widespread uplands that are connected with the geological foundation of the East European Plain. The territory is a section of the Oka-Don lowland. Typical soils – chernozems and grey forest soils (*Kashirskaya* et al. *2020.495; Potapova* et al. *2020.62*) – are formed on loose sandy to clayey Mesozoic to Cenozoic deposits. The sediments in the immediate vicinity of the Ksizovo-1 site formed under the influence of river floods and erosion due to intensive ploughing of the second flood terrace. Today, arable lands occupy up to 85% of the Lipetsk region (*Kurbanova* et al. *2023*) and forests cover only 8%. The climate is highly continental, which implies a wide amplitude of seasonal fluctuations in air temperatures. January temperatures average around –6°C, while July temperatures average +19°C. Precipitation rates are low throughout the year with an average of 25mm in January and 74mm in July (http://council.gov.ru/en/structure/regions/LIP/). Snow cover establishes during late November and persists for a period of around three and half months (https://weatherspark.com/y/101446/Average-Weather-in-Lipetsk-Russia-Year-Round).

The microregion Ksizovo

The site Ksizovo-1 is a single-layer settlement within a compact group of sites, which yielded materials of the Middle Don Catacomb culture in the south of the Lipetsk region, at the confluence of the Snova River with the Don (Figs. 1 and 2). Within the modern forest-steppe zone of Eastern Europe, this settlement represents a well-preserved cultural layer of the Middle Bronze Age, allowing for diverse multidisciplinary studies.

The settlement of Ksizovo-1 was situated on the slope of the first terrace above the floodplain. The meandering of the Snova River caused erosion and damage to both the terrace and the site. However, when the site was discovered by archaeologists in 1964, the remains of several dwellings were found in the outcrops of the riverbank (*Pryakhin 1982*). The authors of the present study Evgenii Gak, Maxim Ivashov, and Elke Kaiser expanded on this initial discovery covery by excavating the area encompassing 640m² from 2019 to 2022, and identified both surface (fireplaces) and sunken features (fire pits) which were used for firing, as well as miscellaneous pits (Fig. 3). No architectural re-

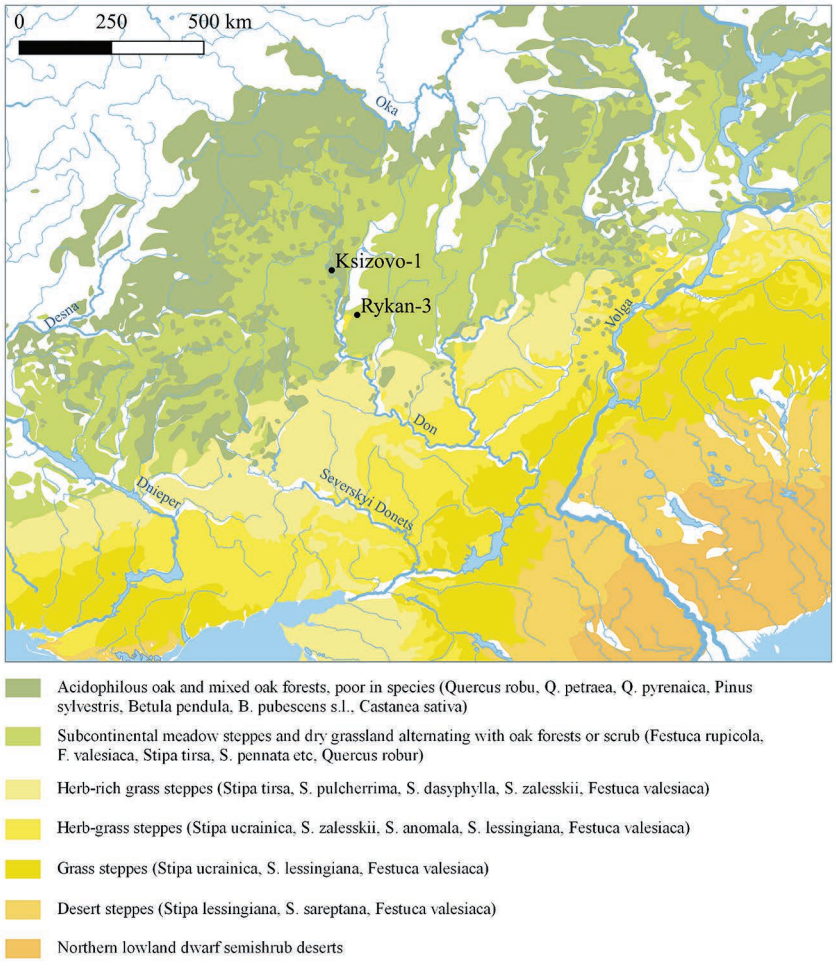

Fig. 1. Location of the study area including Middle Bronze Age sites mentioned in the text (Ksizovo-1: 52°17'23.6"N 39°3'51.9" E; Rykan-3: 51°37'17.7"N 39°33'53.6"E), as well as the main natural vegetation communities of the region. The map was created using QGIS Desktop version 3.22.5 (www.qgis.org), raster and vector map data was acquired from the German Federal Agency for Nature Conservation (see* Bohn *et al.* 2003*). Note: the geographical coordinates of the two sites refer to the closest modern villages Ksizovo (Zadonsk district) and Rykan (Novaya Usman district).

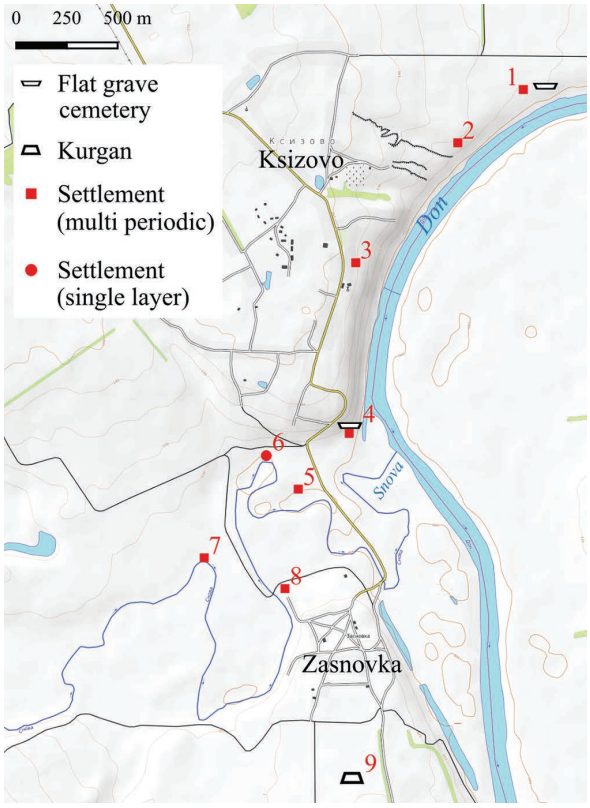

Fig. 2. Archaeological sites in the microregion of Ksizovo.* 1 *settlement and flat grave cemetery Ksizovo-19;* 2 *settlement Ksizovo-17;* 3 *settlement Ksizovo-8;* 4 *Settlement and flat grave cemetery Ksizovo-6;* 5 *settlement Ksizovo-7;* 6 *settlement Ksizovo-1;* 7 *settlement Ksizovo-2;* 8 *settlement Zasnovka-6;* 9 *kurgan Zasnovka 1. Map data: © OpenStreetMap contributors, SRTM. Map display: © OpenTopoMap (CC-BY-SA).

mains or structures such as sunken floors or postholes were found. Material remains included scattered pottery fragments and stone and bone artefacts. The materials suggest that specific work and various craft activities took place, and characterize the excavated area as a multifunctional zone. The number of artefacts indicating production is, however, rather low. It seems that these essentially domestic crafts were practised only when needed, which is consistent with the idea of the role of crafts in the economy of short-lived Middle Bronze Age pastoral camps.

The single occupation horizon of Ksizovo-1 is covered by several stratigraphic layers (Fig. 4). A diluvial layer (A), deposited from the surface to a depth of 1.23m, was formed very rapidly. This was obviously the result of intensive erosion processes caused by the heavy agricultural use of this area in the recent past. This stratum lies above the ancient soil deposited at a depth of 1.23–1.75m (layer B), which covered the settlement layer (C) of the Middle Don Catacomb culture. The upper part of the cultural layer (1.75–1.95m deep) is probably related to the soil erosion that took place immediately after the abandonment of the Catacomb settlement. The underlying layer contains the remains of this settlement, which was formed on the yellow sterile clay, *in situ*, and lies at a depth of 1.95–2.20m. The cultural layer was excavated in three levels (or plasts, after the Russian term for layer or stratum), each about 15cm thick. The archaeological finds were concentrated in levels 2 and 3.

Typical features of the cultural layer are pottery clusters and fire pits/places. Vessels seem to have been crushed, and their remains were deposited in larger and smaller concentrations (in Russian *razval sosuda*). A discussion around the characteristics of this feature, typical of Bronze Age sites, deserves to be the topic of a separate article. These features mostly seem to be refuse matter, but there are cases where such vessels were deliberately piled on hearths before the settlement abandonment.

Animal bones and teeth, fragments of other vessels, and other small objects were found among these clusters. In most cases it is not possible to reconstruct the whole pot, so only parts of the destroyed vessels seem to have been deposited. Figure 5 shows such an accumulation, in which the lower part of a large vessel was found. This large fragment, originally intact but now broken, was used as a kind of flat bowl and contained burning materials, today preserved as charcoal. The interior of this large fragment still shows traces of soot. Along with the pottery fragments, a burnt animal bone was also found in the cluster.

Fire pits are characterized by a circular area of burnt yellow-orange clay with inclusions of dark clay, charcoal, and calcined and burnt animal bones. An example of such a pit is shown in Figure 6. The centre of this fire pit formed a bright orange calcination with a diameter of about 0.6m. The fill is heterogeneous in colour: in the lower part and along the walls, the calcination is reddish-brown, while the upper part was yellow-ochre. It contained 27 fragments of vessels, eight burnt and eight calcined animal bones, and four small pieces of burnt clay. The overall dimensions of the pit were 1x0.7m, with a surface area of 0.8x0.5m. The depth of the pit was 0.25m. It is worth mentioning that no remains of dwellings were found during excavations between 2019 and 2021. This is not unusual, since it is generally assumed in East European archaeology that

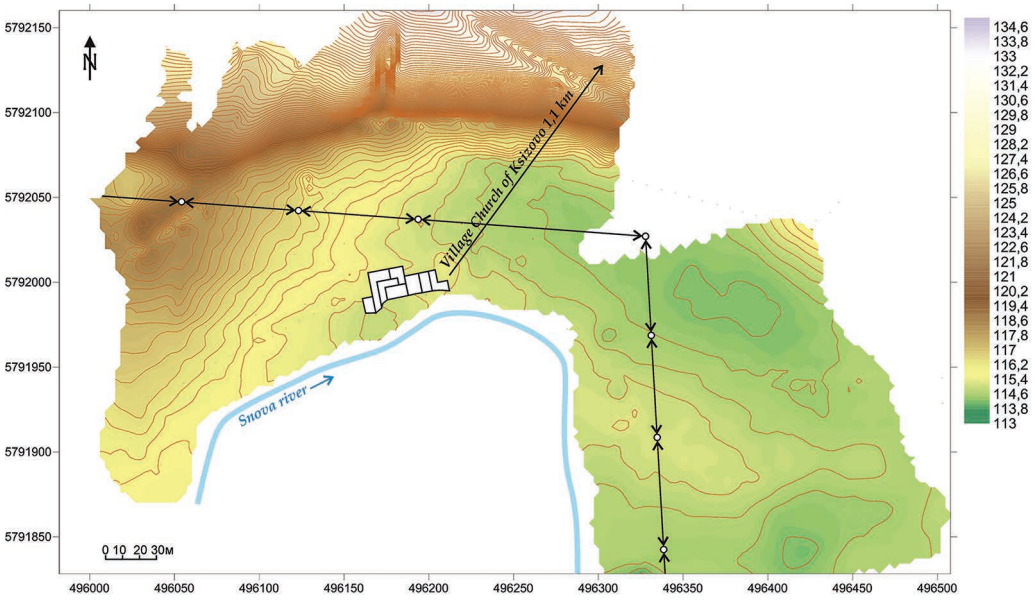

Fig. 3. Topographic plan of Ksizovo-1 and its immediate surroundings with the layout of the excavated areas (created T. Schenk, E. Gak).

settlements were only temporarily inhabited and that the pastoralists of the Catacomb culture probably lived in light structures (*Gak, Borisov 2017*). Another reason might be that only the periphery of the settlement has been preserved. The larger part, including the centre, was washed away by flooding events of the Snova.

Methods and material

The conventional excavations were supplemented with various scientific analyses, including radiocarbon dating, archaeobotanical, zooarchaeological, analyses of isotopes of animal teeth, phytoliths and dung spherulites, and of organic residues on pottery fragments. We applied such an integrated methodology to increase the possibility of accurately deciphering Ksizovo-1's settlement and landscape use patterns. The following sections outline the multidisciplinary methods applied to different types of archaeological material.

Radiocarbon dating

To obtain absolute dates for the site's occupation, 17 samples were sent to the Poznan Radiocarbon Laboratory, Poland. The samples were taken during the excavation process from different contexts which were the results of human activity using fire (fire pits/places). They represent eight samples of animal bones and five of charcoal. Additionally, after the archaeobotanical investigation four charred plant macro-remains were sampled (Table 5 in the appendix). All samples were AMS dated according to the protocol of Poznan Radiocarbon Laboratory (*Goslar 2015*).

Archaeobotanical analysis

Samples for archaeobotanical analysis were systematically collected from various archaeological contexts at the site. The common hand-flotation method using a sieve with a mesh size of 0.5mm was used to obtain plant macroremains (*Lebedeva 2016*). A total of 54 samples, each consisting of a volume of 10 to 20 litres,

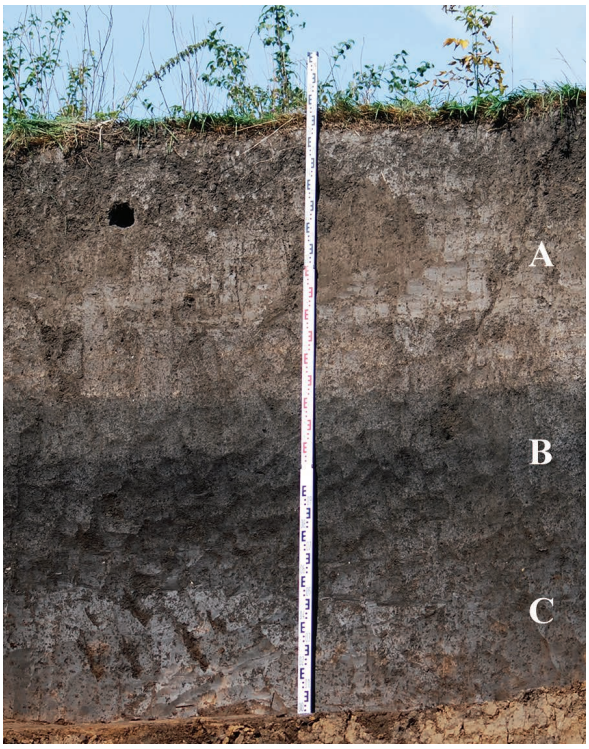

Fig. 4. Stratigraphic profile at the riverbank of the Snova with the cultural layer at the bottom (photo D. Yu. Davydov in 2014).

were processed (Table 6 in the Appendix). The samples were analysed in the Laboratory of Scientific Methods of the Institute of Archaeology of Russian Academy of Sciences (RAS). Sorting of the floats, identification of macroremains, and their selective photofixation were performed using a Leica MZ-7.5 stereomicroscope. The examination revealed not only the rare occurrence of seeds and other plant diaspora, but also charcoal fragments. The small number and size of these fragments (mostly 2–3mm and extremely rarely up to 6–7mm) did not allow us to correctly measure the charcoal volume in the samples, so we calculated their absolute number, although this is not a standard procedure in archaeobotany (Table 6 in the Appendix).

Fig. 5. Concentration of pottery fragments, evidence of crushed vessel in Ksizovo-1.

Zooarchaeological analysis

We zooarchaeologically analysed 3994 specimens. In addition to anatomical and taxonomic identification, taphonomic preservation, the degree of bone fragmentation, and the presence of anthropogenic modifications were examined. Age, sex, bone measurements, and pathologies were recorded where possible. Two different sets of data were obtained: (i) archaeological characteristics of the osteological material, and (ii) biological information on specific animals. The analysis revealed the main orientations and hitherto unexplored features of the animal-related economic activities of the inhabitants of Ksizovo-1. In order to determine the reliability of the biological information thus obtained, the taphonomic status of the osteological material and the degree of bone integrity were also gathered. For this purpose, two quantitative indicators are considered: an estimation of the natural preservation of bone remains (NP) on a five-point scale, and an index of bone fragmentation (FI) defined as the number of fragments per unit of standard volume equal to one cubic dm (following methods developed by Ekaterina Antipina (*2004; 2008; 2016*)).

Fig. 6. Fire pit in Ksizovo-1.

Isotopic analysis on animal remains

A multi-isotope approach (stable carbon ($\delta^{13}C$), stable oxygen ($\delta^{18}O$), and radiogenic strontium ($^{87}Sr/^{86}Sr$)) was applied to selected high-crowned cattle and caprine molars for sequential sampling. Sequential sampling is routinely used to reconstruct herding strategies and animal life histories (*Balasse* et al. *2002; Vaiglova* et al. *2018; Ventresca Miller, Makarewicz 2018; Ventresca Miller* et al. *2020; Eger* et al. *2022; Hermes* et al. *2022; Janzen, Upex 2023; Samei* et al. *2023; Reinhold* et al. *2024*).

We sampled 14 molars of herbivores: seven of cattle and seven of caprine (sheep or goat). Sampling and chemical preparation were conducted at the laboratory facilities of the Integrative Prehistory and Archaeological Science, Department of Environmental Sciences, University of Basel, and followed established procedures (*Gerling 2015; Gerling* et al. *2017*).

Carbon and oxygen isotope compositions were determined using a Gasbench II coupled to a Delta V Advantage mass spectrometer (Thermo Fisher Scientific, Bremen, Germany) at the Aquatic and Isotope Biogeochemistry, Department of Environmental Sciences, University of Basel. The analytical reproducibility of $\delta^{13}C$ and $\delta^{18}O$, respectively, of the three isotopic standards, was ≤ ± 0.10‰. The

analytical reproducibility of $\delta^{13}C$ and $\delta^{18}O$ of each sample was $\leq \pm 0.15$. $^{87}Sr/^{86}Sr$ was analysed using a Thermo Fisher TRITON Thermal Ionization Mass Spectrometer (TIMS) at the National Oceanography Centre, University of Southampton. The long-term $^{87}Sr/^{86}Sr$ average of the international reference material NIST SRM 987 for this instrument is 0.710243± 0.000021 (2σ) (n=303). The average column blank was 0.2ng.

Phytolith and dung spherulite analyses

Fifteen samples from Ksizovo-1 were analysed for both phytoliths and dung spherulites to complement the archaeobotanical and archaeozoological data, providing a deeper understanding of plant use and animal presence at the site.

Phytoliths, solid silica deposits formed in plants after silica uptake from groundwater, differ morphologically between species, allowing identification in archaeological materials (*Piperno 2006; Bates* et al. *2017*). As inorganic compounds, phytoliths are durable in soils but soluble in alkaline conditions. Recovered phytoliths were classified as monocotyledonous (grasses) or dicotyledonous (woody plants) based on their form (*Albert, Weiner 2001*). In grasses, stem/leaf and inflorescence phytoliths can be distinguished, while in woody plants, wood/bark phytoliths are separable from leaf phytoliths. However, grass short cells are found throughout the plant, making part identification challenging.

Dung spherulites, microscopic calcium carbonate features found in animal dung, are key indicators of the presence of herbivores, particularly ruminants (*Canti 1997*). These spherulites are well preserved in alkaline environments or in areas with low water flow (*Canti, Brochier 2017*). Their analysis sheds light not only on animal presence but also on dung use, hygiene conditions, and other cultural practices (*Albert* et al. *2008; Portillo* et al. *2014; Smith* et al. *2019*).

Methods for both analyses included the Rapid Extraction Method for phytoliths (*Katz* et al. *2010*), separating approximately 0.04g of sediment, and statistical analyses following Rosa Albert *et al.* (*1999*) using ICPS 1.0 nomenclature (*Madella* et al. *2005*). Phytoliths were counted across 25 fields per slide, with up to nine morphotypes photographed due to low recovery. Diatom detection was also attempted, but none were found. Dung spherulites were analysed according to Matthew Canti (*1997*), using approximately 0.001g of sediment mounted on slides with Entellan, Neu (Merck). Examination under polarized light revealed no dung spherulites in the samples.

Organic residue analysis on pottery fragments

The analysis of organic residues aimed to obtain new insights into the food habits, diet, and consumption practices of the Bronze Age inhabitants of Ksizovo-1, as well as to assess the general preservation of organic residues at this site. While the archaeological evidence from Bronze Age communities in the Russian steppes suggests a largely pastoral way of life (*e.g., Knipper* et al. *2020*), the exact composition of human diets in this region remains underexplored. To this end, a pilot study was conducted to analyse organic residues on pottery fragments from Ksizovo-1. For this pilot study, samples of food crusts from 18 pottery fragments were subjected to chromatographic and spectrometric analyses performed at the laboratories of the Department of Archaeology at the Max Planck Institute of Geoanthropology, Jena, Germany. The samples were systematically collected by the excavators. Burned food crust remains were removed with a scalpel from the interior surfaces of the vessels.

We used a multi-analytical approach to study the organic remains, including organic residue analysis (ORA) by gas chromatography mass spectrometry (GC-MS) and liquid chromatography tandem mass spectrometry (LC-MS/MS). ORA involves the extraction and analysis of organic compounds, such as lipids and small molecules (metabolites). Such molecules can provide insights into the types of food and drink that were consumed in the past. The samples were extracted following established protocols (*Matyash* et al. *2008; Salem* et al. *2017*), with modifications made for the extraction of ancient samples. Briefly, approximately 20–70mg of sample was homogenized into a fine powder using a micro pestle and solvent extracted with a methyl tert-butyl ether / methanol (3:1, v/v) solution. The samples were homogenized on a vortex mixer and incubated on an orbital shaker for 45min at 300rpm. Subsequently, samples were sonicated for 15min. and centrifuged at 20 000 x g for 5min. At this stage, the biomolecules were separated into two phases: (i) a liquid phase containing lipids as well as semi-polar and polar metabolites, and (ii) a solid precipitated pellet on the bottom composed of proteins and starches. While the liquid phase was transferred to a new vial, the pellet remained in the tube and will be subjected to future palaeoproteomic analysis.

An aliquot of the liquid phase was derivatized with 100µl N,Obis (trimethylsilyl) trifluoroacetamide (BSTFA, containing 1% TMCS, Sigma-Aldrich) for 60min at 70°C and then analysed by GC-MS. GC-MS analyses were performed using an Agilent 8890 GC-System coupled to an Agilent 5977B GC/MSD. Chromatographic separation was achieved on a HP-5ms 60m x 250µm capillary column (Agilent) with a film thickness of 0.25µm. The mass spectrometer was operated in electron impact (EI) mode at 70eV and helium was used as a carrier gas. The GC oven temperature was set at 50°C and held for 2min, then ramped at 120°C at a rate of 30°C/min. The temperature was increased again at 15°C/min to 280°C and at 30°C/min to 320°C with a final hold time of 3min. The total run time was 45min with a solvent delay of 6.5min. The injection volume was 1µl and a split ratio of 10:1 was used. The scanning range was set from m/z 40 to 700. Injection blanks were carried out between each sample to avoid carryover. Transfer line and source temperature were set at 250°C and 230°C, respectively.

Another aliquot of the extract was prepared for LC-ESI-MS/MS analysis in multiple reaction monitoring (MRM) mode. Analysis was performed with a Shimadzu LCMS-8050 triple-quadrupole system operating with an ESI source, with LC-30AD HPLC pumps, using two different columns (Shimadzu Shimpack Velox SP-C18, 2.7µm, 100x2.1mm and Restek Raptor Biphenyl 2.7µm 100x2.1mm). The sample was run with gradients of Acetonitrile (CAN) and H_2O:0.1% Formic Acid (FA) in duplicates with blanks in between.

Methanol (MeOH), and methyl tert-butyl ether (MTBE) were obtained from Sigma-Aldrich (Munich, Germany). MS-grade formic acid was purchased from VWR (Leuven, Belgium), while acetonitrile (CAN) and water used for HPLC-MS/MS analyses were purchased from Biosolve (Valkenswaard, Netherlands). The analytical standards campesterol, cholesterol, 5α-cholestanol, β-sitosterol, stigmasterol and betulinic acid were obtained from Sigma-Aldrich (Munich, Germany), coumarin and oleanolic acid from LGC Standards (Wesel, Germany) and sitostanol from Avanti (Darmstadt, Germany).

Results and discussion

Radiocarbon dating

The large number of samples for AMS dating gave a heterogeneous picture after calibration. Some results are consistent with the relative assignment of Ksizovo-1 to the Catacomb culture of the Middle Don region and its absolute chronology, and thus ten dates fall into the second half of the 3rd millennium BCE (Fig. 7). However, several dates do not correspond to the archaeological expectation. Five samples have considerably younger calibrated time spans, four of which point to the 1st century CE (Poz-148847, Poz-149008, Poz-154710, Poz-154727). Sample Poz-134197 was dated to the 14th to 15th centuries CE. While these five late dates could be explained as inadvertent contaminations, the earlier time span of sample Poz-155171, indicating the beginning of the 3rd millennium BCE, seems odd in the context of a settlement with only one cultural horizon. However, this date can be explained in two ways. The sampled charcoal comes from oak wood for which the trees can live for several hundred years. If the charcoal comes from the inner part of an old tree, the radiocarbon date would correspond to the age of the heartwood (*Schiffer 1986*). A slightly younger date for sample Poz-133605 gave a calibrated interval of 2031–1778 cal BCE (Fig. 7, Tab. 5 in the Appendix). The reason for this date could be a younger intrusion.

The large number of radiocarbon dates contributes significantly to knowledge of the Middle Don Catacomb culture. However, six samples appeared to be intrusions from later times. The two charred remains of cereals and most of the charcoal fragments were probably transported into the cultural layer of the settlements by rodents. Obviously, animal bone fragments yielded more reliable dates, as seven of them fall between 2500 and 2000 BCE after calibration (Fig. 7). Two dates obtained from archaeobotanical macro-remains and only one from charcoal. Nevertheless, the calibrated time spans can be divided into two groups, one with earlier and the second one with later dates. This is probably due to two use phases of this settlement area for various economic activities. With a probability of 95.4%, the dates fall within the period 2400–2100 BCE. This finding is consistent with the assignment of the site based on the pottery typology to the observation of a single relatively thin settlement layer (*Gak* et al. *2017*). However, the nature of these effects has to remain open, as there is also room for debate surrounding the wiggled parts of the calibration curve during this period. In general, the data obtained for this settlement falls within the developed phase of the Catacomb culture (*Kaiser 2019.53–61; Ivashov, Gak 2019*).

Archaeobotanical analysis

Only ten carbonized plant macro-remains were recorded in seven of 54 archaeobotanical samples. Almost

all of them were poorly preserved and fragmented, which greatly limits the possibilities of identification. Crop plants were represented by two definable grains of barley (*Hordeum vulgare*) and millet (*Panicum miliaceum*), as well as two fragments of cereal grains that could not be determined to the genus level (*Cerealia*); two more similar fragments were assigned to this category presumably (cf. *Cerealia*). In addition, a small fragment of a hazelnut shell (*Corylus avellana*), an indeterminate endocarp fragment of the plum genus member (*Prunus* sp., and it may be a bird cherry *P. padus* or a blackthorn *P. spinosa*) and a very small indeterminate fruit shell fragment (*Corylus/Prunus*) were found. The last, tenth charred object was classified as an undefinable fruit/seed. Given the above finds, it cannot be excluded that this is a deformed kernel (seed) from a *Prunus* sp. stone.

Four macro-plant remains from Ksizovo-1 were dated by AMS (Tab. 1). The fragmented shell of a hazelnut and *Prunus* sp. endocarp show almost identical calibrated time spans from 2600 to 2300 BCE (Fig. 8, Poz-149009-149010). However, the charred grains of barley and millet have been dated to the second half of the 1st millennium BCE in this study (Fig. 7, Poz-148847, Poz-149008), confirming the assumption that cereals were not cultivated in Eastern Europe during the Early and Middle Bronze Age (for a more detailed discussion on the occurrence of millet in the Bronze Age see Kirleis *et al.* (*2022*)). There is no doubt that these remains are intrusive to the settlement layer of Ksizovo-1 and are related to an Early Iron Age settlement that was located north on the second terrace above the floodplain (*Gak* et al. *2017*).

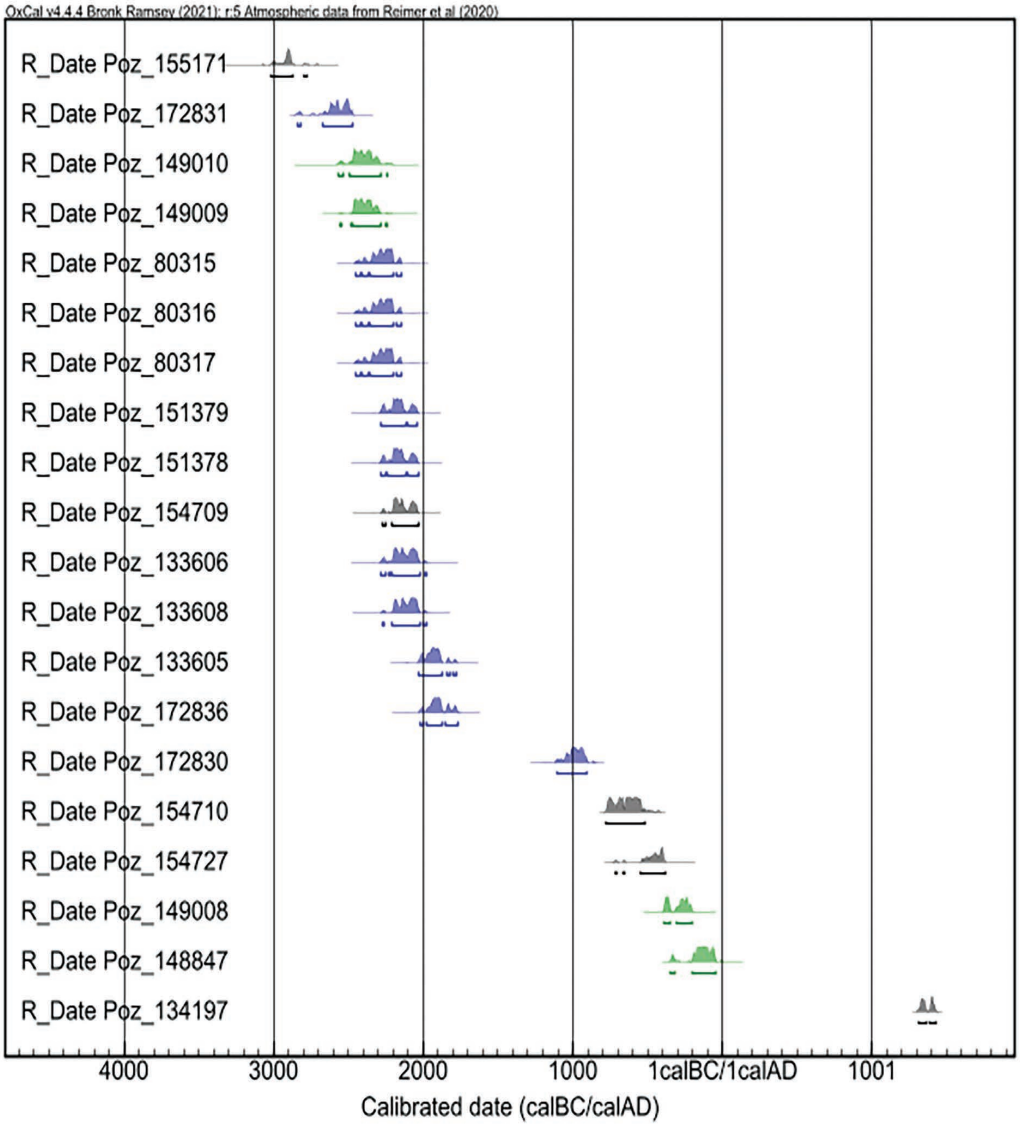

Fig. 7. Radiocarbon dates of all sampled materials from the settlement Ksizovo-1. Calibrated using OxCal v4.4. Blue: animal bone; green: archaeobotanical macro-remains; black: charcoal.

The small number of remains of wild fruits and nuts, despite the verification of their age by radiocarbon dating, does not allow us to unambiguously assess gathering as an economic factor in Ksizovo-1. Moreover, such an assumption is inconsistent with other data provided in this study (archaeozoological, phytolith analyses, *etc*.) regarding the winter season of habitation at the settlement, when forest gathering is simply impossible. From the archaeobotanical perspective, the complete absence of seeds of wild and weedy grasses in the archaeobotanical samples can testify in favour of a winter occupation at Ksizovo-1. Therefore, it cannot be excluded that the macroremains of forest fruits could have appeared at the settlement quite accidentally, for example, while still attached to the trees and shrubs cut down for fuel. Hazelnut, bird cherry, and blackthorn are common in the forests of the Lipetsk region (*Alexandrova* et al. *1996*), and they could have grown along dry gullies and in the river floodplain around the settlement. Such forest areas must have been cut down already by the first settlers (the ^{14}C dates of our finds are almost the earliest).

Wood charcoal is another component of archaeobotanical samples, which marks the seasonal, short-term use of the settlement. Quantitative indicators of the presence of charcoal fragments in the Ksizovo-1 culture layers are extremely low: a total of 1711 fragments were recorded in 54 samples, or an average of 2.8 fragments per 1 litre of sediment (Tab. 6 in the appendix). The charcoal fragments were very small, often 2–3mm, and the few largest pieces did not exceed 7–8mm. It is noticeable that even samples taken from fireplaces and locations presumably associated with metal processing are hardly distinguishable in terms of charcoal abundance. It can be assumed that the total volume of charcoal fragments in the entire collection was hardly more than 4–5ml. In permanent settlements, charcoal accumulates more intensively in the cultural layers, since large volumes of wood are used for fuel, fires occur more often, and so on. In temporary seasonal camps, however, not only was people's activity less intense, but also precipitation (snow, rain) contributed to the destruction of even carbonized organic remains during periods when the settlement was empty. This is probably the case for the Ksizovo-1 settlement.

Archaeozoological analysis

The animal bones from Ksizovo-1 are characterized by poor natural preservation: their surface is broken, the bone tissue is fragile, and the edges of the fractures are vague, but almost all the fractures on the fragments are of relatively ancient origin. On a five-point scale, such bone condition is estimated at 1–2 points (NP, Tab. 2). Due to disturbances of the bone surfaces, traces of artificial exposure have not been preserved: only one single fragment has been recorded with gnawing left by rodents. Bone fragmentation is significant: the fragmentation index (FI) varies for individual specimens from 40 to 190 fragments per 1 cubic dm, its average value for the collection is 74 (see FI, Tab. 2). Visual assessment shows that about 60% of the collection contains fragments between 1 and 5cm, 30% between 5 and 10cm, and only 10% larger than 10cm.

These archaeological characteristics reflect extremely unfavourable taphonomic conditions for the preservation of organic remains: the most important factors were peculiarities of the sediment and its increased seasonal moisture content. An additional factor in the significant fragmentation of the bones was probably the production activity on the studied area of the settlement: both single finds and clusters of different volumes were recorded in the excavated trenches, although often the clusters were the remains of only a single large bone. A small number of burnt bones with

Sample ID	Material	Excavation layer	Lab ID	^{14}C age BP	cal BC (σ 95.4%)	Remarks (Lab)
8/2021	*Hordeum vulgare* (3525)	2	Poz-148847	2115 ± 35 BP	346BC (6.8%) 316BC 205BC (88.6%) 43BC	-
9/2021	*Panicum miliaceum* (3527)	3	Poz-149008	2255 ± 30 BP	393BC (33.2%) 349BC 312BC (62.2%) 206BC	0.4mgC
10/2021	*Corylus avellana* (3526)	4	Poz-149009	3910 ± 35 BP	2552BC (0.2%) 2549BC 2487BC (0.2%) 2485BC 2476BC (94.4%) 2286BC 2247BC (0.7%) 2238BC	0.4mgC
11/2021	*Prunus* sp. (3529)	3	Poz-149010	3920 ± 40 BP	2566BC (4.5%) 2531BC 2495BC (90.4%) 2286BC 2246BC (0.5%) 2239BC	-

Tab. 1. Results of the radiocarbon dating of archaeobotanical samples, for all calibrated dates, see Figure 7.

different colours were also found. Under such unfavourable conditions of preservation, taphonomic losses in the osteological material of Ksizovo-1 are inevitable. However, the total quantitative volume of the collection (total number of fragments, Tab. 2) is substantial: about four thousand fragments are documented, which allows a reliable quantitative assessment of the collection for the main taxonomic groups. The majority – more than two-thirds – of the assemblage was found in the western part, excavated between 2014 and 2017, and only one-third in the eastern part, excavated between 2018 and 2020 (see Table 7 in the appendix), although these two areas are comparable in terms of excavated volume. At the same time, the poor taphonomic condition of the osteological material made it difficult to determine age and reconstruct animal sizes, and also made it impossible to determine the sex of domesticated animals.

Taxonomic identification showed that all bone remains belonged to mammals, and no other taxa were identified. Less than half (41.2%) of the total collection was identified to the species level, but we consider this number sufficient to reveal the hierarchy of species, and to calculate the osteological spectra reflecting the characteristics of the entire collection of osteological material. The species composition includes five domestic species (Tab. 2): cattle (*Bos taurus*), horse (*Equus caballus*), sheep/goats (*Ovis aries/Capra hircus*) and dog (*Canis familiaris*). Bones of domestic pig (*Sus domestica*) were not found. Wild animals include species conventionally hunted in the region until the 19th century: wild boar (*Sus scrofa ferus*), bear (*Ursus arctos*), elk (*Alces alces*), beaver (*Castor fiber*), roe (*Capreolus capreolus*), wolf (*Canis lupus*) and hare (*Lepus* sp.). In addition to animal bones, a fragment of a human humerus was also found in the settlement. Although this finding is considered unusual, it is noteworthy that fragmented human bone remains are repeatedly found in other Bronze Age settlements, for example in the osteological material of Rykan-3 (*Gak* et al. *2023*).

Taxa	NISP	%	%
Domestic animals			**85.8**
Cattle	1103	67.0	
Horse	167	10.1	
Sheep/Goat	135	8.2	
Dog	9	0.5	
Wild animals			**14.2**
Boar	87	5.3	
Bear	72	4.4	
Elk	52	3.2	
Beaver	15	0.9	
Roe deer	5	0.3	
Wolf	1	0.1	
Hare	1	0.1	
Total NISP	1647	100	100
Indeterminate bones			
Large-sized mammal	2153		
Medium-sized mammal	194		
Total n fragments	3994		
% identified fragments	41.2		
Volume	54.0		
Bones' taphonomic status			
FI	74.0		
NP	1-2		

Tab. 2. Species composition and quantitative data of the total osteological collection of Ksizovo-1.

The general osteological spectrum is dominated by six species: three species of domestic animals (cattle, horse, sheep/goat, and distinction between these last two species was not possible) and three species of wild animals (wild boar, bear, elk). The quantitative ratio of bones from domestic and wild animals (86% and 14%, respectively, Tab. 1) clearly shows the focus on meat-oriented animal husbandry in Ksizovo-1.

Among domestic animals, dogs are only represented by a very small proportion of bone fragments. Almost all of the scattered dog remains were found within the western part of the site (Tab. 7 in the appendix). We view the presence of these bones in the cultural layer of Ksizovo-1 as an analogy to the frequent finds of whole skeletons and dispersed remains of dogs in Eastern European settlements of the Middle and Late Bronze Age interpreted as animal sacrifice (*Antipina 2004*). Individual bones of beaver, roe deer, wolf and hare can be considered as components of the species composition of hunted animals: they represent only 1.3% of the whole osteological assemblage.

Two unresolved issues arose when identifying the large mammal faunal remains. The first question concerns the interpretation of several bones (two humeri and three phalanges) from large representatives of the taxonomic tribe *Bovini* (wild cattle) that are significantly larger than any of the other comparable bones identified as domesticated cattle. These large bones could belong to either the European wild cattle (*Bos taurus ferus*) or the European bison (*Bison bonasus*), whose remains have been found at Neolithic and Bronze Age archaeological sites of the Eastern European forest-steppe (*Tsalkin 1958; 1970; Zhuravlev 2001; Antipina*

2011a). However, they could also belong to the skeletons of the largest domestic bulls, which were present in the economy of different cultures of the Bronze Age in the southern regions of Eastern Europe (*Tsalkin 1970*). Furthermore, the upper limits of size variation in prehistoric domestic cattle are not yet determined. The second question concerns the controversial issue of the 'identification' of domestic horses from archaeological bones. In contrast to the horse bones from the Catacomb culture Rykan-3 settlement, for which we were able to determine the status of these animals as domestic (*Gak* et al. *2023*), the situation is not clear for the Ksizovo-1 collection. Moreover, according to the generally accepted opinion of zoologists, wild horses were a common component of the fauna of the forest-steppe regions of Eastern Europe (including the Upper Don) up to the Middle Ages (*Kirikov 1959*). Given the new trends in the identification of ancient domestic horses, in particular the application of 'genetic markers' to reveal their exploitation as a source of dairy food (*Librado* et al. *2021*), we leave the verification of the status (domestic/wild) of Ksizovo-1 horses open. Nevertheless, even if we attribute all the bones of the indicated large cattle and horses to wild animals, this does not change the claim regarding the clear dominance of domestic animals, in particular cattle, in the Ksizovo-1 economy. Therefore, in our study the bone remains of these two groups with 'uncertain status' are further considered alongside domestic animals.

The analysis of the skeletal element distribution of the six most numerous species in the collection of Ksizovo-1 domestic and wild animals confirmed the assumption that their remains represent food refuse. All parts of the skeleton were found with a clear emphasis on the bones with the greatest muscle mass, *i.e.* from the meat parts of the carcasses (Fig. 8). This indicates that both the slaughtering of cattle and the processing of whole carcasses of wild animals took place directly at the settlement. Considering the quantitative occurrence of cattle bones, it can be undoubtedly stated that beef was the basis of the meat diet of the settlement's inhabitants and the herds at Ksizovo-1 were dominated by this species. A similar pattern of meat-oriented cattle breeding with large-scale cattle husbandry is revealed by materials from other Catacomb culture settlements (*Antipina 2008*), in particular at the site of Rykan-3 (*Gak* et al. *2023*).

The anatomical spectra of the main species also show a certain disproportion in relation to the most numerous skeletal elements – teeth, vertebrae and ribs. This disproportion can be explained by poor natural preservation of bones. For all six species, a similar pattern was recorded. The highest numbers were recorded for teeth (the most robust elements) and lowest numbers were recorded for axial skeletal elements – vertebrae and ribs. The low number of vertebrae of all six species is most likely due to the fragile structure of their bone tissue. The low number of rib fragments may be due to taphonomic factors as well as to the use of ribs as tools. For instance, cattle and horse ribs with abrasion traces on the fractures or on the concave edges are known from archaeological sites from the Palaeolithic to the early Middle Ages as 'smoothers' or 'scrapers' that were mostly used in the processing of hides (*Semenov 1968.160–161; Kileinikov 2009.107–109; Roslyakova 2017.483*). When ribs are used as such, their number in food waste tends to decrease sharply. It is worth noting that vertebral and rib fragments are also extremely rare among the group of bone remains that cannot be determined to the species level, which emphasizes the significance of the disproportion in question. It is also worth noting that the proportion of animal skull fragments in the assemblage was extremely low.

Another interesting detail is the isolated occurrence of metapodials and phalanges of bears. Both elements are robust and originally numerous in the skeletons of this species. At the same time, other bones of bears, with the exception of the skull, have been found in considerable numbers at the site. Such a pattern of the limited occurrence of cranial fragments, lower limb bones, and phalanges may be related to the widespread phenomenon of sacralization of the bear's skull, paws and claws with regard to its veneration by ancient populations of Eastern Europe, in particular it is known among the Upper Don population at the turn of the Neolithic and Eneolithic (*Podobed* et al. *2013; Bessudnov* et al. *2015*). These specific parts of the carcass are usually separated for special processing and are rarely found among food refuse.

Based on the dental material which, similarly to all other skeletal elements, is fragmented, it has been possible to obtain some information regarding the age ranges of domestic and wild animals at this location. For cattle, a range of eight to 10 months to 10 years and potentially older has been identified, with a predominance (about 60% of the sample consisting of 114 cheek teeth from mandibles) of the two- to four-year-old age group, using the Anny Grant's (*1982*) methodology.

Given that the 'natural' calving season for cattle falls in the spring months (April to May), it can be assumed that the slaughter of young calves eight to 10 months of age occurred in winter or early spring. The age range of horses was revealed by 30 molars, of which 17 were milk premolars of different stages of wear. In accordance with zootechnical data on the process of change of milk premolars in this species (*Vokken* et al. *1961*), all horse teeth were divided into two groups: young, aged one to two years, and subadult individuals aged three to five years. In addition, among the horse bones was one tooth of an old animal which was at least 20 years old, as well as a fragment of a few weeks-old foal's milk tooth. Most of the teeth of sheep/goat were preserved as enamel flakes with completely destroyed dentin, which did not allow us to identify the age of specific individuals, but all of these teeth certainly belong to the permanent dentition, which begins to wear from an age of about 1.5 years.

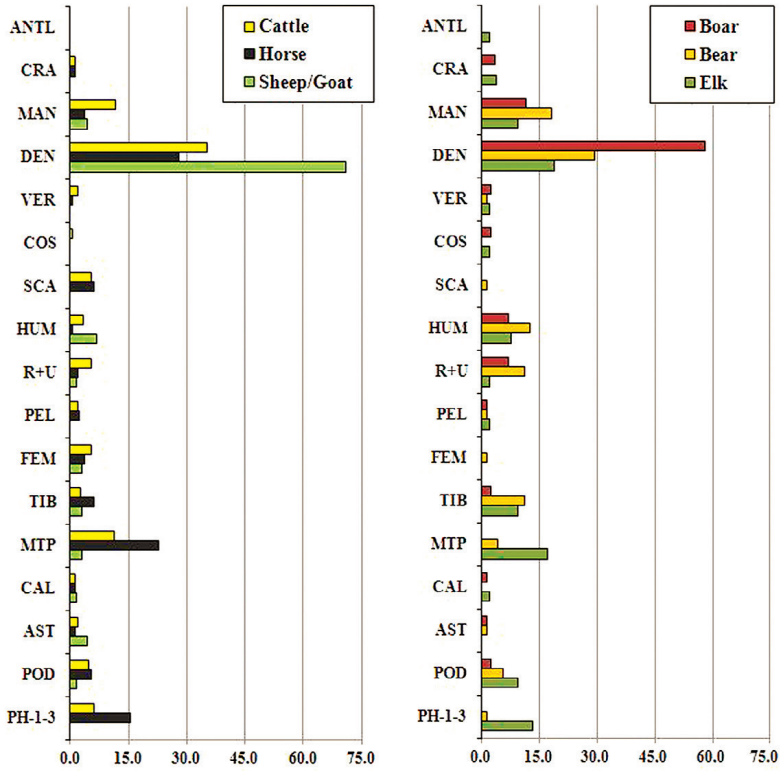

Fig. 8. Skeletal element distribution of the main species in percent.

Despite the small absolute number of preserved teeth of wild animals, our study revealed the presence of wild boar, bear, and elk from all age groups (Tab. 1). The age data for the teeth of wild boar and bear were of particular interest (Fig. 9). In these species, there is a certain frequency of relatively young individuals whose molars do not show wear of the occlusal surface. A relatively accurate age of 12 months could be determined for one individual bear (*Geptner* et al. *1967; Guskov 2014*). According to zoological evidence, the birth of bear cubs usually takes place in January and February (*Geptner* et al. *1967*), thus allowing us to project the hunting of this one-year-old bear cub into the winter period of the year. Considering the pronounced sexual dimorphism in wild boars and bears, significant differences in the size of their permanent molars observed not only on complete teeth in the sample but also on fragmentary teeth suggest that there are both females and males among the procured remains.

The almost complete absence of the measurable bones among the postcranial skeletal remains made it very difficult to characterize the size and exterior features of domestic and wild animals. Nevertheless, at the macro level two major body-size trends were noted. First, the variability in carcass sizes was found to be unusually high in both domestic and wild animals. In male and female cattle, they exceeded the limits of their sexual dimorphism, while in wild boar, bear, and elk, substantial differences in the size of their bones confirm the presence of males and females among the hunted animals, as determined from dental material. Second, it was found that most of the bones of all six species discussed, both domestic and wild mammals, were from large individuals.

Large cattle from Ksizovo-1 can be compared with the East European draught cattle of the Bronze Age (*Tsalkin 1970*), whose height at the withers averaged 130cm, while the sizes of the smallest individuals resemble the appearance of local medieval cattle, barely reaching 100cm at shoulder height (*Tsalkin 1956*). A similar wide variability in size was noted for cattle from Rykan-3 (*Gak 2019*). This could be interpreted as the presence of either dissimilar breed groups, individuals used for different economic purposes, or animals whose fodder base differed sharply in terms of nutritional value. The latter variant could be associated with a change of pastures and thus, to a certain extent, with a mobile form of cattle husbandry. The presence of osteophytes/exostoses on a number of phalanges

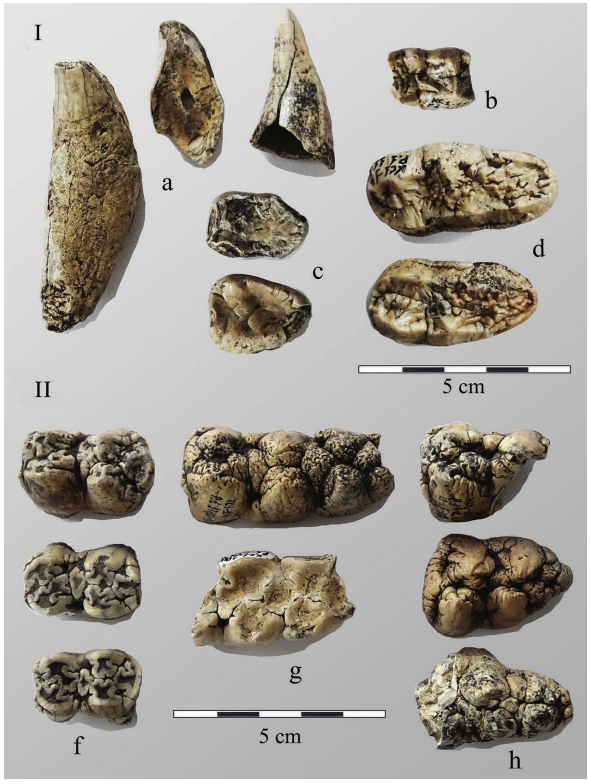

Fig. 9. Example of teeth of bear (I) and wild boar (II).

as well as traces of degenerative changes on the metapodials and femoral joints confirm that one of the ways in which the Ksizovo-1 oxen were exploited as draught animals.

The size characteristics of wild boar, elk, and bear, which indicate a certain predominance of large, male, individuals, prompts attention to the motivation for their hunting, especially in view of their relatively important position in the osteological assemblage. The economic aspect of the hunt is supported by the possibility of obtaining important postmortem products that are less available from the domestic mammals: tense hides and warm fur, as well as valuable parts of the carcass (fat, veins, skin, fur, hair, bear bile, *etc.*). It is likely no coincidence that most of their bones were found in the western part of the area where, according to the archaeological material, hides might have been worked. An extensive corpus of written sources and ethnographic information provides the basis for the conclusion that hunting of these animals was best during the winter season, when the snow cover facilitates tracking and significantly limits the speed of animal movement: winter hunting of moose and wild boar occurred 'on the snow crust', while for bear prey this took place 'in the cave' (*Melnitsky 1915; Kirikov 1966; Geptner* et al. *1967; Rudenko, Semashko 2003*). It is equally important to note that these animals achieve the best condition in terms of their physical parameters in the cold season. We have already mentioned above that the tooth of a one-year-old bear cub found among the bear remains in Ksizovo-1 indicates that it was hunted during the winter. However, it should not be ignored that wild pigs and bears were the most powerful and largest representatives of the fauna of the region and that their killing, even in winter, was a serious endeavour that could often have ended with the death of hunters. The actual risk and emotional intensity of this activity may have been used by the inhabitants of the site as an instrument for the ritual practice of socialization in the initiation of young adults (*Kharusin 1899; Vasilyev 1948; Gulyaev 2019*).

It is very likely that several motives played a role in the hunting of wild pig, bear, and elk, making hunting an important complement to the winter economy of the inhabitants.

Isotopic analysis on animal remains

In Figure 10, exemplary isotopic data are presented for two third molars (M3) of one cattle and one sheep/goat from Ksizovo-1. The complete isotopic data set is published elsewhere (*Gerling* et al. *2024*). Using the $\delta^{18}O$ values obtained from the sequentially sampled tooth enamel representing approximately an annual cycle and the conjointly measured $\delta^{13}C$ values, we can evaluate seasonal trends or changes in the diet of the domestic animals that were herded, which in the case of herbivores corresponds to the plants consumed during tooth formation (*Cerling, Harris 1999; Balasse* et al. *2002*). In both diagrams, a nearly complete sinusoidal variation of $\delta^{18}O$ values along the growth axis of the tooth enamel is shown, reflecting seasonal changes in the oxygen isotope composition of ingested water due to differences in temperature (*Sponheimer, Lee-Thorp 1999; Makarewicz 2017; Pederzani, Britton 2019*). Low $\delta^{18}O$ values reflect the intake of ^{18}O depleted water during winter, whereas high $\delta^{18}O$ values reflect the intake of ^{18}O enriched water during summer (*Fricke, O'Neil 1996*).

The $\delta^{13}C$ values show only minor seasonal variations, which might be considered as natural fluctuations. In general, $\delta^{13}C$ values of the two specimens indicate pure C_3 vegetation-based diet, as expected for the forest-steppe region. It also concurs with the tentative results of the phytolith analyses (see next section).

The strontium isotope ratios ($^{87}Sr/^{86}Sr$) incorporated during tooth formation through food chains reflect the

geological conditions in the area from which fodder was obtained, thus preserving information on dietary catchments (*Capo* et al. *1998; Bentley 2006*). The strontium isotopic variation of the cattle and sheep/goat M3 presented here is low, *i.e.* < 0.0001, between the summer and winter $^{87}Sr/^{86}Sr$ ratios in each tooth and between the two individuals. The preliminary results point to herding mobility restricted to reasonably similar geologies. Overall, all three isotope values analysed in conjunction point to domestic animal management with seasonal movements within the same geology, ecology and climate. The complete isotope data set published in Claudia Gerling *et al.* (*2024*) confirms these interpretations.

Phytolith and dung spherulite analyses

The results of the phytolith analyses are summarized in Table 3. Since there were very few phytoliths observed in the samples (in fact, none were observed in sample K5), no statistical analysis was performed. Multicellular phytoliths were not observed in the samples, but weathered morphotypes were found in nine of the 15 samples (K2, 3, 4, 8, 9, 10, 12, 13, 14) (see Fig. 11). This suggests very strong chemical exposure, which could be due to reactions resulting from heavy rainfall and/or a moist environment.

The determination of the taxa and thus the assignment to C_3 or C_4 plants should be done with great caution, since the number of phytoliths is very low and the preservation was not good. Therefore, the following descriptions remain tentative.

Dendritic/dentate, prickle or bilobate forms (Fig. 12) could be an indication of cereals. These were observed in 10 out of 15 samples (K6, 7, 8, 9, 10, 11, 12, 13, 14, 15), which could be an indication of cereal consumption, most likely collected wild forms, considering the macro-botanical remains.

Blocky phytoliths (Fig. 13), usually characteristic of woody plants, were observed in six samples (K6, 9, 10, 12, 13, 14).

An interesting find was a structure that was not a phytolith but could be a part of a parasitic organism (?) such as a flea or mite in sample K4 (Fig. 14).

In general, the very small number of phytoliths in the samples from Ksizovo-1 is not sufficient for a detailed analysis. The majority of the recovered phytoliths originate from grasses, though it is not possible to distinguish between wild and cultivated species. Given that grasses typically produce more phytoliths than woody plants (*Piperno 2006*), it is unsurprising that they dominate the phytolith assemblage at Ksizovo-1. The presence of cereals, presumably from wild plants, cannot be confirmed, but cereal-specific morphotypes (subfamily Panicoideae) are found in most samples. The absence of multicellular phytoliths in the samples did not allow the species of the grasses to be determined. A very small number of phytoliths from woody plants was also identified (possibly from the wood/bark part of the plant), but does not allow any further conclusions to be drawn.

There may be several reasons for the absence of dung spherulites at Ksizovo-1. Moist environments cause low pH values in sediments which, in turn, affect the preservation of dung spherulites. In a study using geo-

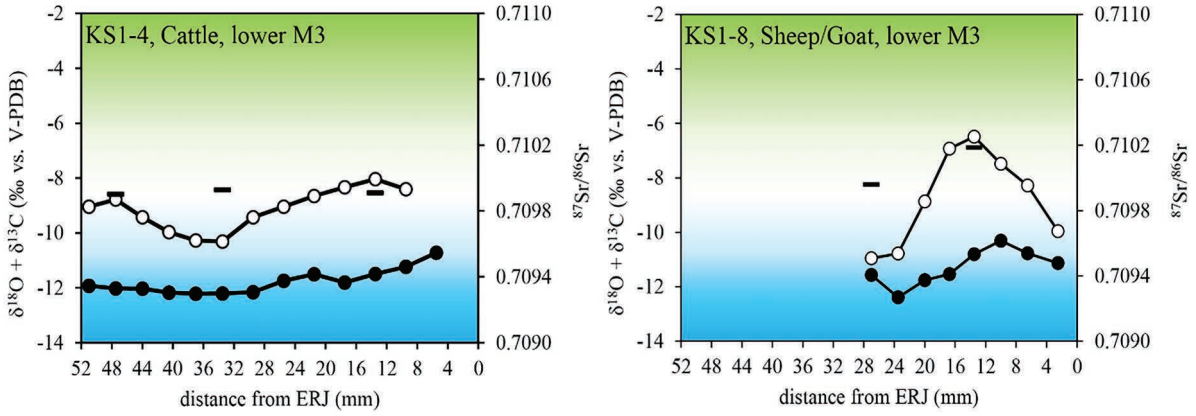

Fig. 10. $\delta^{13}C$ and $\delta^{18}O$ values (black and white circles, respectively), and $^{87}Sr/^{86}Sr$ ratios (black dashes) for third molars (M3) of one cattle and one sheep/goat from Ksizovo-1 representing* c. *1 annual cycle. Blue colouring indicates a C_3 plant-based diet, while green indicates an influence of C_4 plants. C_3 or C_4 plants can be distinguished by isotopic analysis as they use different photosynthetic pathways (*Smith, Epstein 1971; Schwarcz, Schoeninger 1991; Cerling *et al.* 1997; Price, Burton 2011*).

chemical analyses of soil samples from Ksizovo-1, Anastasiya Potapova and her colleagues (*2020*) found that pH values were lower during the occupation of the site than in the period after the settlement was abandoned. These lower pH values could thus be a reason for the absence of dung spherulites in the sample.

The low number of phytoliths could in turn be either because: (i) there was little phytolith formation in the plants, *e.g.*, because the sediment contains little silica; (ii) phytoliths could be dissolved or translocated (*i.e.* transported to deeper layers) due to high pH values, *e.g.*, due to heavy rain activity; or (iii) there was generally little vegetation cover in the vicinity of the site. In addition, the absence of multicellular phytoliths could be related to the insufficient production of phytoliths that were only attached to single cells. There is also the possibility that there are no phytoliths from inflorescences because they did not occur at the site, or that the site was inhabited at a time when plants did not form inflorescences, *i.e.* in winter.

Comparable phytolith analyses were conducted at the Late Bronze Age settlement of Krasnosamarskoe in the Samara River Valley in the northern Russian steppe (*Weisskopf, Rosen 2016*), though the environmental conditions there differ from those at Ksizovo-1. Despite this, a notable similarity emerged: both sites exhi-bited an absence of multicellular phytoliths. At Krasno-

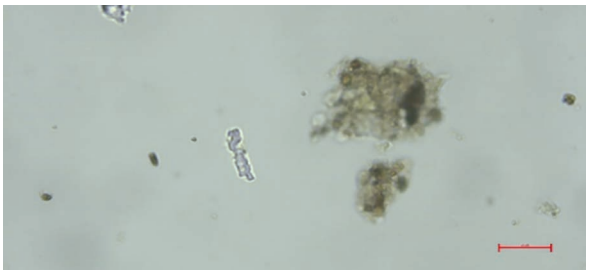

Fig. 11. Weathered phytolith from sample K2.

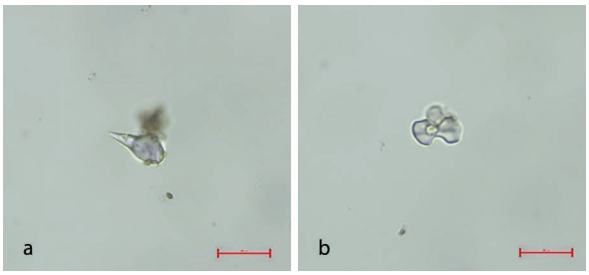

Fig. 12. Prickle (a) and bilobate (b) phytoliths from sample K6.

Fig. 13. Blocky phytoliths from sample K12.

Sample ID	Amount of phytoliths per 1g of sediment	# of phytoliths observed in 25 fields	Possible taxa	C_3/C_4	Condition	Other remarks
K1	19620	3	(Wild) grasses	C_3		
K2	13080	2	(Wild) grasses	C_3	Weathered	
K3	26160	4	(Wild) grasses	C_3	Weathered	
K4	13080	2	(Wild) grasses	C_3	Weathered	
K5	NA	-				
K6	39240	6	(Wild) grasses and Cereals? Panicoideae, wood	C_3 (and C_4?)		Millet?
K7	39240	6	(Wild) grasses and cereals?	C_3	1 broken = physical impact?	Broken from grinding?
K8	32700	5	(Wild) grasses and cereals?	C_3	Weathered	
K9	19620	3	Cereals and Wood	C_3	Weathered	
K10	26160	4	Cereals and Wood	C_3	Weathered	
K11	26160	4	(Wild) grasses and cereals?			
K12	58860	9	Cereals and Wood	C_3	Weathered	
K13	13080	2	Cereals and Wood	C_3	Weathered	
K14	13080	2	Cereals and Wood	C_3	Weathered	
K15	6540	1	(Wild) grasses and cereals?	C_3		

Tab. 3. Amount, number, possible taxa, possible C_3/C_4 plants, condition and other remarques on the phytoliths samples of Ksizovo-1.

samarskoe, this absence has been linked to reduced evapotranspiration in humid environments. It is possible that a similar process occurred at Ksizovo-1. Additionally, this pattern may reflect seasonal occupation, with the site being used during winter when surrounding plants would not have produced inflorescences. This seasonal factor could further explain the absence of multicellular phytoliths at Ksizovo-1.

Organic residue analysis on pottery fragments

The GC-MS analysis revealed that the food crusts contain constituents deriving from both plant and animal sources. The overall lipid compositions were dominated by saturated fatty acids, predominantly palmitic acid ($C_{16:0}$), and to a lesser extent by myristic acid ($C_{14:0}$), stearic acid ($C_{18:0}$) and lauric acid ($C_{12:0}$). Occasionally, unsaturated fatty acids, such as oleic acid ($C_{18:1}$) and palmitoleic acid ($C_{16:1}$), were part of the lipid profiles as well (Fig. 15). Additionally, the odd-carbon-numbered fatty acids pentadecanoicacid ($C_{15:0}$) and heptadecanoic acid ($C_{17:0}$) were present in some of the samples. Apart from the fatty acids, fatty alcohols were also partially detected in low abundances. The present compounds can derive from degraded animal fats as well as from plant oils (*Dunne* et al. *2016; Whelton* et al. *2021*). Thus, the GC-MS results suggest a mixture of aged animal fats and plant oils.

The LC-MS/MS analysis confirmed this interpretation by documenting the presence of sterols (Tab. 4). We detected the compounds cholesterol and 5α-cholestanol, which occur in all animal and human cells. In the context of these samples (food crusts in vessels), they most likely reflect animal fat. Additionally, a number of phytosterols and stanols were present in the samples as well. These compounds are clear evidence for plant products. Phytosterols occur in a wide range of different plants (*e.g.*, fruits, seeds, nuts) and the richest naturally occurring sources of phytosterols are vegetable oils. The same applies to the compound coumarin, which is also widely distributed in the plant kingdom and was detected in all samples from Ksizovo-1. Furthermore, there was evidence for betulinic and oleanolic acid in some of the samples. However, these compounds were mainly present in trace amounts, with the exception of sample KS1-02. Both compounds also occur in a wide variety of plant products, such as oils, but are not species specific.

To summarize, both GC-MS and LC-MS/MS analyses showed a mixture of plant and animal products in the samples. The 18 tested vessels had a similar distribution of compounds, indicating that similar foods were consumed. Exact identifications (*e.g.*, plant species) cannot be made on the basis of this evidence. The plant markers most likely reflect vegetable origin.

Fig. 14. A part of a parasite (?) from sample K4.

Conclusions

Systematic excavations of Bronze Age settlements, especially of the Catacomb culture, and complementary multidisciplinary investigations are still relatively limited within Eastern European archaeology. Therefore, the results of the interdisciplinary research presented here are of great importance for gaining insights into the life and economy of pastoral communities in the second half of the 3rd millennium BCE.

The settlement of Ksizovo-1 consisted of a single cultural layer. Unfortunately, no remains of dwellings were preserved, which can be explained by several factors: any constructions were probably light and mainly composed of organic material, the site was only temporarily/seasonally inhabited, and only the edge or the settlement was preserved. Due to the flooding of the Snova River, a large part of the settlement area had already been washed away in the Bronze Age. Regardless, the careful and systematic excavation by Gak and Ivashov recovered features, finds, and ecofacts that are available for evaluation and laboratory examination. We focused on providing information about the interactions of Ksizovo-1's inhabitants with the natural environment, including their mobility patterns as pastoralists.

By comparing the archaeozoological data from Ksizovo-1 with the information and data from other Middle and Late Bronze Age settlement sites, especially the settlement of Rykan-3 (*Antipina 1997; 2011a; 2011b; Zhuravlev 2001; Antipina, Morales 2005; Gak* et al. *2023*), we are able to draw several important conclusions. Based on the large amount of osteological material and its taxonomic identification, the species composition of the Ksizovo-1 faunal assemblage confirms the primacy of cattle husbandry in the subsistence

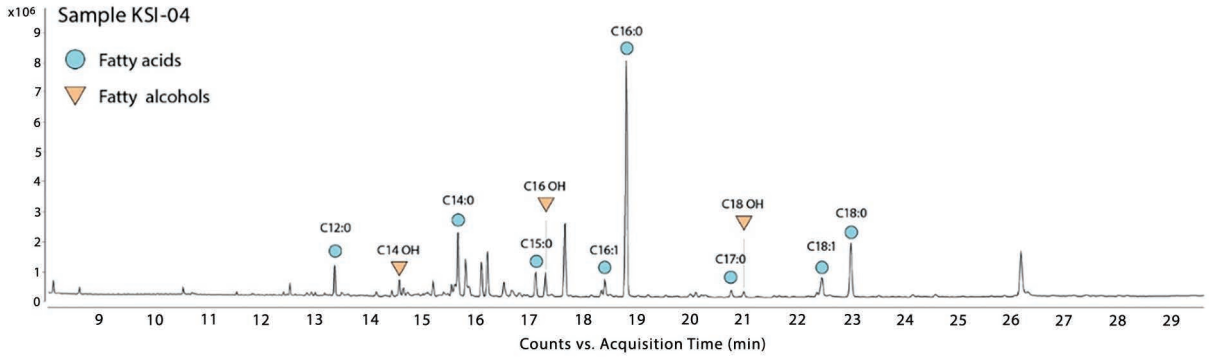

Fig. 15. Partial TIC chromatogram of sample KS1-04 displaying the distribution of fatty acids and alcohols (n:0 = saturated fatty acids,* e.g., *$C_{14:0}$, $C_{16:0}$, $C_{18:0}$, and n:1 = unsaturated fatty acids,* e.g., *$C_{16:1}$, $C_{18:1}$).

system for the inhabitants of the settlement. With a proportion of 14% of wild animal remains, hunting played a minor role. A great variability in the size of the postcranial elements of cattle was observed. One of the possible reasons for this might be variable fodder provisioning and nutritional intake, which, in turn, might be related to the change of pastures and thus, to some extent, to the mobile form of cattle husbandry. The age determination of domestic and wild animals based on dental material, especially the identification of calves slaughtered at the age of eight to 10 months, a newborn foal, and a one-year-old bear, indicates economic activity in the pre-winter and winter periods. These conclusions are consistent with the idea that Ksizovo-1 was a seasonal camp occupied primarily during the winter months. Stable and strontium isotope data can be considered as providing indications of domestic animal husbandry practices with seasonal, small-scale movements, most likely confined to the Ksizovo-1 microregion.

Systematic archaeobotanical sampling and investigations yielded only isolated charred plant macro-remains. The two AMS-dated cereal grains proved to be much younger intrusions. However, the fragments of wild plum and hazelnut could be reliably dated to the period of the time of the Ksizovo-1 settlement by radiocarbon analysis. This data represents the first radiocarbon record of those periods for the entire Eastern European steppe area of the 3rd millennium BCE. The results of the radiocarbon dating of the plant remains thus confirm what was already evident for other settlements, such as Rykan-3 (Voronezh district), Krasnosamarskoe (Samara district), Olgino (Chelyabinsk district), Odaia-Miciurin (Rep. Moldova), that cereal cultivation seemed to have a minor role in Bronze Age's Eastern Europe (*Sava, Kaiser 2011; Rühl* et al. *2015; Popova 2016; Gak* et al. *2023*). Pastoralists inhabiting the grasslands and forest-steppes based their subsistence economy on animal husbandry and probably gathered wild fruits and other plants that grew in the immediate vicinity. The analysis of organic residues on pottery sherds from Ksizovo-1 provides additional evidence that the wild flora of the surrounding natural area was indeed intensively exploited. Although only a few food crusts could be examined in our pilot study, a mixture of plant residues and animal fats were found in the vessels.

Compounds	KS1-01	KS1-02	KS1-03	KS1-04	KS1-05	KS1-06	KS1-07	KS1-08	KS1-09	KS1-10	KS1-11	KS1-12	KS1-13	KS1-14	KS1-15	KS1-16	KS1-17	KS1-18
Coumarin	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Cholesterol	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
5α-Cholestanol	□	□	□	□	□	□	□	□	□	□	□	□	□	tr	□	□	□	□
Campesterol	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
β-Sitosterol	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Sitostanol	□	□	□	□	□	□	□	□	tr	tr	□	tr	tr	□	tr	□	□	□
Stigmasterol	□	□	□	□	□	□	tr	tr	tr	tr	tr	tr	tr	□	□	tr	□	□
Betulinic acid	tr	□	□	□	□	□	□	tr	tr	□	□	□	□	□	tr	□	tr	tr
Oleanolic acid	□	□	□	□	□	tr	□	□	□	□	□	□	□	□	□	□	□	tr

***Tab. 4. Table of LC-MS/MS results from 18 food crust samples from Ksizovo-1 showing the presence and absence of compounds per sample. Compounds at trace level are indicated as* tr.**

Residues of various grasses were mainly found in the samples examined for phytoliths, corresponding to the location of Ksizovo-1. In particular, the absence of phytoliths with inflorescences could be a cautious indication of the season when the settlement was inhabited, namely winter. Thus, these results support the conclusions of the archaeozoological data. However, other questions remain unanswered. These include the specific period during which the site was repeatedly inhabited. The radiocarbon dates indicate two phases of use that occurred between 2400 and 2100 BCE. However, a preliminary analysis of the forms and decorations of the pottery shows a span of occupation within a few generations, which does not allow the settlement as a whole to be considered as inhabited for such a long period of time. While many details of the exploitation of the forest-steppe in the Bronze Age are still to be clarified, our results contribute significantly to our understanding of the particular microregion and the Upper Don course in the mid of the 3rd millennium BCE, ikewise demonstrating the great potential of multidisciplinary collaboration.

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Appendix

Sample ID	Material	Level (plast)	Lab ID	^{14}C age BP	cal BC (σ 95.4%)	Remarks (Lab)
01/2021	animal bone *(cattle)*	3	Poz-80315	3825 ± 35 BP	2456 BC (5.5%) 2418 BC 2407 BC (6.2%) 2375 BC 2368 BC (1.3%) 2356 BC 2351 BC (77.8%) 2196 BC 2173 BC (4.7%) 2146 BC	0.8%N 4.8%C 1.5%coll
02/2021	animal bone (cattle)	3	Poz-80316	3835 ± 35 BP	2458 BC (94.7%) 2199 BC 2159 BC (0.7%) 2154 BC	0.9%N 4.7%C 1.5%coll
03/2021	animal bone (cattle)	2	Poz-80317	3835 ± 35 BP	2458 BC (94.7%) 2199 BC 2159 BC (0.7%) 2154 BC	0.7%N 4.7%C 1.9%coll
4/2021	animal bone (cattle)	3	Poz-133605	3580 ± 35 BP	2031 BC (87.8%) 1875 BC 1844 BC (4.9%) 1821 BC 1797 BC (2.8%) 1778 BC	0.7%N 4.4%C 0.4%coll
5/2021	animal bone (cattle)	2	Poz-133606	3730 ± 40 BP	2283 BC (5.6%) 2250 BC 2232 BC (1.1%) 2220 BC 2210 BC (87.6%) 2023 BC 1994 BC (1.1%) 1983 BC	0.4%N 3.6%C 0.3%coll
6/2021	animal bone (cattle)	3	Poz-133608	3720 ± 35 BP	2274 BC (1.9%) 2257 BC 2206 BC (92.1%) 2022 BC 1995 BC (1.5%) 1982 BC	1.1%N 5%C 1.6%coll
7/2021	charcoal	3	Poz-134197	565 ± 30 BP	1308 AD (53.7%) 1363 AD 1386 AD (41.8%) 1425 AD	-
12/2022	animal bone (cattle)	4	Poz-151378	3750 ± 35 BP	2286 BC (11.1%) 2247 BC 2236BC (59.6%) 2110 BC 2105 BC (24.8%) 2036 BC	0.9%N 4.4%C 0.8%coll
13/2022	animal bone (cattle)	3	Poz-151379	3755 ± 35 BP	2288 BC (74.8%) 2115 BC 2100 BC (20.7%) 2037 BC	1.1%N 5.0%C 1.1%coll
15/2022	charcoal	2	Poz-154709	3740 ± 30 BP	2277 BC (4.7%) 2255 BC 2207 BC (90.7%) 2035 BC	-
16/2022	charcoal	2	Poz-155171	4290 ± 40 BP	3022 BC (92.6%) 2870 BC 2800 BC (2.8%) 2778 BC	-
17/2022	charcoal	4	Poz-154710	2495 ± 30 BP	776 BC (95.4%) 516 BC	-
18/2022	charcoal	4	Poz-154727	2370 ± 35 BP	722 BC (2.0%) 707 BC 663 BC (1.5%) 652 BC 545 BC (91.9%) 386BC	-

Tab. 5. Results of the radiocarbon dating of animal bone collagen and charcoal, for calibrated dates see Figure 7. Please note that sample number 14 was omitted by accident.

Sample	Archive No.	Year	Sampling location	Soil volume, litres	Charcoal, specimens	Charcoal, per 10 litres
1		2014	Trench 1, Square 1 (3), Layer 2, above crushed vessel 1	15		
2		2014	Trench 1, Square 1 (4), Layer 2, above crushed vessel 1	15		
3		2014	Trench 1, Square 1,19, Layer 3, under crushed vessel 1	15	21	1
4		2014	Trench 1, Square 7(3), Layer 3, concentration 1	15	44	29
5		2014	Trench 1, Square 20, object 1 (fire installation)	10	13	13
6		2014	Trench 1, Square 16, object 3 (fire installation)	15	24	16
7		2014	Trench 1, Square 16, object 3 (fire installation)	20	40	20
8		2014	Trench 1, Square 16, object 4 (fire installation)	15	5	3
9	3525	2015	Trench 2, Square 36 (3), Layer 2, concentration 9 (crushed vessel)	10	47	24
10		2015	Trench 2, Square 20 (4), Layer 2, crushed vessel 4	10	68	34
11		2015	Trench 2, Square 20 (4), Layer 2, crushed vessel 4	10	48	48
12		2015	Trench 2, Square 35 (4), object 6 (fire installation)	10	16	16
17		2016	Trench 3, Square 65 (2) Baulk 3, Layer 3, concentration 14 (crushed vessel)	10	15	15
18		2016	Trench 3, Square 65(1), Layer 3, concentration 14 (crushed vessel)	10		
19		2016	Trench 3, Square 65(2, 4), Layer 3, concentration 14 (crushed vessel)	10		
20		2016	Trench 3, Square 61(1, 2), Layer 4, pathway (mass inclusions of animal bones)	10	2	2
21	3526	2016	Trench 3, Square 61(3, 4), Layer 4, pathway (mass inclusions of animal bones)	10	97	97
22		2016	Trench 2 (reconstruction), Square 32/27, object 7 (pit)	10	98	98
23		2016	Trench 3, Square 55(4), object 7 (pit)	10	14	14
24		2017	Trench 4, Square 86-89, Layer 4, traces of bronze melting	45	55	12
25		2017	Trench 4, Square 86-89, Layer 4, traces of bronze melting	10		
26		2017	Tr. 4, Sq. 83(2), Layer 4, accumulation of ceramics from the Catacomb culture	30	13	4
27		2017	Trench 4, Square 86-89, Layer 4, traces of bronze melting	30	3	1
28		2017	Trench 4, Square 86-89, Layer 4, traces of bronze melting	30	4	1
29		2017	Trench 4, Square 86-89, Layer 4, traces of bronze melting	25		
30	3527	2017	Tr. 4, Sq. 89(4), Layer 3, accumulation of ceramics from the Catacomb culture	30	6	2
31		2017	Trench 4, Square 87(4), Layer 4, concentration 16 (animal bones)	10	5	5
32		2017	Tr. 4, Sq. 86(4), Layer 3, accumulation of ceramics from the Catacomb culture	10	8	8
33		2017	Tr. 4, Sq. 83(3), Layer 3, accumulation of ceramics from the Catacomb culture	10	4	4
34		2018	Tr. 5, Sq. 109(2), Layer 2, accumulation of ceramics from the Catacomb culture	20	10	5
35		2018	Tr. 5, Sq. 101(1), Layer 2, accumulation of ceramics from the Catacomb culture	20	4	2
36		2018	Tr. 5, Sq. 99(3), Layer 2, accumulation of ceramics from the Catacomb culture	20	36	18
37	3528	2018	Trench 5, Square 94(1), Layer 3, concentration 22 (ceramics, animal bones)	20	42	21
38	3529	2018	Trench 5, Square 95, Layer 3, concentration 21 (ceramics, animal bones)	20	109	55
39		2019	Trench 6, Square 130(2), Layer 3, at SW edge of fire installation (object 15)	10	20	20
40	3530	2019	Trench 6, Square 128, object 13 (fire installation)	10	106	106
41		2019	Tr. 6, Sq. 122(3), Lay. 2, eastern edge concentration 25 (ceramics, animal bones)	10	1	1
42		2019	Trench 6, Square 130, Layer 3, concentration 24	10	128	128
43		2019	Trench 6, Square 128, object 13 (fire installation), northern half	10	34	34
44		2019	Trench 6, Square 128, object 13 (fire installation), southern half	10	37	37
45		2019	Tr. 6, Sq. 122(4), Layer 2, accumulation of ceramics from the Catacomb culture	10	44	44
46		2019	Tr. 6, Sq. 118(3), Layer 3, accumulation of ceramics from the Catacomb culture	10	50	50
47		2019	Trench 6, Square 127(1), object 12 (fire installation)	10	97	97
48		2019	Tr. 6, Square 117(4), Layer 2, above concentration 25 (ceramics, animal bones)	10	11	11
49		2019	Tr. 6, Square 117(4)-118(2), Layer 3, concentration 25 (ceramics, animal bones)	10	4	4
50	3531	2019	Trench 6, Square 123, object 14 (fire installation)	10	5	5
51		2019	Trench 6, Square 117, object 11 (fire installation), southern half	10	63	63

Tab. 6. List of investigated archaeobotanical specimens. Note: Sample numbers are listed according to the excavation documentation; internal archive numbers are based on the database of the Laboratory of Natural Science Methods of the Institute of Archaeology of the Russian Academy of Sciences.

52		2019	Trench 6, Square 130, Layer 3, concentration 24 (crushed vessel “b”)	2	20	100
53		2020	Trench 6, Square 138(1), Layer 2, concentration 23 (ceramics)	20	34	17
54		2020	Trench 6, Square 137(3), Layer 2, concentration 23 (ceramics)	10	8	8
55		2020	Trench 6, Square 138(1), Layer 3, concentration 23 (ceramics)	10	63	63
56		2020	Trench 6, Square 138(1), Baulk, Layer 3, concentration 23 (ceramics)	20	19	10
57		2020	Trench 6, Square 138(1), Layer 3, concentration 23 (ceramics)	10	68	68
58		2020	Trench 6, Square 138(1), Layer 3, concentration 23 (ceramics)	10	48	48
56		2020	Trench 6, Square 138(1), Baulk, Layer 3, concentration 23 (ceramics)	20	19	10
57		2020	Trench 6, Square 138(1), Layer 3, concentration 23 (ceramics)	10	68	68
58		2020	Trench 6, Square 138(1), Layer 3, concentration 23 (ceramics)	10	48	48

Tab. 6. Continued

Year of excavations	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**SUM**		
Territory of excavation	western part				eastern part			number	%	%
Domestic animals										**85.8**
Cattle	145	262	312	130	116	70	68	1103	67.0	
Horse	14	47	30	20	27	19	10	167	10.1	
Sheep/Goat	15	33	22	24	21	11	9	135	8.2	
Dog	0	8	0	0	1	0	0	9	0.5	
Wild animals										**14.2**
Boar	25	19	16	13	4	7	3	87	5.3	
Bear	16	23	20	5	4	3	1	72	4.4	
Elk	1	20	19	7	4	0	1	52	3.2	
Beaver	5	4	1	3	1	1	0	15	0.9	
Roe deer	0	2	2	1	0	0	0	5	0.3	
Wolf	1	0	0	0	0	0	0	1	0.1	
Hare	0	0	0	0	1	0	0	1	0.1	
NISP	222	418	422	203	179	111	92	1647	100	**100**
Indeterminate bones										
Indet L	377	424	644	227	281	149	51	2153		
Indet M	43	55	53	15	6	13	9	194		
NR	642	897	1119	445	466	273	152	3994		
% NISP	34.6	46.6	37.7	45.6	38.4	40.7	60.5	41.2		
Volume	8.4	12.6	14.8	6.7	6.2	2.8	2.5	54.0		
Bones taphonomic status										
FI	76.4	71.2	75.6	66.4	75.2	97.5	60.8	74.0		
NP	1-2	2	1	1-2	1	1	2	1-2		
HOMO		1								

Tab. 7. Species composition and quantitative data of the osteological collection of Ksizovo-1.

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Zooming in and out the outcomes of geophysical research at the Western Tripolye culture site Kamenets-Podolskiy (Tatarysky)

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ABSTRACT – *This paper reports the results of magnetic surveys contextualized with the landscape via water drainage analysis, and summarizes the results of excavations at the Cucuteni-Tripolye settlement Kamenets-Podolskiy (Tatarysky), 3950–3900 BCE. Incorporation of topographic information and water drainage analysis to the studies of settlement structures revealed by magnetometry makes it possible to understand how such features function and, therefore, the intentionality behind the arrangement of houses and utility structures. The correlation between magnetic susceptibility and the mass of burnt daub coming from the individual dwelling reveals a possible weakness in interpretations, due to the influence of heat on magnetization.*

KEY WORDS – *Cucuteni-Tripolye cultural complex; settlement structure; wattle-and-daub architecture; burnt daub*

Povečani in pomanjšani rezultati geofizikalnih raziskav na najdišču Kamenets-Podolskiy (Tatarysky) kulture Zahodno Tripolje

IZVLEČEK – *V članku predstavljamo rezultate geomagnetnih raziskav, ki smo jih v pokrajini kontekstualizirali s pomočjo analize odvodnjavanja ter povzemamo rezultate izkopavanj naselja Kamenets-Podolskiy (Tatarysky), 3950–3900 pr. n. št., ki pripada kulturi Cucuteni-Tripolye. Vključitev topografskih informacij in analiz odtekanja vode v študije naselbinskih struktur, odkritih s pomočjo magnetometrije, je omogočila razumeti njihovo delovanje, načrtovaje in namembnost hiš ter gospodarskih poslopij. Korelacija med magnetno susceptibilnostjo in ožganim hišnim ometom opozarja na mogočo težavo pri interpretiranju zaradi vpliva gorenja na magnetizacijo.*

KLJUČNE BESEDE – *kulturni kompleks Cucuteni-Tripolye; naselbinske strukture; gradnja s prepletom iz vej in gline; ožgan omet*

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Introduction

The development of the geophysical research of archaeological sites has been advanced significantly by the decades of work at the settlements of the Cucuteni-Tripolye cultural complex (hereinafter – CTCC) in Romania, the Republic of Moldova and Ukraine. The deliberate burning of houses is noted for the entire duration of this cultural complex, *c.* 5000–3000/2950 BCE. Since the remains of burnt dwellings (so-called *ploshchadki*) can be easily identified in the geophysical data, archaeological interest in revealing settlement structures or number of houses (leading to an estimate of the population) is not surprising. Starting in the 1960s, geophysical surveys of the Cucuteni-Tripolye sites were increased significantly with the discovery of the mega-sites in the Southern Bug and Dnieper interfluve, the largest population agglomerations of Neo-Eneolithic Europe (*e.g., Dudkin 1978*; also see *Koshelev 2005; Videiko, Rassmann 2016* for the history of research). Meanwhile, the precision of the geophysical plans of such mega-sites and other settlements of various size from different regions has improved considerably since the late 2000s and early 2010s. This became possible with the usage of modern gradiometer systems of different designs (*Chapman* et al. *2014; Rassmann* et al. *2016a; 2016b*). New equipment, due to its high sensitivity and resolution, allowed for the identification of features (*e.g.,* pits of different size, ditches, kilns) which the previously used Soviet magnetometers M27 and M127 failed to identify (*e.g., Rassmann et al. 2016b; Ohlrau 2020*). Recent studies have also shown a correlation between the burnt daub mass and magnetization, which allows more a detailed interpretation of the geophysical prospection (*Pickartz* et al. *2019; 2022*).

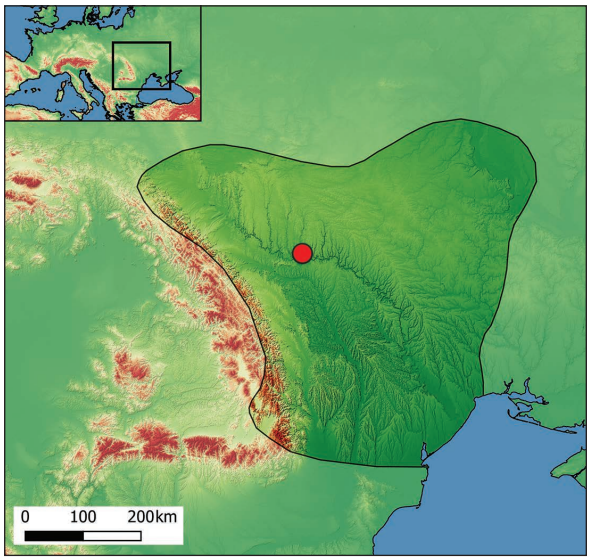

Fig. 1. Kamenets-Podolskiy (Tatarysky). Site location (red dot). The shadow polygon approximates the extent of the Cucuteni-Tripolye ecumene.

This paper reports the results of magnetic surveys contextualized with the landscape via water drainage analysis and summarizes the findings of excavations at the settlement Kamenets-Podolskiy (Tatarysky). Our analysis of the magnetic results is focused on revealing the evolution of the settlement structure and on understanding the internal structure of individual dwellings.

Archaeological background

The analysed site is located in the current administrative borders of Kamenets-Podolskiy (Khmelnitskaya oblast, Ukraine), over the gorge of the Smotrich River, south of Kamenets-Podolskiy Castle (Fig. 1). The settlement was set on a promontory separated from the north, west and south by the steep slopes of the gorge incised into the loess and chalk soil covering limestone bedrock. The overall area of the promontory is nearly 9ha, and is covered by *c.* 30–40cm of chernozemic soil occurring on the surface. The extension of a site to the south of this promontory is not clear enough to point to a boundary (*Levinzon 2021*). The non-invasive research reported here was conducted in the spring of 2019 and followed by excavations in 2019–2021.

Three excavation seasons were focused on the exploration of different features in Kamenets-Podolskiy (Tatarysky). Two out of three excavation sites were located outside the non-invasive prospection area in agreement with the farmer. The proximity to the surveyed area made it possible to target features whose anomalies were mapped with magnetometry and expected to expand outside the surveyed area. Excavations confirmed the results of the geophysical research, revealing pottery kilns (*Diachenko, Sobkowiak-Tabaka 2020*), house remains (*Diachenko* et al. *2021*) and a ditch (*Sobkowiak-Tabaka* et al. *2024*). Materials from excavation and earlier surface collections (*Levinzon 2021*) included homogenous ceramic assemblages, indicating a single occupation of this site in the Eneolithic. Kamenets-Podolskiy (Tatarysky) is taxonomically referred to as the second phase of the Mereshovskaya local group of the Western Tripolye culture (hereinafter – WTC), and dated to *c.* 3950–3900 BCE (*Tkachuk 2015; Diachenko, Sobkowiak-Tabaka 2021; Levinzon 2021; cf. Ryzhov 2003*).

Methods

Due to the expected presence of Eneolithic housing structures, which were subjected to high temperatures (*ploshchadki*), the site was surveyed with the use of magnetometry. This geophysical method is based on measuring the local disturbances of the Earth's magnetic field, caused by the differentiation of the magnetic properties of subsurface materials (*Aitken 1958; Weymouth, Huggins 1985; Aspinall* et al. *2008*). Two main types of magnetism, *i.e.* remanent and inductive, cause disturbances that are taken into account during analysis (*Fassbinder 2015*). With regard to the first type, a further division reveals thermoremanent magnetization, which occurs archaeologically after heating up material that contains a considerable amount of iron oxides. In Kamenets-Podolskiy (Tatarysky) such material was expected to be represented by the daub structures, which were subjected to high temperatures, reaching 1000°C (*e.g., Kruts 2003; Johnston* et al. *2018; 2019*). The daub made of clay (with/without organic admixtures) that contains a considerable amount of iron minerals requires heating of *c.* 570–670°C in order to gain the additional magnetic properties (*Gaffney, Gater 2003*). The latter are usually revealed in magnetometry results as the bipolar anomalies of undistinguishable centres, as they comprise concentrations of material rather than selected singular features. Another type of magnetism is related to the induction caused by the presence of objects of higher magnetic susceptibility in relation to adjacent values of the Earth's magnetic field (*Le Borgne 1955; Weymouth, Huggins 1985*). Such objects at the prospected site were expected to be pits or ditches filled by lithological material which is different from the geological background (calcareous loess sediments and the chernozem soil). Due to the sedentary nature of the site, its features were expected to be revealed by both types of magnetization.

Magnetometry was conducted by using two types of fluxgate gradiometer: the Bartington Grad-601-2 and Geoscan FM256. The first instrument was equipped with two probes and each of those contained two sensors separated by an interval of 1m vertically. The horizontal distance between the probes was 1m. The FM256 is a single probe device with two sensors set vertically half a meter apart.

The geological background of the area shows the vast occurrence of loess sediments, which in terms of magnetic properties should have a homogeneous value and, therefore, allow a clear view of any anomalies. Moreover, the uniform surface of loess material and chernozem excludes the possibility of major natural interferences, like stones containing ferromagnetic minerals.

The magnetic survey was conducted within a net of 20x20m grids. In total, an area of 8.96ha was subjected to the survey (Fig. 2). The overall area was chosen based on the distribution of the archaeological material on the surface, but also limited by the borders of the ploughed field accessible for the survey.

Due to application of two different magnetometers, the prospection area was divided into two parts. The western part was surveyed by the Geoscan Research equipment and the eastern part was measured by the Bartington instrument (Fig. 2). The sampling density in both areas was 0.5x0.25m, using different methods of sampling, *i.e.* parallel mode in the eastern part and zig-zag in the western part. Both instruments were set

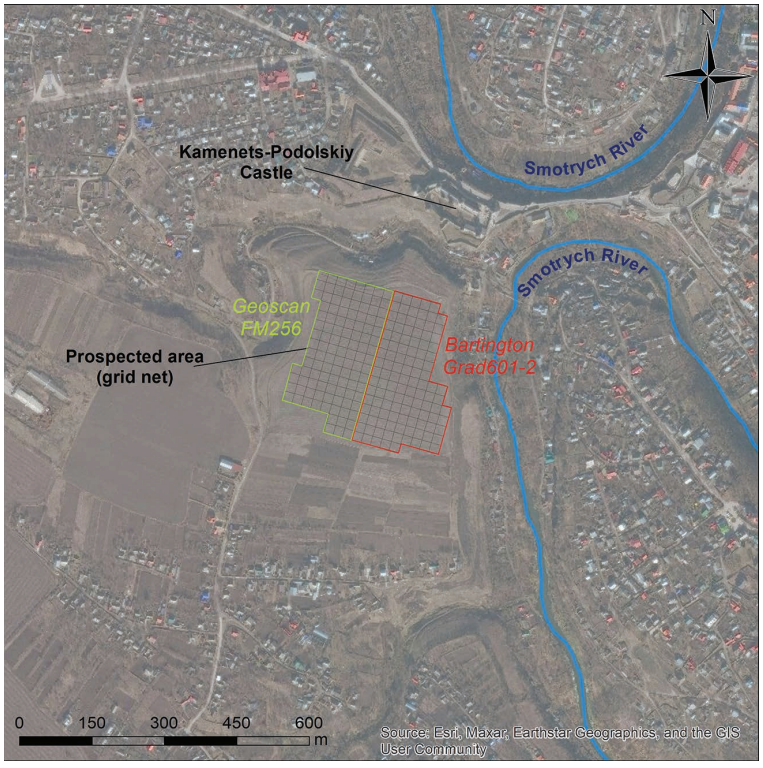

Fig. 2. Kamenets-Podolskiy (Tatarysky). Area subjected to magnetic prospection (red: Bartington Grad 601, and green: Geoscan FM 256).

to the resolution of 0.1nT. Despite usage of different instruments and sampling methods, the results of a survey were in concordance on the borders, revealing the continuation of magnetic gradient between the two research polygons (Fig. 3).

The magnetic data were processed with a use of Geoplot 4.0 software. The despike, zero mean traverse, destagger and deslope filters were applied. Afterwards, the .grd file was transferred to the ArcGIS software in order to re-interpolate the raster and erase any measurement bias, *e.g.,* any metal scrap that was detected at the surface. The analysis of the distribution of magnetic anomalies was performed on four different ranges of values: –50/50nT, –10/10nT, –5/5nT and –1/1nT (Fig. 3). The widest range was set to identify anomalies related to modern waste or artefacts such as artillery shells – the remains of the turbulent history of Kamenets-Podolskiy castle. The second and third ranges were used to search for the main features expected on this site – the *ploshchadki*. The narrowest one was used to look for minor anomalies corresponding to pits, which could occur in the proximity of the higher intensity anomalies.

Additionally, a magnetic susceptibility meter (SM30 by ZH Instruments, Brno) was applied to measure the susceptibility of a sample of the weighted daub fragments (n=74) from *Ploshchadka* 1. Our sample included fragments of daub coming from the upper storey of a house and component parts of its interior. House remains are analysed elsewhere (*Diachenko* et al. *2021*), while the necessary brief summary of its construction details and interior is provided in the General Interpretation and Discussion section.

Moreover, the results of the magnetic survey were compared with those obtained from the drainage network analysis and aerial photography. The water drainage network analysis, simulating a local hydrological trend without consideration of contemporary meteorological and hydrological conditions (see the details in: *Sobkowiak-Tabaka* et al. *2024*), was performed in SAGA GIS ver. 2.3.2 software on a digital terrain model obtained from a topographic map at a scale of 1:25 000 with height intervals of 2.5m. Google Earth images from 2013 were used (source: Google Earth, Maxar Technologies) for the observation of the vegetation indicators used to identify potential archaeological sites. The contrast in the aerial photographs was enhanced to highlight the observed structures.

Results

Settlement structure

The analysis of the magnetic data revealed several types of anomalies based on their magnetic properties, size, shape and distribution (Tab. 1). At first, all the small-sized bipolar anomalies with the highest intensity, caused by iron objects, were identified in the data and excluded from further analysis. Afterwards a total of 483 anomalies were distinguished and categorized into ten types (Types I – X, Fig. 4).

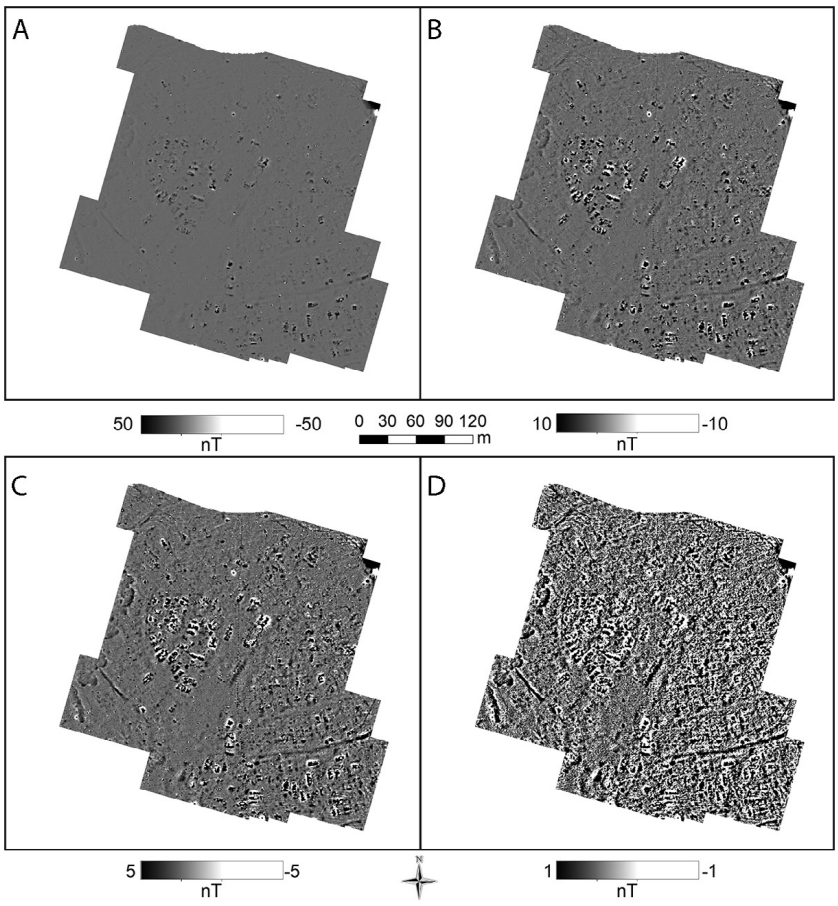

Fig. 3. Kamenets-Podolskiy (Tatarysky). Results of magnetic prospection. **A** ***–50/50nT range;*** **B** ***– 10/10nT range;*** **C** ***–5/5nT range;*** **D** ***– 1/1nT range. The extent of the prospected area is marked in Figure 2.***

Type I

The first type of anomalies corresponds to *c.* 100 structures characterized by relatively high magnetic gradient – in a range between –100/100nT (or both larger) (Fig. 4; Tab. 1). These features are mainly rectangular in shape and comprise a bipolar field distribution. However, some of these lack the negative signals. The average size of features attributed to this type is 12x5m, but a few exceed 20m in length and 10m in width. Often, they include an internal positive signal which is perpendicular to the long axis of the features. According to the results of similar surveys and excavations in other CTCC sites, features of this type should represent the remains of burnt dwellings, *i.e. ploshchadki* (*e.g., Chapman* et al. *2014; Rassmann* et al. *2016a; 2016b; Przybyła* et al. *2017*). This explanation is supported by the high values measured by the magnetometers and the bipolar character of the anomalies, which points to high temperatures affecting the daub.

The Type I anomalies are agglomerated into two clusters. The first of those, comprising 40 features, is located in the north-western part of the research area (Fig. 4). This cluster has a semicircular shape 'cut' from the eastern side. In light of the distribution of the anomalies, the size of this arrangement is estimated at 0.8ha. The second cluster covering an area of 1.7ha includes features loosely distributed in the south-eastern part of the survey field. It is possible to distinguish the further division of dwellings within this cluster, which are located between the internal and external ditches. Besides this, additional anomalies resembling dwellings were revealed in the eastern and north-western parts of the site, outside these clusters.

Exploration of *Ploshchadka* 1 in the southern part of our site confirms the high precision of geophysical research, accurately revealing the location of daub, 'gaps' in its spatial distribution and pottery debris in the vicinity of a house (see the General Interpretation and Discussion section).

Type II

The second type comprises only one anomaly oriented on the NNE – SSW axis, which is similar to Type I in in terms of magnetic values (as represented on the

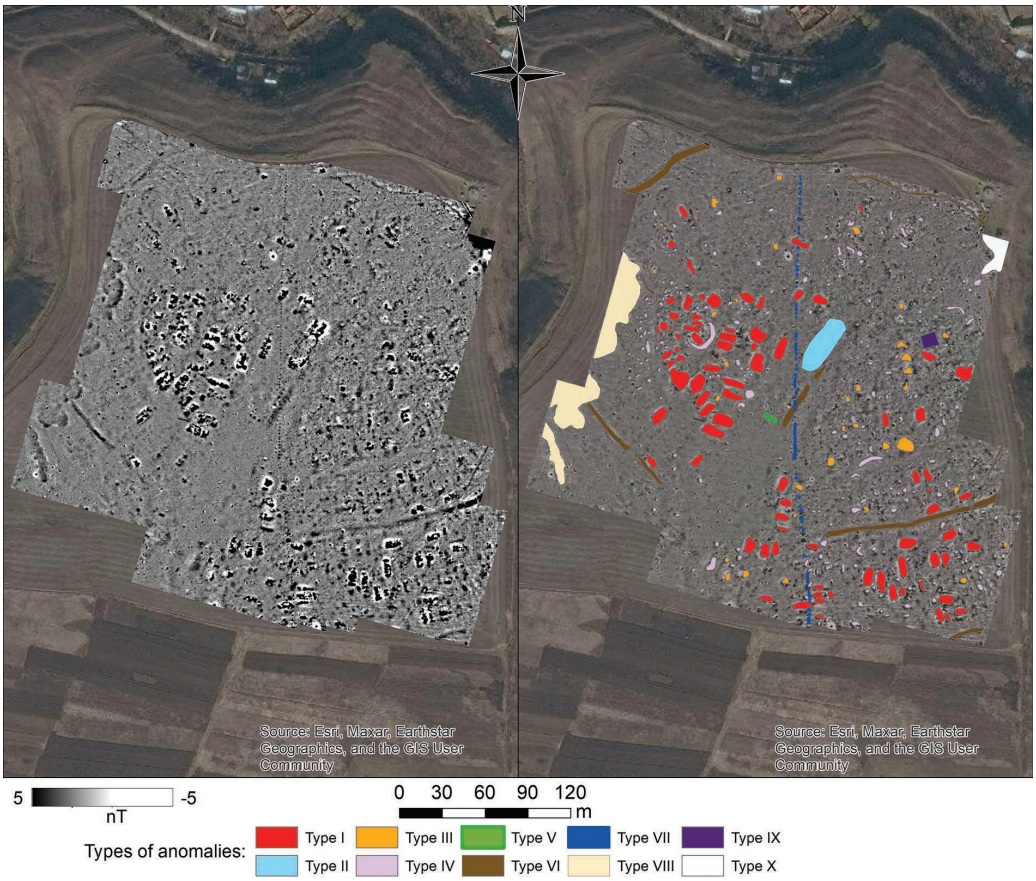

Fig. 4. Kamenets-Podolskiy (Tatarsky). Results (left) and interpretation of the magnetic prospection (right). The magnetic plan was set to 50% transparency in order to provide a better view on the anomalies' locations.

plan). The difference is the size of the feature, which measures to 41x21m. The presence of a bipolar pattern of magnetic fields and relatively high values (corresponding to the ones recorded in Type I), may indicate a larger building (or the so-called 'mega-structure', see *Hofmann* et al. *2019; Nebbia* et al. *2019*) in the central part of the area between the two housing clusters. This structure is not continuous in its length as some places, especially the middle part, lack any magnetic disturbances.

Moreover, it is possible that with the addition of adjacent anomalies of Types V and VI (see below), this feature can measure 85m in length. The presence of a gap between two anomalies of Type 1 may result from the absence of daub-made structures, their replacement (for instance, by wooden construction), or redeposition in the result of post-depositional processes. However, an alternative interpretation of this feature is also possible when contextualized with water drainage analysis (see below).

Type III

The objects in this group of anomalies are similar to those in Types I and II with regard to their bipolar character. However, they differ in shape, spatial distribution and number. Type III anomalies are elliptic in shape with a distinguishable centre of the anomaly. There are 37 features of such characteristics visible on the magnetic map. It is therefore highly probable that these anomalies represent concentrations of burnt clay, indicating destroyed dwellings, kilns or pits filled with the daub. Such an interpretation is additionally supported by the frequent occurrence of the Type III anomalies in close proximity or within (parts of destroyed dwellings and pits) the Type I and II anomalies.

Type IV

This type of anomalies represents the highest number of features recorded on the magnetic map, n=257. They are characterized by the occurrence of a positive signal (max 3nT) with an indistinguishable negative reading. Due to the relatively low magnetic values, these features might indicate the presence of lithological differences, like concavities backfilled with the sediments richer in organic material. In the aerial imagery, they do form more compact oblong structures resembling ditches (see also the description of the Type IV anomalies). Magnetic anomalies of Type IV seem to be comparable to those observable in the loess-dominated areas (*e.g., Cwaliński, Niebieszczański 2015; Cwaliński* et al. *2018; Król, Niebieszczański 2019*). As such, these features, most probably, represent the topmost outlines of pits, which is confirmed by analogies from the other sites (*e.g., Rassmann* et al. *2016a; 2016b; Müller* et al. *2017*).

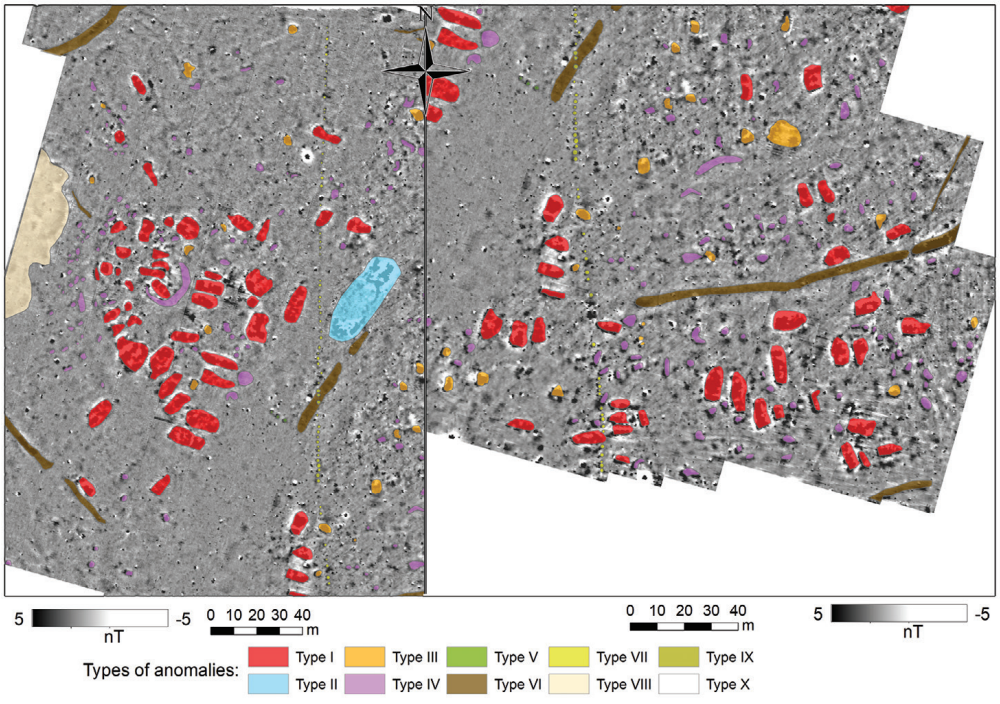

Fig. 5. Kamenets-Podolskiy (Tatarysky). Two clusters of anomalies resembling dwellings. Left: the north-western cluster. Right: the south-eastern cluster.

Especially intriguing is the fact that Type IV anomalies often accompany the anomalies of Types I and II. Moreover, in some examples their elongated shape and orientation parallel to the *ploshchadki* indicate their connection and function as waste pits, ditches or the remains of places from where the clay material was extracted to construct the houses (and then their secondary use as waste pits). A linear arrangement of this type of anomalies is also visible at the eastern and western outlines of the central agglomeration.

Type V

Only one structure was classified as Type V, and it is located in the north-eastern edge of the survey area. This feature represents a concentration of Type IV anomalies which forms a rectangle with the dimensions of 8x8m. Particular anomalies of this arrangement might mark the presence of postholes. However, this interpretation, as well as the feature's chronology, requires further verification.

Type VI

This type includes several linear anomalies of positive magnetic values (up to 15nT). The interpretation assumes that these features represent ditches backfilled with sediments, which are different lithologically from the geological background (*e.g., Chapman* et al. *2016; Mischka* et al. *2016; Rassmann* et al. *2016a; 2016b; Przybyła* et al. *2018; Asăndulesei* et al. *2020; Hale 2020; Rud* et al. *2021; Saile* et al. *2021;* for ditches on other prehistoric sites see *e.g., Niebieszczański* et al. *2018; Pető* et al. *2019*). The linear anomalies revealed in Kamanets-Podolskiy are characterized by higher magnetic values, which suggests a different lithological material infilling the concavity than the sediments overlying other parts of archaeological site and natural background. The enhanced readings can therefore be a result of increased mineral admixture (iron oxides and organic material) due to deluvial processes and by a possible abundance of daub and pottery as waste. A total of 14 such structures were recorded on the plan. Some of these form two 'interrupted' ditches in the northern and south-eastern parts of a site. Some other additional lines were also registered. The 'ditch-shaped' lines located in the north seem to be the remains of modern ditches encircling the plough area. Their magnetic properties are also much higher than those of the ditches in the south. The most interesting archaeologically are the lines located in the southern part of the prospection area. They measure from 4–12m in width. Excavation confirmed that the ditch had a depth of 1.4–1.6m from the Tripolye-time surface (2–2.2m below the modern surface) filled with humus loam and with artefacts and animal bones at the bottom. Internal structures of this ditch suggest using its excavated section as a tannery (*Sobkowiak-Tabaka* et al. *2024*). In the case of aerial photographs and drainage analysis, this type of anomaly, along with Type IV, is represented by a system of long linear structures, forming a complete arrangement of three or four arc-shaped ditches (including the excavated ditch to the south) aligned with the layout of the site.

Type VII

Small size anomalies reaching up to 5nT and arranged in a very regular way across the site were described as Type VII. These are singular anomalies of positive fields that shape a straight line of 320m running through the central part of the site on a N-S axis. These anomalies represent postholes remaining from a makeshift power-supply line from the second half of the 20th century, which was confirmed by the exploration of a feature corresponding to the Type VII anomaly in the south-eastern corner of Excavation 2.

Type VIII

This type is the only one reflecting the natural processes occurring at our site. Anomalies of this type are located in the westernmost part of the field and have elongated irregular shapes. Their course corresponds to the morphological threshold of the slope. Considering the loess sediments overlying the calcareous bedrock, these features are probably the result of erosion and slope processes in form of mass movements (Fig. 4).

Type IX

A singular square-shaped arrangement of anomalies has been recorded in the north-eastern part of the prospected area. The anomalies comprise only positive records which outline the edges of a square area relatively free of anomalies. It measures 8x8m and may represent some younger feature as no thermomagnetic signal was encountered within it.

Type X

It is located in the north-eastern margin of the surveyed field and comprises high amplitude values. This anomaly is caused by an iron cross monument standing several metres away from the prospection margins.

Magnetic susceptibility of the excavated dwelling structure

Magnetic susceptibility measurements of daub fragments found in the excavated trench were conducted in order to test the potential of reconstructing the interior of CTCC dwellings from geophysical plans. All the measured pieces of daub were characterized by the high susceptibility ranging from 0.71 to 14.1. Figure 6 presents the distribution of daub mass and magnetic susceptibility.

In the majority of cases our analysis finds a correlation between the daub weight and magnetic susceptibility measures, which fits the outcomes obtained by Natalie Pickartz *et al.* (*2019; 2022*). However, a number of the burnt daub fragments fall out of this trend, being characterized by a higher weight than expected from the obtained correlation. The latter fragments represent daub covering the wooden construction of the second storey floor below the oven and, in one case, a fragment of the elevation near the eastern back wall of a house.

General interpretation and discussion

The geophysical plan of Kamenets-Podolskiy (Tatarysky) represents component parts which are common for numerous CTCC settlements. These are *ploshchadkas*, pits, kilns, and ditches (*Rassmann* et al. *2016a; 2016b*). However, we may note similarities and differences between the spatial arrangement of these component parts at our site and other Cucuteni AB-Cucuteni B – Tripolye BII-BIII settlements (the periodization of WTC sites follows *Ryzhov 2021*). The closest similarities to the structure of the investigated site are represented by geophysical plans of Ripiceni-Popoaia and Ripiceni-Holm (*Asăndulesei* et al. *2020*).

In an area of 6ha, housing structures, numerous pits and probable kilns, as well as the complex of ditch

Anomaly type	nT values (min/max)	Number of features	Properties	Interpretation
Type I	Av. -100/100	*c.* 100	Bipolar anomalies; undefined centre of magnetic signal emission; rectangular plan (av. 12mx5m)	*Ploshchadki* / burnt clay structures
Type II	-100/100	1	Singular feature represented by bipolar anomalies of undefined magnetic signal emission; rectangular plan (41x21m or 85x21m)	"Mega-structure" (?) see: *Hofmann* et al. *2019*; *Nebbia* et al. *2019*
Type III	-100 / 100	37	Bipolar anomalies with distinguishable magnetic signal emission; elliptic shapes	Burnt clay structures (kilns or pits filled with daub)
Type IV	>0; <3	257	Single-pole anomalies (indistinguishable negative signals); circular shapes (various sizes)	Pits with organic backfill
Type V	>0; <3	1	Anomalies of Type IV arranged in a rectangular shape	Remains of building marked by postholes (needs further verification)
Type VI	>0; <15	14	Linear positive anomalies; 4–12m in width and various lengths	Ditches filled with anthropogenic deposits and organic remains
Type VII	>0; <5	*c.* 82	Small-size positive anomalies of circular shapes arranged in a linear pattern across the surveyed area	Postholes remaining from a makeshift power-supply line from the second half of the 20th century
Type VIII	various	uncountable	Elongated irregular shapes	Manifestation of erosion and slope processes
Type IX	-10 / 7	1	Rectangular outline made of bipolar anomalies	Remains of a younger building (remains of a wooden and brick foundation?)
Type X	-100/100	1	Vast bipolar anomaly	Magnetic field of an iron cross monument at the edge of the site

Tab. 1. List of types of anomalies recorded at Kamenets-Podolskiy (Tatarysky), their properties and interpretation.

structures, were distinguished on the magnetic maps and confirmed by the excavations (Fig. 7). In the case of dwellings, the main archaeological feature represented by the magnetic anomalies was the daub material that was subjected to high temperatures. It was also possible to provide insights into the internal structure of dwellings based on the magnetic data.

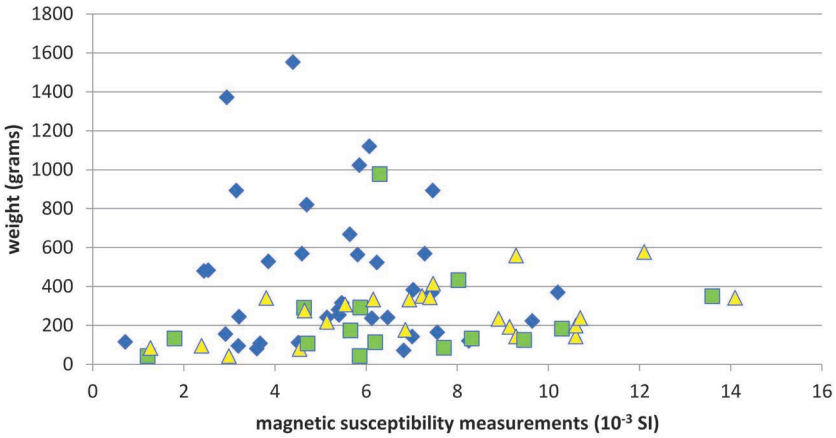

Fig. 6. Kamenets-Podolskiy (Tatarysky), Ploshchadka 1: weight and magnetic susceptibility measurements of burnt daub. Blue rhombuses: daub covering the wooden construction of the second storey floor in the entrance room and the western part of the living room. Green squares: elevation (clay without organic admixtures) and daub covering the wooden construction of the second storey floor near the [eastern] back wall (clay with organic admixtures). Yellow triangles: daub covering the wooden construction of the second storey floor near the long northern wall.

Meanwhile, our work finds different functions for similar features, and therefore different behavioural processes beyond them (*Schiffer 1987*), as the major issue in the analysis of evolution of the CTCC settlement structures. A question on the supply of water to the inhabitants of the high-elevated Kamenets-Podolskiy (Tatarysky) is successfully resolved by comparing the geophysical research results with the water drainage analysis (Fig. 8). The results, as confirmed by the excavations and laboratory analyses, reveal access to water was the primary function of the ditches, and the various production complexes were placed within (tannery) or near (kilns) external and internal ditches in the eastern part of our site (*Sobkowiak-Tabaka* et al. *2024*). Besides the excavated features, other production complexes within the internal ditch may be assumed from the distribution of 'dwelling-like' anomalies (if the daub fragments were not redeposited into the ditch from its surroundings). Different functions for ditches, such as for defensive purposes or water drainage, would potentially change their location and the arrangement of other features. In our case access to water shaped the settlement structure as follows.

The abundance of around 100 anomalies associated with dwellings in Kamenets-Podolskiy (Tatarysky) indicates a relatively high occupation density estimated at *c.* 11.1 dwellings per 1ha (the overall surveyed area) or *c.* 16.7 dwelling per 1ha (actual inhabited area of *c.* 6ha). According to the evidence from other settlements, the vast majority of buildings are represented by houses (*e.g., Chernovol 2012*, but also see *Chernovol 2021a*). The estimates correspond to the trend of increasing WTC settlement size and decreasing density of dwellings (= population density) from the Dniester to the Dnieper, *i.e.* from the west to the east (*Diachenko, Menotti 2017*). As in the majority of other CTCC sites, the dwellings are clustered (Fig. 9). In our case, such small clusters include two to nine buildings. However, detached dwellings are also notable. A general pattern in the spatial distribution of dwellings may be explained by the location of the internal and external ditches and a probable ditch crossing the central and northern part of a settlement from the south to the north (Fig. 8). The arrangements of buildings in the north-western and south-eastern parts of a settlement, each arrangement placed between two ditches, are determined by the close proximity to water. The location of several dwellings outside the arrangements, but (with a few exceptions) in the proximity of ditches, fits the same trend (Figs. 8 and 9). Of course, the proposed explanation should be confirmed by further excavation of a probable ditch 'cutting' the north-western semicircular arrangement of dwellings from the east.

At first glance, the magnetic map of Kamenets-Podolskiy (Tatarysky) reveals a mega-structure in the central part of a site. Mega-structures usually interpreted as communal buildings are noted in the central part of smaller settlements and within the so-called 'quarters' of the mega-sites (*e.g., Kruts 1989; Chapman* et al. *2016; Hofmann* et al. *2019; Nebbia* et al. *2019; Ohlrau* et al. *2019; Hale 2020*) (Fig. 5). The probable 'ditch' in the central and northern part of Kamenets-Podolskiy (Tatarysky) suggest alternative un-

derstanding. Given evidence of production within other 'ditches' and their close proximity, it is possible that the anomalies composing a supposed 'mega-structure' represent a few houses and production areas whose location is explained by access to water. For instance, the location of Type III features to the east of this 'ditch' makes possible an assumption regarding the placement of pottery kilns here. The anomalies of Type III interpreted as the kilns can be compared to the research conducted in Talianki and Maidanetske (*e.g., Korvin-Piorovskiy* et al. *2016; Müller* et al. *2017; Ohlrau 2020*) and other sites which revealed daub structures that underwent high temperature activity (*i.e. Niebieszczański* et al. *2018*). Kilns were indeed revealed during the test excavations (*Diachenko, Sobkowiak-Tabaka 2020*). However, we cannot correlate these features with a particular anomaly as they were investigated outside the magnetic map.

By narrowing our study to the single CTCC dwelling, we may confirm the usefulness of geophysical research for revealing the internal structure of dwellings (*Pickartz* et al. *2019*). Magnetic data of the site represents *Ploshchadka* 1 as the coupled anomalies. According to the results of the excavations, these anomalies correspond to the entrance room (western part, *c.* 4.2x2m) and living room (eastern part, *c.* 7.4x2m) of a house. It is worth mentioning that the size of the living room ex-

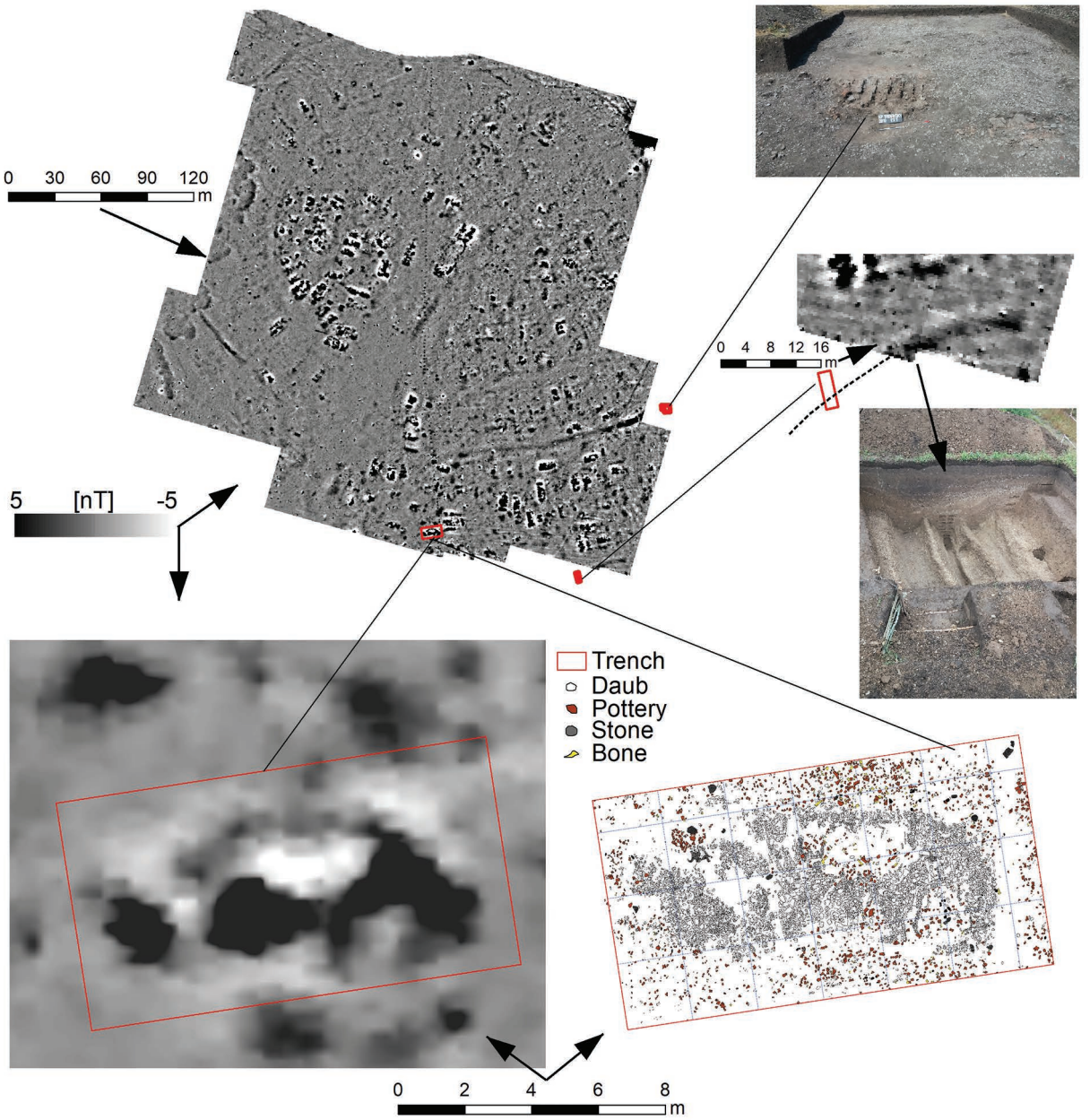

Fig. 7. Correlation between the magnetometry and test excavation' results in Kamenets-Podolskiy (Tatarysky).

ceeds that of the entrance room in the vast majority of the CTCC houses, and entrance rooms are characterized by the 'eroded' distribution of daub (*e.g., Chernovol 2012; 2021b*).

However, the results of our study confirm the conclusion of Pickartz *et al.* (*2019*) regarding the weakness of interpreting dwellings' interiors based on the analysis of geophysical plans, which is caused due to influence of heat on magnetic susceptibility. Our case study demonstrates that the overall trend of correlation between the daub mass and magnetic susceptibility is not met by the daub covering the wooden construction of a second-storey floor below an oven. This layer of daub was deliberately made thicker than the daub layers covering other parts of the floor in order to protect the wooden constructions of houses from occasional fires (*Chernovol 2021b*). For the same reason, the effects of heat on this layer were weaker compared to other parts of a floor. Therefore, daub mass has significantly lower susceptibility than expected from the general trend in the mass-magnetic susceptibility correlation.

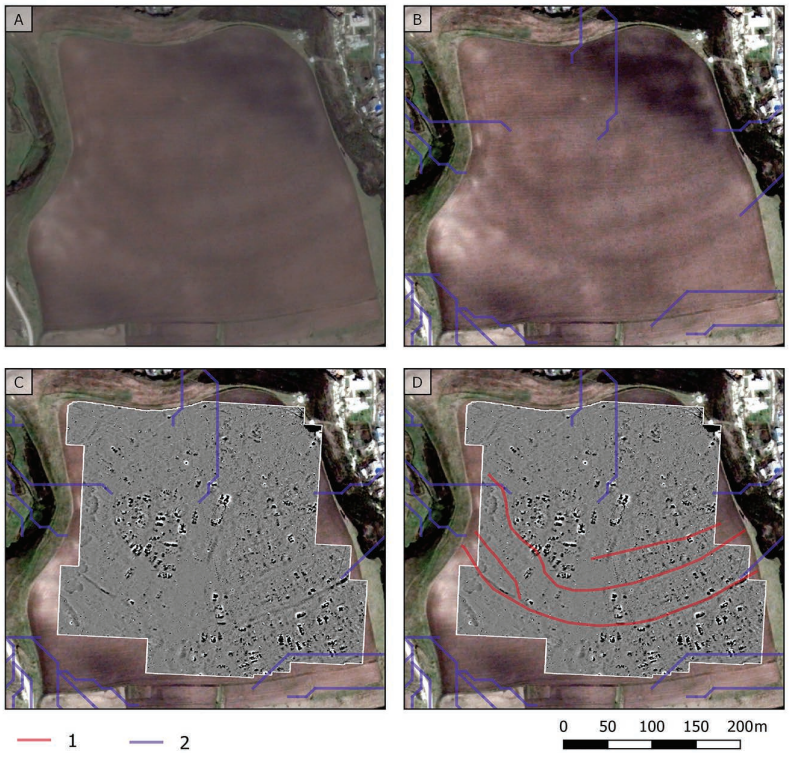

Fig. 8. Kamenets-Podolskiy (Tatarysky).* A *aerial photography of site area from 2013 (source Google Earth).* B *aerial photography with enhanced contrast.* C, D *results of magnetometry prospection (10/–10nT range);* 1 *interpretations from aerial photography;* 2 *drainage analysis results.

Conclusion

The 'Tripolye mega-site revolution', as defined by John Chapman and collaborators (*2014*), shed new light and forced a change on research programmes dealing with the CTCC sites. Earlier studies mostly opposed mega-sites to smaller settlements, questioning the formation, development and decline of the largest population agglomerations. Current theoretical and methodological advances (*e.g., Furholt 2016; Sindbaek 2022; Bruvoll 2023*) enable research on the social processes underlying the non-linear evolutionary trajectories of the CTCC settlement structures. Geophysical plans are the primary source for this work. However, their interpretation requires care and contextualization, as exemplified by our data. Incorporation of topographic information and water drainage analysis to the studies of settlement structures revealed by magnetometry makes it possible to understand the function of certain features and, therefore, the intentionality behind the ar-

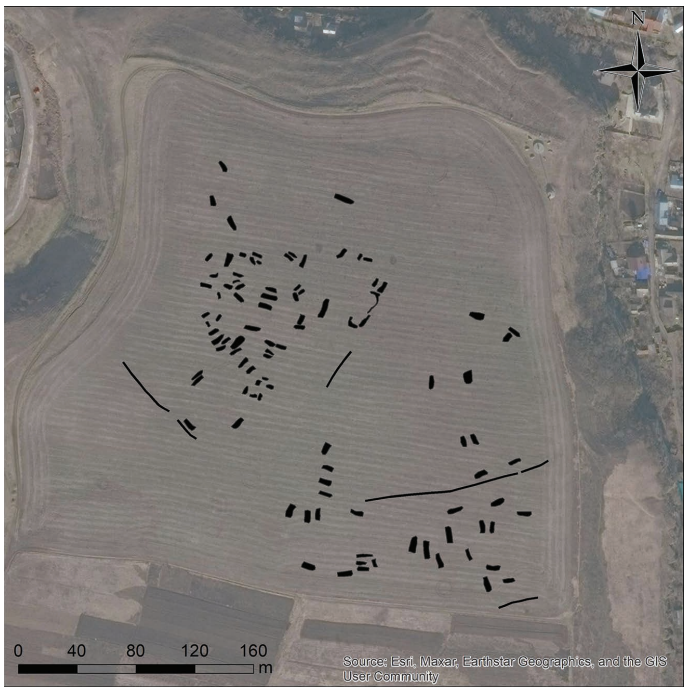

Fig. 9. Kamenets-Podolskiy (Tatarysky). Arrangement of houses and ditches interpreted and verified through the application of non-invasive and invasive methods.

rangement of houses and utility structures. Further work in this direction would reveal more useful insights into the social and economic complexity of the inhabitants of CTCC settlements.

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New data on Ditch 5 from the site of Marroquíes (Jaén, Spain): its use in the last phases of a funerary rite

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ABSTRACT – *This study presents the results of an archaeological intervention (area RU-1 (1-2-3)/SUNP-1) in the city of Jaén (Andalusia, Spain) on a sector of the vast prehistoric site of Marroquíes. The excavation specifically explored a segment of Ditch 5, one of several concentric ditches forming part of the vast enclosure. As elsewhere at the site, this ditch is characterized by a trough-shaped section and, although there is no evidence of a flanking wall, one of its backfills (Stratigraphic Unit 11) could stem from the dismantlement or erosion of an adjacent earthwork or adobe wall. The presence of secondary depositions of specific human remains atop the layer of backfill (Stratigraphic Unit 11) of the ditch appears to correspond to the final phase of a funerary practice. As radiocarbon dates and stratigraphic analysis suggest, these secondary human depositions were deliberately placed here (in a partly filled and abandoned ditch along the boundaries of the settlement), probably long after their deaths. Radiocarbon dating places the deaths of these individuals in the second half of the 3rd millennium cal BC, but they ended up in the ditch at a later date. They appear not to have served as references to specific ancestors or families, but to the community as a whole, which would have been bonded by acknowledging these anonymous ancestors. In any case, the space between Ditch 5 and Ditch 4 was not intended for households but for funerary activities and possibly for farmlands and areas for livestock.*

KEY WORDS – *Copper Age; Iberian Peninsula; enclosure; radiocarbon dating; funerary practice*

Novi podatki o jarku 5 z najdišča Marroquíes (Jaén, Španija): njegova uporaba v zadnjih fazah pogrebnega obreda

IZVLEČEK – *V študiji predstavljamo rezultate arheoloških izkopavanj (na območju RU-1 (1-2-3)/SUNP-1) v mestu Jaén (Andaluzija, Španija), ki predstavlja del obsežnega prazgodovinskega najdišča Marroquíes. Izkopavanja so bila osredotočena na del jarka 5 – enega od koncentričnih jarkov, ki so tvorili del obsežnega obrambnega sistema. Tako kot drugi jarki ima tudi ta skledasto obliko. Čeprav ob njem ni dokazov o obzidju, bi lahko eno od njegovih polnil (stratigrafska enota 11) predstavljalo ostanke erodiranega ali razgrajenega zemeljskega nasipa oz. zidu iz na soncu sušene opeke. Na vrhu omenjene plasti so bile odkrite sekundarno odložene človeške kosti in zdi se, da predstavljajo končno fazo pogrebnega obreda. Radiokarbonsko datiranje in stratigrafska analiza kažeta, da so bili človeški ostanki v jarek namerno položeni precej po smrti – v času, ko je bil jarek že opuščen in delno zasipan, na robu nekdanje naselbine. Radiokarbonska umestitev smrti teh posameznikov sega v drugo polovico 3. tisočletja pr. n. št., njihova ponovna vključitev v prostor pa je časovno ločena od samega dogodka smrti. Zdi se, da ostanki ne predstavljajo posameznikov ali družine, temveč simbolizirajo kolektivne prednike celotne skupnosti. Prostor med jarkoma 5 in 4 zagotovo ni bil namenjen bivanjskim dejavnostim, ampak pokopom in morda kmetovanju ali oboram za živali.*

KLJUČNE BESEDE – *bakrena doba; Iberski plotok; ograde; radiokarbonsko datiranje; pogrebne prakse*

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Introduction

Most of the archaeological evidence related to the Neolithic and Chalcolithic periods in Southern Iberia comes from research carried out on sites labelled as either 'silo fields' or 'ditched enclosures'. Most of these sites are devoid of emergent structures, and almost all of their artefacts are collected from the backfills of negative structures generally dug into Tertiary marls. These sites are mainly characterized by two types of structures: simple or pyriform pits, traditionally interpreted as silos, and trenches or vast ditches with 'U' or 'V' shaped sections (*Márquez, Jiménez 2010.5*). It is rare for these structures to be completely preserved, as they are usually devoid of their upper section due to erosion or anthropic actions. The ditches or trenches at these sites usually range between 4 m and 2m in width and 7m and 1m in depth, but some of them are larger.

Many of these sites, as Marroquíes, are characterized by multiple concentric ditches. However, as their construction and different features are not necessarily contemporary, their layouts present a wide range of designs (*Márquez, Jiménez 2010.6*).

Interpretations differ as to the nature of the different layers of backfill in these ditches. They usually consist of thin silty layers at the base covered by thicker levels containing rocks, adobes and charcoal remains. Thicker layers in certain cases derive from adjacent or flanking earthworks, walls and/or palisades, while in others their origin remains unclear. Although most of these layers contain few archaeological remains, other more superficial levels can yield large amounts of findings. According to some researchers, these layers and materials could either represent deliberate depositions (*Márquez, Jiménez 2010.8*) or simply originate from cumulative processes of erosion and deposition (*Arteaga* et al. *2017*). In any case, the presence of human and animal remains (suids, canids, bovids, cervids, ovicaprids, and in some cases, equids), either incomplete or partially articulated. means that it cannot be ruled out that their accumulation is the result of ritual activities.

Although the study and interpretation of ditched enclosures benefits from a century-old tradition, it is recent archaeological work that has unveiled the complexity of this phenomenon on the Iberian Peninsula. This is the case of interventions in the Guadiana and Tagus River Basins (*Liesau* et al. *2008; Valera 2012; 2013; Valera, Pereiro 2013; Ríos* et al. *2014; Valera* et al. *2014b*), as well as in the Duero (*García 2013; Delibes* et al. *2014; 2019*) and Guadalquivir Valleys (*Zafra* et al. *1999; Lizcano* et al. *2004; Aranda Jiménez* et al. *2016; García* et al. *2017; 2020; Mederos* et al. *2021; 2023*). In addition to the traditional view of these ditches as defensive features delimiting settlements (*Cámara, Molina 2013*), new evidence suggests that they were also used to monumentalize residential areas *(Díaz del Río 2001; 2003; Delibes* et al. *2014*) or to circumscribe spaces where sporadic ritual meetings took place (*Márquez, Jiménez 2010; Márquez 2013*). Other researchers have considered concentric ditches as features to regulate water supply for farming (*Zafra* et al. *1999*). In any case, it is noteworthy that the symbolic interpretation of these enclosures does not exclude a defensive role. We dismiss the use of these sites as non-permanent settlements, because this assertion would involve a series of questionable arguments, such as the existence of a clear separation between sacred and profane spheres in prehistoric societies, or the consideration of buildings made from perishable materials as temporary.

The ditched enclosures in Southern Iberia are dated between the 4th and 2nd millennia BC (*Márquez, Jiménez 2010.8; Valera* et al. *2014b*). The cases yielding earlier radiocarbon dates (*Valera* et al. *2014b*) could stem from samples of older materials that found their way into the backfills, either intentionally or by erosion. As noted by Gonzalo Aranda Jiménez *et al*. (*2016*), the difficulty linked to dating sites yielding only sunken features and devoid of stratigraphic overlaps can only be solved by multiplying the number of radiocarbon analyses available. The ditched enclosures are particularly complex as the strata and their content derive from both erosive processes and/or intentional fillings. In fact, the samples serving for the radiocarbon analyses yield dates corresponding to their deaths, but they end up in the ditch at a later date. Moreover, the time of deposition does not necessarily equate with the construction, use or abandonment of the ditch, and the natural collapse of sections of this structure may further complicate its interpretation.

For these reasons, it is advisable (when possible) to analyse samples from the initial silty layer of fill, as items with this stratigraphic position can offer an approximate date of the last use of the ditch (and therefore, serve as a *terminus ante quem* for its construction). Another option is to focus on the dating of intentional depositions of ritual character that sealed the ditch or one of its layers. This last option ideally offers a *terminus ante quem* for the use of the ditch. How-

ever, as highlighted here, the moment of death of the sampled remains does not necessarily coincide with the moment of their deposition. Ultimately, the only precise means of dating the construction and use these types of features is to resort to their relationship with other structures. It is thus best to focus on potential structure overlaps or to turn to, whenever possible, the remains of palisades preserved either *in situ* or displaced into the ditch.

Background

Research on sites from the 4th and 3rd millennia cal BC in Southern Iberia faces particular difficulties concerning chronology, settlement and enclosure interpretation, and the roles of metallurgy and rituals within (*Nocete 2001; Nocete* et al. *2011; Cámara, Molina 2013; García, Murillo 2013; Molina* et al. *2016; García* et al. *2017; 2018; 2020; Risch 2018; Mederos* et al. *2023*). Although other sites along the Upper Guadalquivir Valley have yielded relevant data (*Nocete 1994; Lizcano 1999; Nocete* et al. *2010; Afonso* et al. *2014; Lechuga* et al. *2014; Conlin* et al. *2020; Milesi* et al. *2020; Pinillos* et al. *2022*), it is the rediscovery in 1995 of Marroquíes (Jaén) (*Lizcano* et al. *1995; 2004; Zafra* et al. *1999*), the focus of this study, that undoubtedly launched a new phase of research on sites from this chronological timeframe.

Marroquíes occupies a vast area (Fig. 1) along the northern edge of the city of Jaén (Andalusia, Spain) at the foot of the Jabalcuz Massif, a point marking the outset of the region known as Campiña Alta (*Pérez, Cámara 1999*). This urban site has been known since the 1950s due to the discovery of burials in an area designated as Marroquíes Altos (*Espantaleón 1957; 1960; Lucas* 1968). Its archaeological value, however, was only recognized in recent times due to urban expansion, which has led to the almost complete disappearance of the site. Fortunately, the creation of the Zona *Arqueológica de Marroquíes Bajos* (ZAMB) (*Castro* et al. *2010*) has made it possible to excavate many of the areas before the construction of new buildings.

These archaeological interventions, of varying quality, remain for the most part unpublished (*Cámara, Molina 2016*). However, certain papers (including *Pérez, Cámara 1999; Pérez, Sánchez 1999; Sánchez* et al. *2004; Rodríguez* et al. *2006; Barba, Navarro*

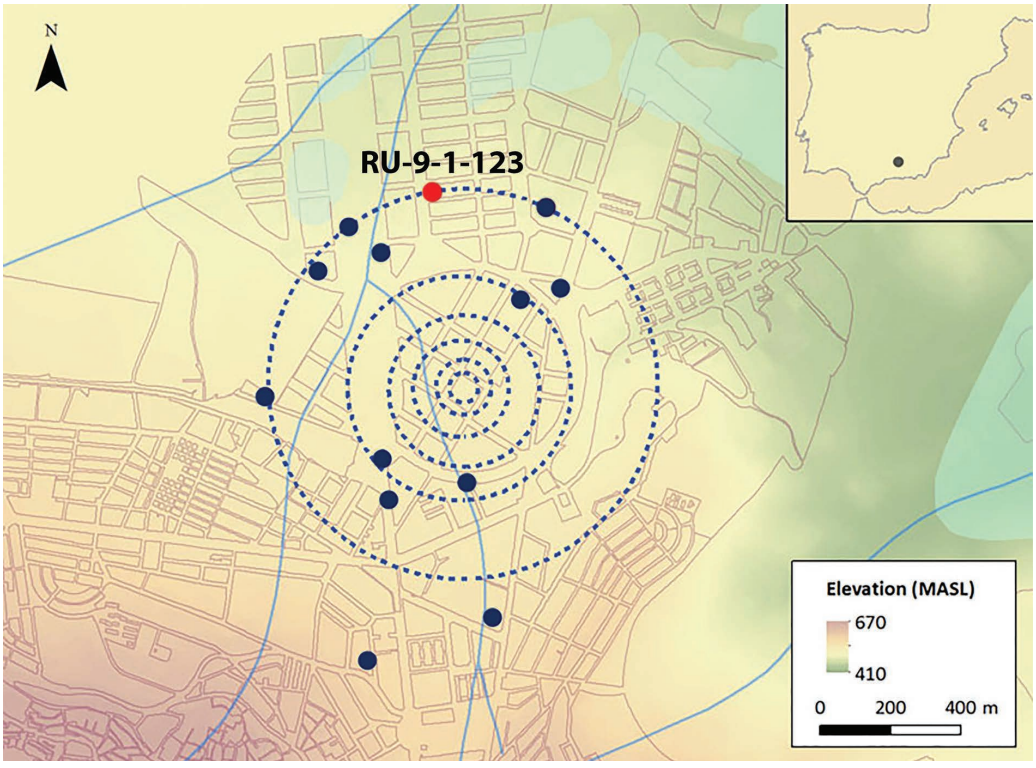

Fig. 1. Schema of the different concentric enclosure ditches of the vast prehistoric site of Marroquíes in Jaén (Andalusia, Spain). The red dot indicates the position of the excavation of Ditch 5 in plot RU-1 (1-2-3)/SUNP-1, the object of this study. The blue dots mark other excavations yielding prehistoric human remains (modified from* Díaz-Zorita *et al.* 2020*).

2010; Portero et al. *2010b; Cámara* et al. *2012a*) have made it possible to yield a general outline of the development of the domestic space and the enclosure itself (*Zafra* et al. *1999; 2010; Lizcano* et al. *2004*). Other papers have also delved into questions of regional chronology (*Cámara* et al. *2012a; 2012b; Aranda Jiménez* et al. *2016; Díaz-Zorita* et al. *2020*) as well as ancient funerary rites, economic strategies, diet, environment and mobility (*Cámara* et al. *2012a; 2016; Yanes* et al. *2013; Beck 2016a; 2016b; 2017; Nicás, Cámara 2017; Beck* et al. *2018; Díaz-Zorita* et al. *2018; 2020*). In any case, the research results clearly show that the great volume of archaeological data, coupled with the site's characteristics, can cast new light on specific historical problems.

The vast extension of the Marroquíes site, surpassing 130 hectares (*Zafra* et al. *1999; 2010*), evokes other sites located for the most part beyond the area, notably Valencina de la Concepción (Seville) (*García* et al. *2017; 2018*; *Mederos* et al. *2023*) in the southwest of Iberia. However, two prehistoric sites in the same Province of Jaén, Alcores-Albalate-Berral (Porcuna) (*Arteaga 1987; Arteaga* et al. *1987; 1993; Nocete 1994*) and Úbeda (*Nocete* et al. *2010*), suggest that Marroquíes is not the sole mega-site in the Upper Guadalquivir Valley.

Marroquíes shares features with many Iberian mega-sites, notably concentric ditches delimiting a domestic space (*Márquez, Jiménez 2010; 2013; Valera* et al. *2014b*).

Moreover, some mega-sites are clearly associated with walled fortifications (*Zafra* et al. *1999; 2003; 2010; Lizcano* et al. *2004; Nicás, Cámara 2017; Monje, Crespo 2024*), as in the case of other sites from the Southeastern Iberia (*Cámara, Molina 2013*) and the Upper Guadalquivir Valley (*Milesi* et al. *2020*).

Another key aspect of Marroquíes is the presence of previous occupations in the area, (*e.g.*, El Corte Inglés) (*Portero* et al. *2010b; Serrano* et al. *2011*), dating back to the 5th millennium cal BC. However, there is no evidence of a continuity between these earlier Neolithic occupations and the vast Chalcolithic settlement, in spite of the discovery of several features from the late 4th and early 3rd millennia cal BC (*Serrano* et al. *2011*). As noted above, the scarcity of superimposed structures at these sites complicates assessing their continuity over time, thus making it necessary to multiply the number of radiocarbon analyses. Furthermore, gaining a grasp of the relationship of Marroquíes with the surrounding Neolithic sites would require initiating new systematic archaeological research projects throughout the city of Jaén (*Lizcano 1999; Zafra 2006; Zafra* et al. *2010*). Yet new excavations in the framework of urban archaeology probably offer little new data, as the prehistoric features usually only appear at levels below the foundations of modern constructions.

The known initial Chalcolithic settlement of Marroquíes, enclosed by a palisade and a ditch (Ditch 0) dating to around 2800/2700 cal BC, extended over a rather modest surface of 0.3ha. It has been proposed that a new phase surpassed and cancelled the initial enclosure, reaching a surface area of more than 11 000m^2 (Ditch 1) Best known is the true mega-site, built around 2500 cal BC, and which represents a substantial change in size and design. A perimeter wall with bastions and towers (in adobe, stone and wood) and a flanking ditch (Ditch 4), enclosing a vast settlement extending over 34 ha was erected (*Zafra* et al. *2010*). It was possibly related to, at least two other interior enclosures (Ditches 2 and 3) (*Zafra* et al. *2010*). However, not all the ditches, or at least not all of their segments, survived until the end of the settlement, as many saw their layout undergo important modifications (*Pérez, Cámara 1999; Nicás, Cámara 2017*).

Although certain researchers attribute this great increase in surface area to a process of synoecism affecting an extensive area (*Zafra 2006; Zafra* et al. *2010*), the survival of key neighbouring settlements such as Venta del Llano (Mengíbar) (*Portero* et al. *2010a*) and Venta del Rapa (Mancha Real) (*Lechuga* et al. *2014*) suggest that the process only affected sites in the immediate area (*Cámara* et al. *2012b*), where, as noted above, the density of the different Neolithic occupations was relatively high (*Lizcnao 1999; Zafra 2006*). Even taking into account the aforementioned problems for dating the ditches, a new feature (Ditch 5) appeared a short time after the construction of this complex defensive system, possibly still in the second half of the 3rd millennium cal BC, encircling 113ha. This supposedly more recent structure was accompanied by a defensive wall raised with stone and adobe with towers (at least in certain areas near the gates). A significant decrease in the density of structures in the space between Ditches 5 and 4 (*Zafra* et al. *2010*), along with the increase in burials (*Cámara* et al. *2012a; 2016; Beck 2016a; 2016b; 2017; Beck* et al. *2018; Díaz-Zorita* et al. *2018; 2020*), suggest that this space was not residential.

In any case, the chronological sequence of these concentric features remains unclear (*Zafra* et al. *2003; 2010; Cámara* et al. *2012b; Aranda Jiménez* et al. *2016; Nicás, Cámara 2017*). It is in fact probable that not only were the initial enclosures abandoned at different times, before the rapid expansion of the settlement, but Ditches 2 and 3 also ceased to be in use before 2200 cal BC, or at least certain segments of these ditches underwent transformations (*Pérez, Cámara 1999; Nicás, Cámara 2017*).

In this sense, the datings currently available (*Cámara* et al. *2012a; 2012b; 2016; Beck* et al. 2018*; Díaz-Zorita* et al. *2018; 2020*) suggest that some of the ritual activities were performed at the periphery of the settlement since at least the middle of the 3rd millennium cal BC. This situation can be traced in certain zones that have been explored, and especially along the outer limits of Marroquíes (*García 2009; Serrano* et al. *2011; Cámara* et al. *2012a; 2016; Beck 2016a; 2016b; 2017; Beck* et al. *2018; Díaz-Zorita* et al. *2018; 2020*). Yet certain changes in the organization of these peripheral areas could have potentially taken place at different times, either due to the transformation of certain internal structures (*Rabanal* et al. *2009*) or due to ditch modifications (*Montilla* et al. *2009*).

Fig. 2. Marroquíes. Detail of the segment of Ditch 5 brought to light during the excavation of plot RU-1 (1-2-3)/SUNP-1.

The transformation presumably took place earlier in the area delimited by Ditch 5. This would be the case when assuming that it did not serve from the outset as the boundary of the settlement, but included funerary areas and zones of intensive farming. The current study goes deeper into this argument based in part on the findings and datings of different excavations (*Sánchez* et al. *2005; Beck 2016a; 2016b; Díaz-Zorita* et al. *2020*), and in part on new radiocarbon dates of samples collected in a specific area of Ditch 5.

Objectives

The first objective of this study is to assess the funerary practices linked to the different Marroquíes ditches, and in particular those of Ditch 5. The second objective is to evaluate the function pf Ditch 5 in terms of its features and depositions both in and beyond the segments explored in previous years. The final aim is to attempt to specify the timeframe of the abandonment of Ditch 5 and its meaning in relation to the final phases of Marroquíes.

Archaeological excavations at RU-9-1-1-2-3, contextualization of the finds and results

Description of the area, structures and strata

The archaeological intervention (380m2), authorized by the *Dirección General de Bienes Culturales* of the *Junta de Andalucía*, focused on a rectangular surface (area SUNP-1/RU-9-1:1-2-3) sloping slightly from north to south (UTM coordinates: X 430703E and Y 4182631N; 464.54masl). The work took place in three phases.

The first was the sinking of trial trenches (81m2). This was followed by an enlargement of these trenches from north to south, attaining a surface area of 164.65m2. The third phase consisted of surveying the removal of earth from the construction area, an action that increased the total studied surface to 380m2. These activities led to the identification of the following 12 stratigraphic layers, of which nine (SU 4-11) are fills of Ditch 5 (from top to bottom) (Figs. 2,3,4):

SU 1. Layer of gravel deriving from modern urbanization work in the area.
SU 2. Layer of blackish clay corresponding to the arable earth preceding the modern constructions.
SU 3. Layer of greyish clay corresponding to an upper backfill of Ditch 5.
SU 4. Thin layer of small stones observed in trial

trenches 1, 2 and 3 corresponding to a fill of Ditch 5.
SU 5. Layer of light grey clay.
SU 6. Layer of rounded pebbles identical to those in riverbeds.
SU 7. Layer of light grey clay.
SU 8. Layer of yellow sediment possibly corresponding to the collapse of the upper natural strata cut by the ditch.
SU 9. Layer containing many small rounded pebbles.
SU 10. Layer of yellowish clay with small stones and archaeological materials.
SU 11. Layer of sterile yellow clay.
SU 12. Bedrock cut during digging of Ditch 5.

Fig. 3. Marroquíes. General view of the segment of Ditch 5 excavated in plot RU-1 (1-2-3)/SUNP-1.

Sequence

The findings of the intervention make it possible to identify four phases of occupation.

Phase 1

This earliest phase of Ditch 5 falls in line with a Chalcolithic occupation that can be divided into two subphases. The first is the construction of Ditch 5 while the second relates to its use. The ditch segment brought to light here cuts through the geological substrate (SU 12) following a clearly defined, albeit heterogeneous, course, which in fact reveals differences in width and depth stemming from adapting to the slope. The ditch crosses the entire excavated area from east to west attaining a width surpassing 20m at its northern and southern ends. According to trial trenches 1, 2 and 3, its maximum depth is 4.50m and its section ranges from U-shaped at certain points to quadrangular at others. Worth highlighting is that although its general section coincides with a trough-shape observed in earlier interventions since 1996 (*Sánchez* et al. *2005; Sánchez, Gutiérrez 2009; Díaz-Zorita* et al. *2020*), its dimensions differ as they exceed the previously noted 2m to3 m depth and 10m to 13m width. No layer was identified corresponding to the sub-phase of initial use, suggesting it was subjected to periodic cleanings.

Phase 2

The second phase is characterized by the abandonment and initial backfilling of the ditch. The different layers of this phase can be divided into two main units related to the end of the original use of the ditch. The earliest (SU 11) corresponds to a practically 'sterile' clayish, yellowish stratum containing small stones potentially deriving from an intentional backfilling or, more likely, from the natural dismantlement of adjacent structures such as an earthwork. Here there are in fact no traces of stone walls, as these features are thought to only be near the gates along Ditch 5 (*Zafra* et al. *2010*). Another possibility explaining this initial layer of fill is that it stemmed from a flanking adobe wall whose individual components disintegrated over time after their collapse into the ditch. The second layer is highlighted by the deposition of human remains (SU 10) capping the earlier SU 11. This deposition of human remains is followed by a stratum (SU 9) containing numerous rolled pebbles, possibly of anthropic origin. The ritual practices linked to these levels can be considered a second subphase (2b) following the collapse or destruction of the bank/adobe wall (subphase 2a). The subsequent levels are greyish clays that also comprise rolled pebbles (SU 8 to 3), apparently transported by erosion, and they can be considered as part of other sub-phase (2c) that ended and sealed the prehistoric occupation.

Phase 3

This phase is characterized by a blackish clay (SU 2) corresponding to contemporary arable earth (for agriculture) dating to a time prior to modern urbanization.

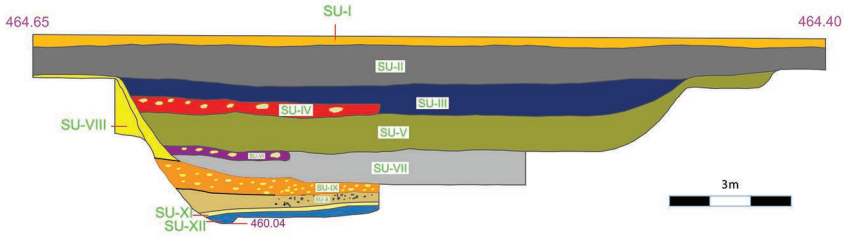

Fig. 4. Marroquíes. Western section of Ditch 5 with stratigraphic units.

Phase 4
The last phase, characterized by gravel (SU 1), corresponds to the modern urbanization of the area.

Anthropological remains
A total of 94 human bones (whole, fragments and segments) were recovered from SU 10 of Ditch 5 (Tab. 1; Fig. 5). Their quantity and favourable state of preservation – hardly affected by taphonomic processes – enabled exhaustive analyses as to the number of individuals, choice of bone and distribution according to age and sex. The analyses likewise shed light on potential pathologies and causes of death. The work was entrusted to Sylvia A. Jiménez Brobeil of the Department of Legal Medicine, Toxicology and Physical Anthropology of the University of Granada and to MD Zita Lanfranchi, a physical anthropologist.

The analyses applied methods advanced by Mirjana Roksandic (*2002*), Philippe Chambon (*2003*) and Jacqueline I. McKinley (*2004*). The estimation of the number of individuals derives from the work of Bradley J. Adams and Lyle W. Konigsberg (*2004*). When the pelvis was not present, sex was determined by the most common criteria, notably anthropometric differences between robust and graceful individuals.

The anatomical examinations indicated no complete skeleton. Most, in fact, correspond to selections of mandibles and hemimandibles, cranial fragments, vertebrae, humerus fragments and other long bones (both epiphyseal and diaphyseal). Their distribution denotes a minimum of five individuals, notably one mature male (more than 41 years old), two adult males (between 21 and 40 years), an adult female and a subadult (possibly a juvenile judging by the size of the fragments).

Otherwise, the observations offered no indicators of maxillo dental pathologies, osteoarthritis, metabolic or infectious diseases or traumatic injuries. The only two lumbar vertebrae bearing traces of Schmorl's nodes belong to the older male. Schmorl's nodes indicate the existence of intradiscal hernias and usually appear among mature subjects or those having experienced intense physical activity. There is also no evidence of the development of enthesophytes or other markers linked to physical activity.

Radiocarbon analyses
The samples for ^{14}C collagen analyses were taken from six of the larger, better preserved bones, avoiding, as much as possible, repeated datings from the same individuals, but still aiming to get a high number of datings. They yielded results ranging from 3799±32 to 3936±32 BP (Tab. 2). These were then calibrated according the IntCal20 curve with the CALIB8.1.0 application (*Reimer* et al. *2020*).

Statistical analyses of the datings of Ditch 5

A synchronicity of the deaths could serve as an argument favouring a contemporaneous deposition of the remains on the layers related to the collapse of the embankment or adobe wall filling Ditch 5. However, a lack of synchronicity would likewise not rule out a single deposition event since, given the choice and fragmentation of the skeletal remains, the deposition could represent a single moment of 're-burial' of bones that had been progressively interred elsewhere.

Fig. 5. The anthropological remains from layer SU 10 of Ditch 5.

Nº	ANATOMIC ELEMENT	RELEVANT DATA		PATHOLOGY	SEX AND AGE
DJ/DA, RU-91-123	Symphysis and left hemimandible	Square chin, protruding mental tubercle, chin foramen under P2, everted angle of the mandible, and high and broad coronoid process.	Left C, P1, P2 and M1 preserved in situ, reveals medium intensity wear and the alveoli of the four incisors.		Male adults
	Fragment of left mandible	Tall and robust with low mental foramen P1	P1, P2 and M1 and M2 preserved in situ, with intense wear, and a visible alveolus of C-		
	Chin and left hemimandible, without condyle	Parabolic chin, symphysis, tall body, and rough angle of the mandible.	M1, M2 and M3 preserved, with medium wear on the first two and initiated on the third and on the alveoli of the first two incisors and on the second, canine and premolars on the right side.		
	1 iliac blade fragment				
	1 right proximal femoral epiphysis				
	1 right distal femoral epiphysis				
	1 left calcaneus				
	1 right calcaneus				
	1 cuboid bone				
	1 atlas				
	1 lumbar vertebra			Presents a trace of a Schmorl's node on both sides of the body, in a central position	
	1 lumbar vertebra elements			Presents a trace of a Schmorl's node in the centre of the articular surface	
	1 left talus				
	1 humerus fragment				
	1 right proximal ulna epiphysis				
	1 right proximal ulna epiphysis	Incomplete			
	1 right distal femoral epiphysis	Incomplete			
	1 fragment of distal femoral epiphysis				
	1 right proximal fibula epiphysis				
	1 right distal epiphysis of a fibula				
	Small skull fragment: 1 parietal	Open sagittal suture			Female
	1 humerus fragment				
	1 right distal humerus fragment				

Tab. 1. List of the anthropological remains from layer SU 10 of Ditch 5.

Nº	ANATOMIC ELEMENT	RELEVANT DATA		PATHOLOGY	SEX AND AGE
DJ/DA, RU-91-123	1 right ulna	Incomplete			Female
	1 left proximal ulnar epiphysis				
	1 right proximal femoral epiphysis	Incomplete			
	1 left proximal femoral epiphysis				
	1 tibial shaft fragment			No traces linked to periostitis	
	1 left distal epiphysis of a clavicle				
	Small cranial fragment: 1 parietal				Enfant
	1 sacrum vertebra				
	1 fragment of humeral shaft				
	1 tibial shaft fragment			No traces linked to periostitis	
	1 left humeral distal epiphysis				
	Small cranial fragment: 1 occipital				Undetermined
	Small cranial fragment: 3 from frontal area				
	Small cranial fragment: 5 parietals				
	Small cranial fragment: 1 parietal	First three coronal suture sections are open			
	Small cranial fragment: 1 parietal	S2 section is open			
	2 ischium fragments				
	4 fragments of femoral condyles				
	1 incomplete left tibial distal epiphysis				
	1 twelfth dorsal vertebra				
	7 dorsal vertebrae				
	3 spinous dorsal vertebrae				
	2 lumbar vertebrae				
	1 lumbar vertebra				
	1 femoral shaft fragment				
	2 tibial shaft fragments			No traces linked to periostitis	
	2 fragments of shaft of fibula				
	1 occiput fragment				
	2 rib fragments				
	1 fragment of a lumbar vertebra arch				
	3 humeral shaft fragments				
	1 radial shaft fragment				
	2 femoral shaft fragments				
	2 tibial shaft fragments				
	4 fibula shaft fragments				
	1 incomplete right calcaneus				
	3 metatarsals				

Tab. 1. Continued

A statistical analysis was carried out of six samples assumed to come from the same episode of deposition (SU 10 of SUNP-1/RU-9-1:1-2-3) to determine if the moment of their death more or less coincided. In this sense, the probability density function of the datings, as well as their subsequent analyses by means of a Chi-squared test and an agreement adjustment, suggest that not all the individuals died at the same date.

As the Acomb of the six dates (29) is less than 60%, one must rule out that their deaths were contemporaneous. There are nonetheless four dates (Ua-73804, Ua-77570, Ua-77571 and Ua-77573) whose A values (129.5, 129.4, 128.7, 110.2) suggest a certain contemporaneousness. The other two dates (Ua-77572, Ua-73803), in turn, yield A values (28.5, 36.6) that are incompatible with a contemporary scenario, both with respect to the other six samples and with each other (Fig. 6).

Secondly, a single contiguous phase MCMC model was generated for the six datings. The indices yielded by the model, Amodel (92.6) and Aoverall (95.5), respectively, do not rule out a near relationship between the different episodes of death.

The separate calibration of Ua-77572, the sum of probabilities of the four potential coeval dates (Ua-73804, Ua-77570, Ua-77571 and Ua-77573), and the separate calibration of Ua-73803 suggest that Ua-77572 is slightly older than the other ones (2566-2299 cal BC, 95.4 probability), with a median of 2422 cal BC. In addition, the sum of probabilities of Ua-73804, Ua-77570, Ua-77571 and Ua-77573 yields an interval of 2457–2153 cal BC (95.4 probability), with a median of approximately 2305 cal BC. Finally, Ua-73803 is slightly more recent (2400–2136 cal BC, 95.4 probability), with a median of 2236 cal BC.

Thirdly, according these results three MCMC models were generated with the dating divided into three phases (1 = Ua-77572, 2 = conjunction of the four central datings, 3 = Ua-73803) taking into consideration three scenarios: contiguous, sequential and overlapping phases. The results indicate that the model of con-

Name	Unmodelled (BC/AD)				Modelled (BC/AD)				Indices	
	from_95_4	to_95_4	from_99_7	to_99_7	from_95_4	to_95_4	from_99_7	to_99_7	Acomb	A
R_Date Ua-73803	-2400	-2136	-2456	-2042	-2405	-2210	-2455	-2207		36.6
R_Date Ua-73804	-2455	-2153	-2465	-2142	-2405	-2210	-2455	-2207		110.2
R_Date Ua-77571	-2456	-2204	-2466	-2146	-2405	-2210	-2455	-2207		128.7
R_Date Ua-77570	-2457	-2205	-2467	-2146	-2405	-2210	-2455	-2207		129.4
R_Date Ua-77573	-2457	-2205	-2468	-2147	-2405	-2210	-2455	-2207		129.5
R_Date Ua-77572	-2566	-2299	-2575	-2238	-2405	-2210	-2455	-2207		28.5
Combine SU-X	-2405	-2210	-2455	-2207					56.6	

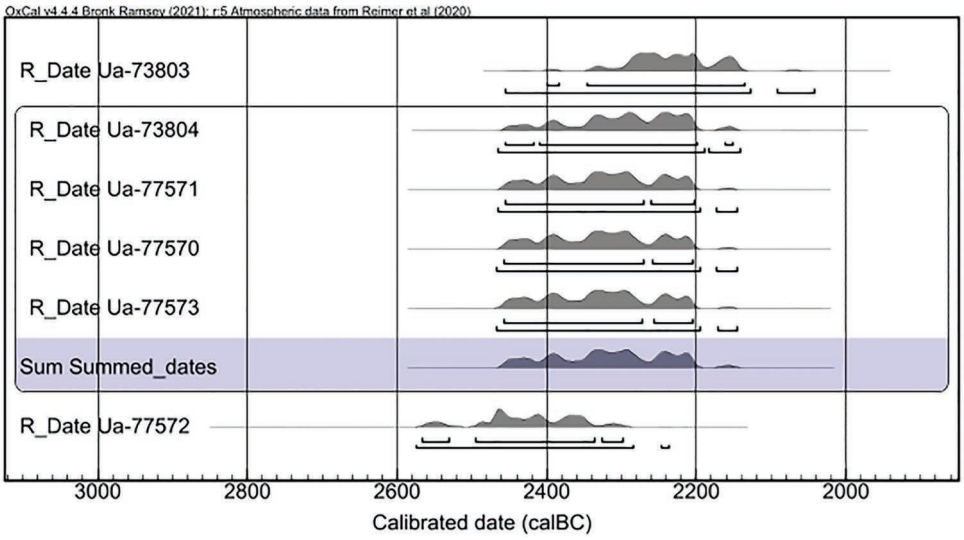

Fig. 6. Probability density function of the samples retrieved from the stratigraphic layers associated with the collapse of the embankment or the adobe wall infilling Ditch 5.

Excavation num.	Laboratory num.	δ13C‰	δ15N‰	C-N	FECHA B.P.	1σ cal AC	2σ cal AC	Anthropological data
DJ/DA 08114	Ua-73803	-20.1	11.0	3.2	3799±32	2287-2150	2399-2070	Adult
DJ/DA 08119	Ua-73804	-19.8	9.3	3.3	3836±32	2393-2205	2455-2152	Adult
DJ/DA 08101	Ua-77570	-20.1	10.9	3.3	3852±32	2435-2208	2457-2204	
DJ/DA 08108	Ua-77571	-19.7	9.7	3.2	3850±32	2403-2207	2457-2204	Adult male
DJ/DA 08113	Ua-77572	-20.2	10.6	3.2	3936±32	2473-2347	2565-2300	
DJ/DA 08124	Ua-77573	-19.6	10.5	3.2	3854±32	2439-2209	2458-2205	

Tab. 2. Results of the radiocarbon dates including the isotopic inforation.

tiguous phases (Amodel: 135.7; Aoverall 132.6), as well as sequential (Amodel: 145.7; Aoverall: 141.2) and overlapping phases (Amodel 120.1; Aoverall: 116) are all feasible. However, when considering the Amodel and Aoverall indices as model fit values, it is possible to deduce that sequential scenario is the most realistic of the three possibilities, followed by the contiguous and the overlapping ones.

The sum of the analyses indicate that the remains deposited in SU 10 of SUNP-1/RU-9-1:1-2-3 presumably correspond to individuals who died at least at three different times. One (Ua-77570) is slightly older than the others, while four could be contemporary. This is especially the case of Ua-77573 and Ua-77570, which are statistically identical, and this is not strange considering that the MNI is 5 and not 6. The third and last (Ua-73803) is slightly more recent. Moreover, given that all the human remains come from the same stratigraphic unit, they would not have been deposited in Ditch 5 before the death of the most recent individual (2400–2136 cal BC). However, we can argue that a second deposition could have taken place long after their death given the great probability that the skeletal remains remained for an undetermined amount of time in their initial place of burial.

Likewise, the fact that these samples represent intermixed bones recovered in the same level suggests that the difference in chronology between the individuals was not the result of a successive deposition during the process of filling Ditch 5. In fact, the evidence appears to indicate that all the remains were moved at once from their original resting place (or places), from where they would have been gradually deposited as they died, a notion suggested for other similar cases (*Beck 2016; Beck* et al. *2018; Díaz-Zorita* et al. *2020*). It must be noted, in this sense, that the transfer of remains between funerary structures was previously confirmed at Marroquíes (*Cámara* et al. *2016*). Even in the sectors of Ditch 5 where the depositions were assigned to different stratigraphic units, the statistical analyses of the datings reveal a null relationship between chronology and stratigraphic superposition, suggesting practices affecting individuals previously buried elsewhere (*Díaz-Zorita* et al. *2020*).

Discussion

The characteristics and findings of Ditch 5: boundary and ritual use

The segment of Ditch 5 excavated in SUNP-1/RU-9-1:1-2-3 shows a certain similarity when we compare it to segments explored in other archaeological interventions at the site. However, Ditch 5 here, despite the restricted excavated surface, also reveals some differences in its layout and, above all, radical deviations in width and depth when compared to its other segments, especially at each extremity of the excavated area at SUNP-1/RU-9-1:1-2-3. These deviations possibly stem from topographic factors specific to the excavated area, characterized by a slighter slope, but other causes can be explored, such as distance to the gates. Although its section, as noted elsewhere (*Sánchez* et al. *2005; Sánchez, Gutiérrez 2009; Díaz-Zorita* et al. *2020*), is U-shaped, it tends towards the quadrangular at certain points of the studied segment at SUNP-1/RU-9-1:1-2-3.

It must be specified that, along the rather extensive surface of the excavated area, this particular segment of Ditch 5 reveals no signs of preserved flanking structures. This contrasts with a segment studied in another excavation (area SUNP-1/DOC-1), where this structure was flanked by a walled feature, as evidenced by its collapse in the backfill (*Sánchez* et al. *2005*). These finds suggest the existence, based on the whitish layers under the secondary burials (*ibid.*), of an earlier mud/adobe wall raised on a stone base. In fact, different excavations at Marroquíes reveal evidence of flanking walls combining adobe and stone (*Zafra* et al. *2003*).

In any case, these differences may be more supposed than real. As noted above, the yellow stratum of Ditch 5 at SUNP-1/RU-9-1:1-2-3, containing stones (SU 11),

could derive from the collapse and erosion of an earthwork. It is also feasible that an adobe wall flanking the ditch may have toppled over into it before progressively disintegrating and leaving no trace beyond this yellow sediment.

The dimensions of this segment of Ditch 5 at SUNP-1/RU-9-1:1-2-3, with a maximum width greater than 20m and a maximum depth of 4.50m, surpasses those observed elsewhere at the site, as noted above. It is possible to think that these larger dimensions could in some way relate to its greater distance from the gates where, by contrast, flanking earthen or adobe walls were raised on a stone footing (*Zafra* et al. *2010*), resulting in a better preservation of the structure. To get into the settlement, certain features near the gates would be necessary to cross the ditch, and part of them can still be observed at other sites (*Cámara, Molina 2013*; *Cámara* et al. *2021*). As ditches in these areas had to be narrower, other defensive features were built. On the other hand, areas with no gates could be equipped with larger ditches and simple earthen or adobe walls.

It is clear that Ditch 5, outside an earthen or adobe wall with especially fortified gates, along with Ditch 4 and its stone and adobe wall, served to protect the population and their property. In any case, the space between Ditches 4 and 5, almost devoid of 'domestic' structures, took on a key symbolic role, a dimension accentuated when, at least at a certain time after their abandonment or backfilling, these ditches, especially Ditch 5, began to receive disarticulated human corpses.

In fact, the long segment of Ditch 5 excavated in area SUNP-1/DOC-1 also contained human remains belonging to a minimum of five individuals: one subadult and four adults (one presumably elderly) (*Sánchez* et al. *2005*). Here, likewise, no skeleton was complete as the only bones found were skulls, jaws and long bone diaphysis. The choice of certain anatomical elements (portions of skull, jaws and long bones) coincides with the observations of other segments of Ditch 5 elsewhere at Marroquíes, for a total of, at least, 10 individuals, although most of remains coming from Trench 7 of SUNP-1/DOC-1 (*Díaz-Zorita* et al. *2020*) reveal secondary depositions and/or ossuaries (*Roksandic 2002*). Unlike those remains from the current study on SUNP-1/RU-9-1:1-2-3, the ones found in SUNP-1/DOC-1 reveal pathologies such as anaemias, caries and osteoarthritis (*Sánchez* et al. *2005*). Secondary depositions of this type were also recognized in trenches near Ditch 4 (*Nicás, Cámara 2017*). Similarly, these types of depositions in ditches/trenches linked to funerary rites have been widely observed in recent decades at other enclosures (see, *Hurtado 2010; Valera, Godinho 2010; Blasco* et al. *2011; Márquez, Jiménez 2013; García* et al. *2013; 2018; Ríos* et al. *2014; Valera* et al. *2014a; Valera 2019*).

The human remains in this study, as with analogous finds elsewhere at this site (*Sánchez* et al. *2005; Díaz-Zorita* et al. *2020*), are interpreted as intentional, albeit secondary, depositions coinciding with the abandonment of Ditch 5. The finds from each of these excavations indicate that the bone remains were placed on layers subsequent to the collapse of the flanking earthworks and/or adobe walls. This is based on their stratigraphic position above the homogeneous yellowish fill observed at SUNP-1/RU-9-1:1-2-3 and the whitish layer observed during earlier fieldwork at SUNP-1/DOC-1. Moreover, each of these excavations reveal no indication that the burials were contained in a pit sunk through the backfill of the ditch. Furthermore, as indicated above, their very disposition and skeletal parts reveal no anatomical connections, showing they were not primary burials. In addition, they represent a selection of the larger, more durable and representative elements.

It is therefore apparent that the bones were removed from their initial burials, probably elsewhere at Marroquíes (*Cámara* et al. *2012a; 2016; Beck 2016a; 2017; Díaz-Zorita* et al. *2020)*, before transfer to Ditch 5. The fact that they suffered few taphonomic actions suggests they were rapidly covered (SU 9 at SUNP-1/RU-9-1:1-2-3). They are thus the result of intentional actions that characterize the end of a long tradition of rites of managing the dead (*Harrison 2004; Barley 2005; Buttitta 2006; Naumov 2007; Fowler 2013; Cámara* et al. *2016*).

The excavation at SUNP-1/RU-9-1:1-2-3 also yielded no grave goods, an absence coinciding with the practices identified in other segments of Ditch 5 (*Díaz-Zorita* et al. *2020*). However, in other segments the presence of several animal bones is attested but their origin and relationship to human remains are still unclear (*Sanchez* et al. *2005*). Some associations between animal and human bones are indicated in the original graves, where animal parts were offerings (*Cámara* et al. *2016*), as may also be suggested by the discovery of vulture bones at structural complex IX of the Paseo de la Estación area, a trench near Ditch 4 (*Nicás, Cámara*

2017.49). In any case, the widespread absence of grave goods in these features can possibly be explained by a selection restricted to the larger, most representative and better preserved remains (skulls, long bones, and so on). Moreover, the preservation factors that affected the initial burials must also have played a role here.

It must also be noted that these secondary depositions in trenches/ditches most likely took place years after the deaths of the earlier members of the community, when the dead no longer had direct ties to those frequenting or living at the site. However, recognizing them remained important, if not as ancestors of specific lineages, then as tokens of the community as a whole (*Naumov 2007; Cámara* et al. *2016; Nicás, Cámara 2017*).

In short, the bones of SU 10 from SUNP-1/RU-9-1:1-2-3 must have been either deposited or cast into the ditch and either immediately or later concealed by stones and earth (SU 9), actions that would have brought the funerary rite to an end. Thus, by placing them at what was formerly the edge of the site, they became emblems of the community. They evidence a homogenous funerary rite that, in its final phase, would have been linked to the ditches of Marroquíes. This homogeneity is also seen through the anthropological analyses of age and sex. In fact, there is evidence at SUNP-1/RU-9-1:1-2-3 that the chosen skeletal remains belonged not only to adults of both sexes, but also to a subadult and an elderly individual. It is noteworthy that the presence of both sexes and all ages in funerary rites associated with ancestor veneration is reported in different areas of the Iberian Peninsula (*Waterman, Thomas 2011; Beck 2016a; 2017; Cámara* et al. *2016*).

No specific reasons can explain the choice of the individuals deposited in the ditches. Skeletal elements with signs of diseases and pathologies are, in fact, more frequent in other segments of Ditch 5, such as SUNP-1/DOC-1 (*Sánchez* et al. *2005*). Only the oldest individual from this segment at SUNP-1/RU-9-1:1-2-3 reveals some ailment, notably an intradiscal hernia due to advanced age or intense activities. A potential explanation for the final deposition in ditches is that the deceased buried there no longer had descendants, which would have brought on the end of the cult of ancestor veneration directly linked to a specific family (*Cámara* et al. *2016*).

As noted above, new radiocarbon analyses were carried out on six of the better-preserved bones from Ditch 5, which include bones from an estimated five individuals. The results reveal that these individuals died in at least three different events between 2566 and 2136 2s cal BC (95% probability), and their bodies were introduced into Ditch 5 later.

These new dates from SUNP-1/DOC-1, in addition to those for the other 11 samples previously published (*Díaz-Zorita* et al. *2020*), offer a more precise and complete portrait of the funerary rite in Ditch 5. However, as previously noted, the fact that these depositions are secondary prevents securely connecting their date of death to the moment of their deposition in the ditch. The dates therefore cannot serve as a *terminus ante quem* for the abandonment of the Ditch 5, for the same reason.

Implications for the chronology of the end of Marroquíes: a comparative view according published dates (see Supplementary data)

In order to get a more complete view of the relationship between Ditch 5 abandonment and the secondary burials inside it, an MCMC model was generated of a single contiguous phase with all the available dates for Ditch 5 (Fig. 7), notably the six advanced here as well as those published in previous studies (*Díaz-Zorita* et al. *2020*). The results reveal agreement at the lower acceptance limit (Amodel=58.4) meaning there appears little internal consistency between the datings.

An analysis (Fig. 8) was then carried out in order to determine if the 17 samples from Ditch 5 could form part of the same deposition event, even taking into account that, as referred above, deposition and deaths are not related in these cases. The probability density function of the datings and their subsequent analysis by means of a Chi-squared test and their agreement adjustment clearly indicate that the samples are not contemporaneous according the very low Acomb (3.4) and the very high chi-square (43.09 *versus* 26.3 for 95%).

However, a series of datings of Trench 7 of SUNP-1/DOC-1 (SU-42: Ua-20267; SU-68: GrM-14047; SU-75: ETH-89500, GrM-14048, ETH-89501; GrM-14198) and SU 10 of SUNP-1/RU-9-1:1-2-3 (Ua-77572, Ua-77573, Ua-77570, Ua-77571) may correspond to the same original deposition event (possibly in one or different graves). In fact, when including only these dates in a Bayesian analysis (Fig. 9), the model yields an Acomb of 86.3 and a chi-square of 8.670 (95% 16.919), values suggesting the death of the individuals may have been relatively near in time.

The same occurs when comparing, on the one hand (Fig. 10), the 'most recent' datings of Trench 7, notably SUNP-1/DOC-1 (SU-75: GrM-14648, ETH-89503; SU-42: Ua-21455) and SU 10 of SUNP-1/RU-9-1:1-2-3 (Ua-73804, Ua-73803) with, on other hand (Fig. 10), the oldest datings (GrM-14049 y ETH-89502).

Additionally, to evaluate the possible differences between the depositions of the two sections of the ditch, three two-phase MCMC models were generated following contiguous, sequential and overlapping scenarios based on the depositions of Trench 7 of SUNP -1/DOC-1 as one phase and those of SU 10 of SUNP-1/RU-9-1:1-2-3 as another.

The model revealing the contiguous phases yielded Amodel (16) and Aoverall (13.6) indices suggesting this scenario to not be plausible. The same occurs with the sequential model (Amodel; 13.8; Aoverall: 11). On the other hand, the overlapping model yields indices (Amodel: 71.2; Aoverall: 56.4) suggesting that the scenario is possible. However, we must take into account that there are outliers among a series of datings of Trench 7 of SUNP-1/DOC-1 (ETH-89503 and Ua-21455).

The adjustments and mismatches between the datings of human remains of the different sections of Ditch 5 of Marroquíes once again suggest that these remains

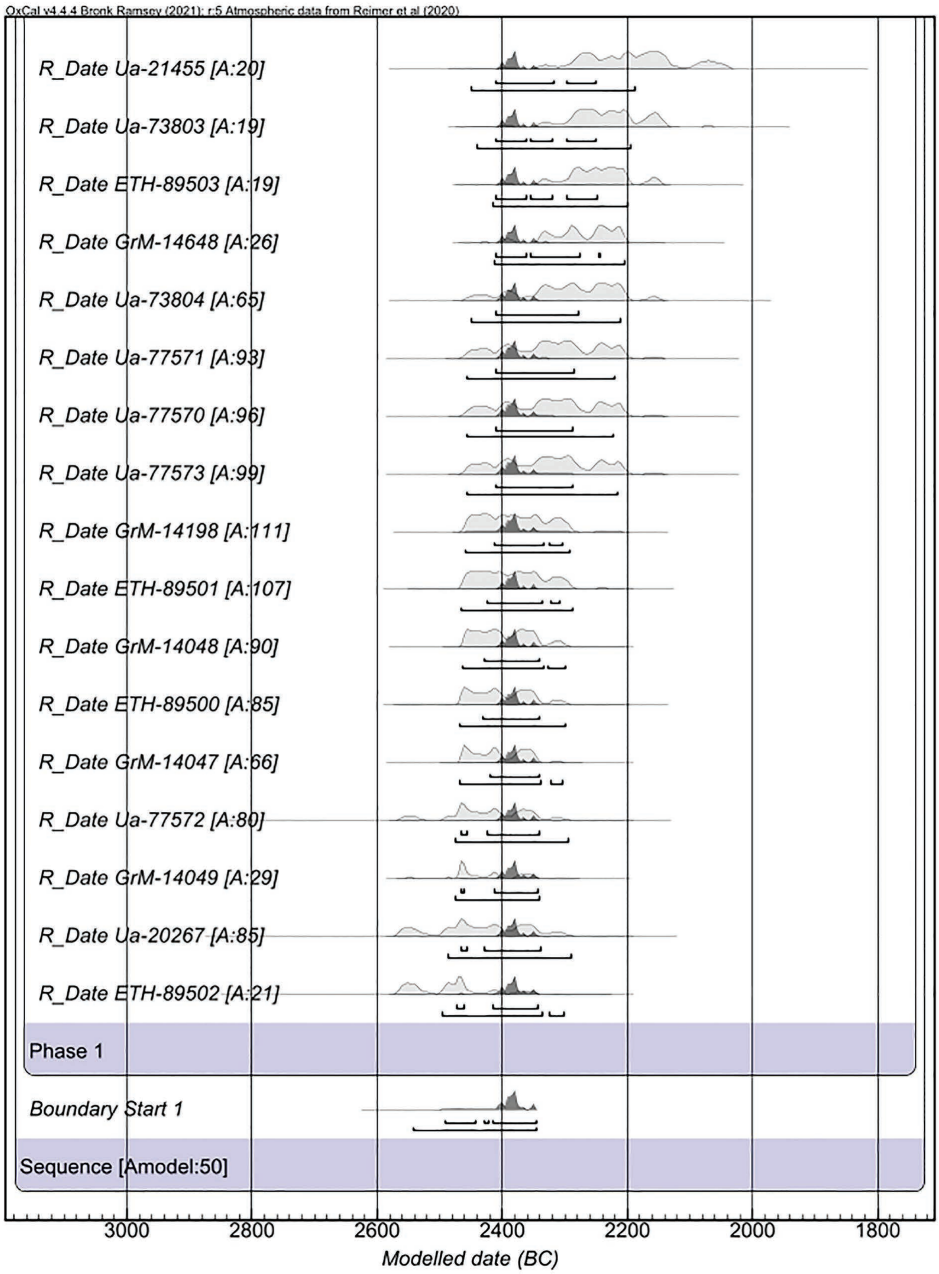

Fig. 7. MCMC model of a single continuous phase with all available dates for Ditch 5.

must have originally been placed in different funerary structures. Later they would have been removed and deposited in the levels of collapse of the embankments and walls of Ditch 5 at times in the company of other remains. Defining this moment has to date remained imprecise. However, based on the most recent analyses of the remains, the deposition appears to have taken place around the last third of the 3rd millennium cal BC.

Although it is likely that Ditch 5 was abandoned as an area of burial prior to burial use of trenches parallel to Ditch 4 as Structure IX of the complex of Paseo de la Estación (*Nicás, Cámara 2017*), such an extreme notion cannot be demonstrated based on the current set of radiocarbon dates. This difficulty may be due to the scarcity of samples or to the notion already cited that the date of death of the individuals buried in the different areas of ditches or trenches does not necessarily correspond (a more likely scenario) to the date of their deposition in the ditches (*Nicás, Cámara 2017; Díaz-Zorita* et al. *2020*). Furthermore, as stated, the datings of materials in the fills, although attempted (*Aranda Jiménez* et al. *2016*), do not offer results related to the abandonment/fill of the ditches as they are linked to erosive drifts and/or intentional depositions that may be significantly older than the moment of their final arrival in the ditch.

Nevertheless, a comparative analysis has been conducted between the dating of human remains from Ditch 5, including those previously published (*Díaz-*

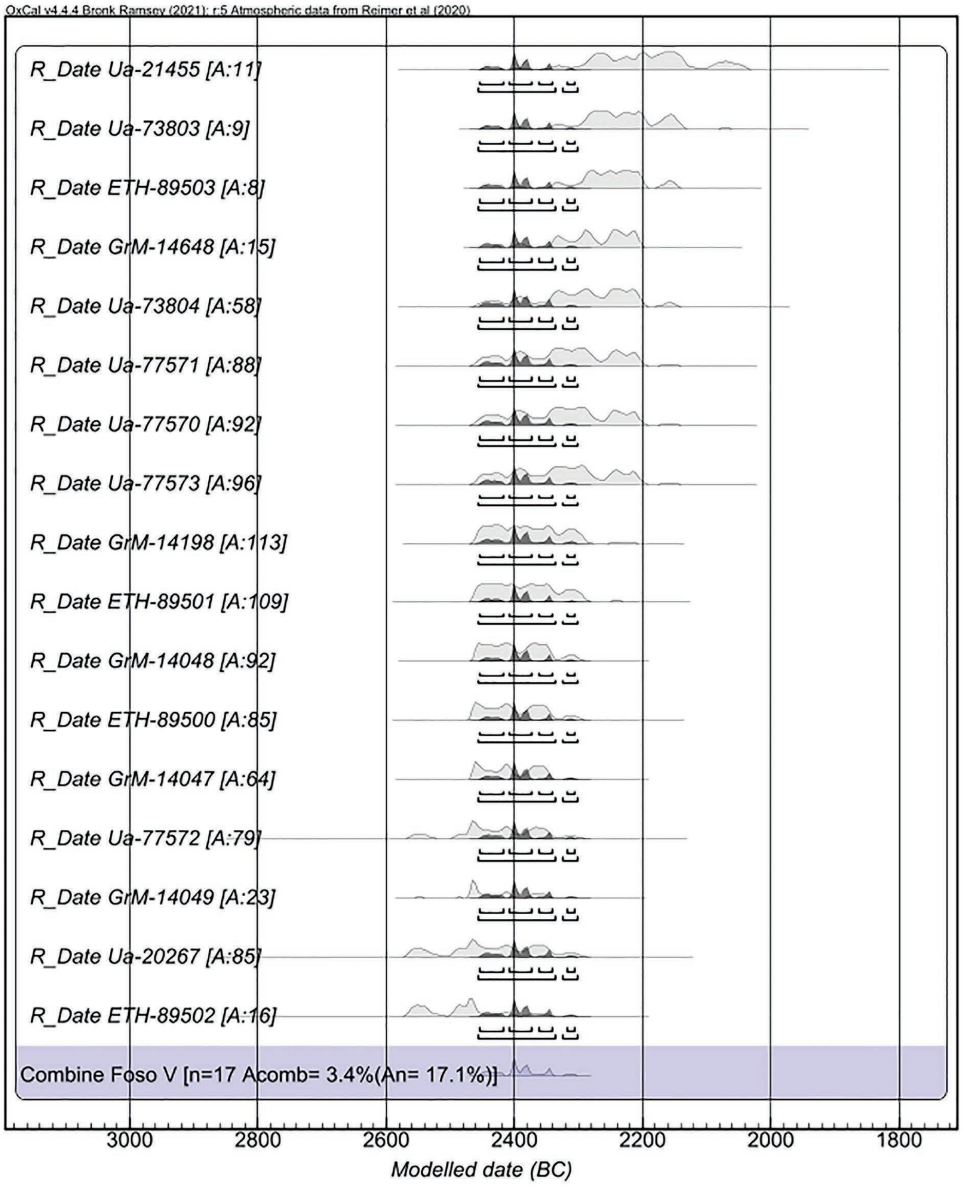

Fig. 8. Analysis in order to determine if the 17 samples from Ditch 5 could form part of the same deposition event.

Zorita et al. *2020*), and the dating from Ditch 4, mostly carried out on animal bone remains (*Aranda Jiménez* et al. *2016*).

Three Bayesian models have been generated to establish whether there are temporal differences in the backfilling of one area or the other, considering Ditch 5 as one phase and Ditch 4 as another. It should be specified that only the dates directly attributed to the filling of these two moats have been taken into account (and not, for example, those derived from the dating of the funerary context of STJ-PE (CE IX), see *Nicás, Cámara 2017*). Among the three possible scenarios-contiguous phases, sequential phases, and overlapping phases-only the last model shows some significance (Fig. 11).

The contiguous phases model yields Amodel (15.6) and Aoverall (14.7) indices that suggest this scenario would not be feasible. It also identifies a total of 7 dates as outliers (Ditch 5: ETH-89502, GrM-14049, GrM-14648, ETH-89503, Ua-73803, Ua-21455; Ditch 4: Beta-405556). If these 7 outliers are removed, the resulting model now shows a new outlier (Ua-73804), but the indices already point to values above the acceptance threshold (Amodel: 74.3, Aoverall: 74). According to this model, the remains from Ditch 5 would start to be deposited around 2477–2357, with a transition between the fill of Ditches 4 and 5 around 2444–2321, while the end of Ditch 4 would be situated at 2255–2012, dates that coincide with the end of the Copper Age (*Molina, Cámara 2005; Lull* et al. *2010; Micó* et al. *2024*). In any case, although the results of the two contiguous phase models suggest a trend in which Ditch 5 would be filled with older remains than Ditch 4, this would not imply a real relationship with the process of abandonment and filling of the negative structures, as we have discussed previously, because the fillings, whether erosive or intentional, would include remains from different periods.

Similarly, the sequential phase model provides Amodel (13.2) and Aoverall (11.9) indices that suggest such a scenario is not plausible. Again, the model detects a total of 8 dates as outliers (Ditch 5: ETH-89502, GrM-14049, Ua-73804, GrM-14648, ETH-89503, Ua-73803, Ua-21455; Pit 4: Beta-405556). If those 8 outliers are removed, the resulting model exceeds the acceptance

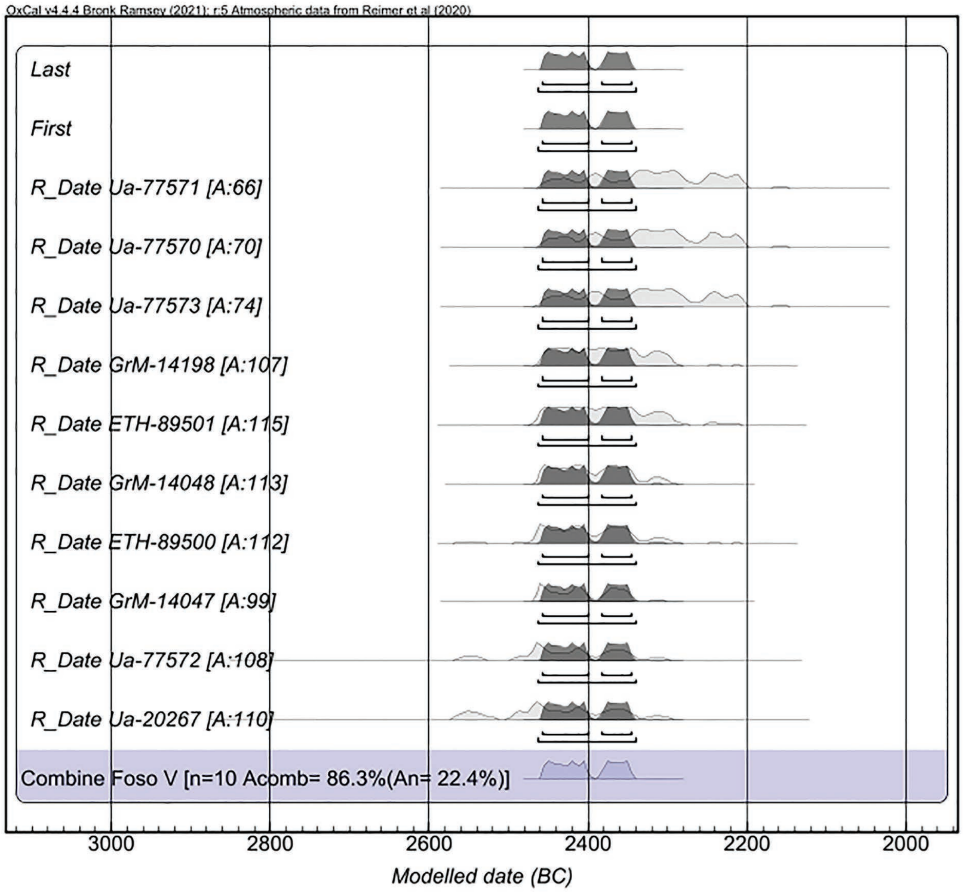

Fig. 9. Datings of Trench 7 of SUNP-1/DOC-1 and SU 10 of SUNP-1/RU-9-1:1-2-3 that may correspond to the same original deposition event.

threshold (Amodel: 78.8, Aoverall: 73.3), although, once again, it detects a new outlier (Ditch 4: CNA-3143). The results of this second model would suggest that Ditch 5 would begin to fill no earlier than 2476–2358, and the most recent remains would be included in 2452–2337. Meanwhile, Ditch 4 would not start to fill before 2428–2302, and the most recent remains would date from 2266–2033, which could again indicate the transformations that took place at the end of the 3rd millennium BC throughout the southern Iberian Peninsula.

The overlapping phases model yields Amodel (77.8) and Aoverall (62,5) indices that suggest this scenario is feasible. Again, outliers are identified, although they are limited to a single of dates, in Ditch 4 (Beta-405556). Moreover, the stratigraphic position (SU 30) of the few human bones localized in the segment of Ditch 4 explored at Ciudad de la Justicia area (*Aranda Jiménez* et al. *2016*) appears to offer an *ante quem* term for the abandonment of the ditch. Although it is evident, as in the case of the burials of Ditch 5, that the moment of deposition of these individuals did not necessarily coincide with their death, it is possible to presume that Ditch 4 saw a much longer use as site boundary than Ditch 5. In fact, the comparison between the dates of the human remains deposited in Ditch 5 and the other available dates on human remains for the Marroquíes settlement shows that the deposits in Ditch 5 are concentrated in the centre of the distribution (Fig. 12), with the differences being statistically significant according to the permutation test performed (Global p-value: 0.03796). However, it must be taken into account that this may be due to the different number of samples that make up each of the compared sets.

Conclusions

The study of one of the latest urban archaeological excavation at Marroquíes site (area SUNP-1/RU-9-1: 1-2-3) raises a series of questions linked both to the characteristics of Ditch 5 and to the funerary practices carried out at this mega-site during Late Prehistory. Furthermore, the problems deriving from the lack of correlation between the moment of death of the individuals and their final deposition in the ditch serve to shed light on the timeframe of the abandonment of Ditch 5 and its relationship with the site's final phases.

Many of the features of Ditch 5 at SUNP-1/RU-9-1:1-2-3, including its trough-shaped section and its layout, fall in line with the results of the excavation of other of its

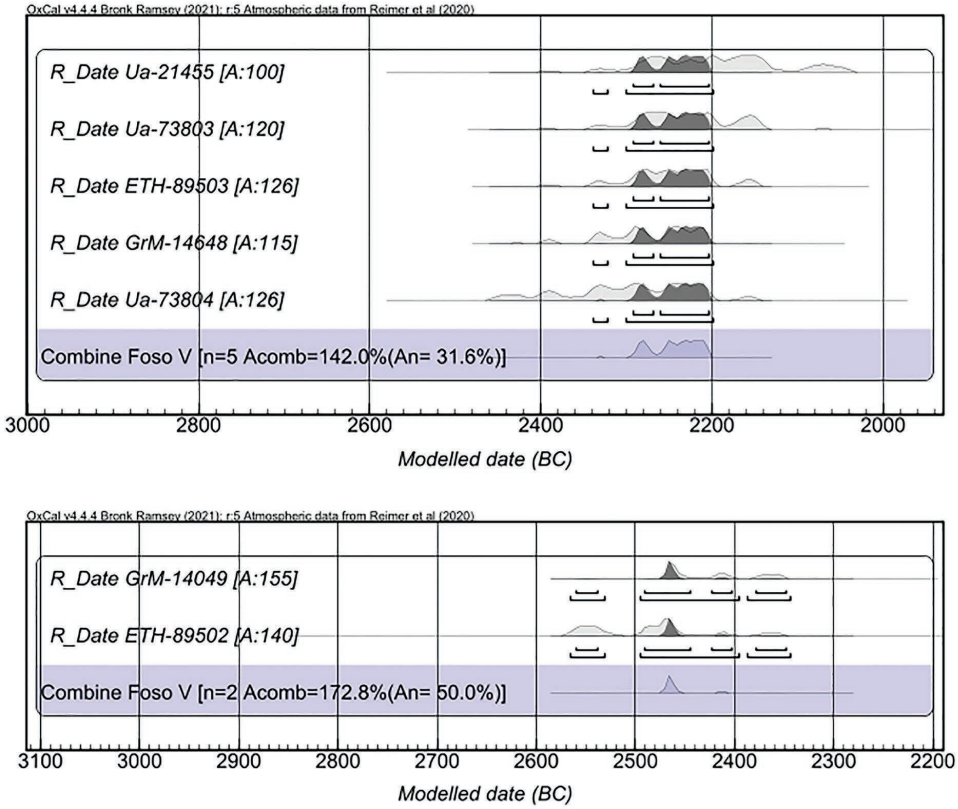

Fig. 10. Comparison of the 'most recent' datings of Trench 7, notably SUNP-1/DOC-1 (SU-75: GrM-14648, ETH-89503; SU-42: Ua-21455), SU 10 of SUNP-1/RU-9-1:1-2-3 (Ua-73804, Ua-73803) and the oldest datings.

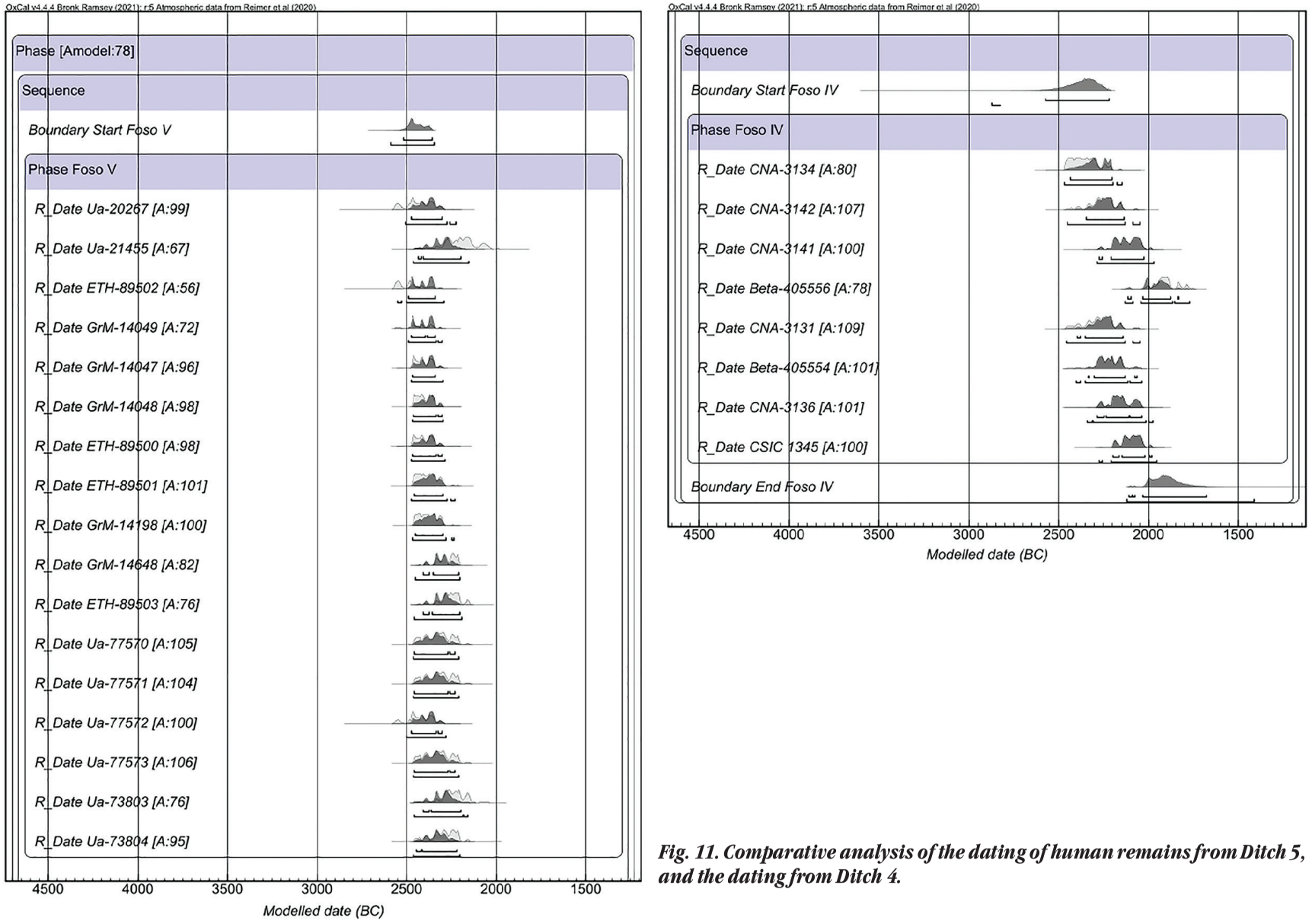

Fig. 11. Comparative analysis of the dating of human remains from Ditch 5, and the dating from Ditch 4.

segments since 1996. The current study has established that the dimensions observed in this latest excavation exceed those of prior fieldwork. In addition, contrary to some other segments, here there is no clear evidence of a flanking stonewall or defensive towers. One layer (SU 11) could nevertheless correspond to elements originally forming part of an earthwork or even an adobe wall. However, this last notion clashes with the proposals restricting the presence of walls along Ditch 5 to areas near the gates (*Zafra* et al. *2010*). In fact, the greater dimensions of this segment of Ditch 5 potentially relate not only to a flatter topography, but also to a greater distance from the gates, placing the segment studied here in an area where there was no need to cross the ditch. For this reason, the ditch became wider and the possible fortification wall less complex, with no stones as basement.

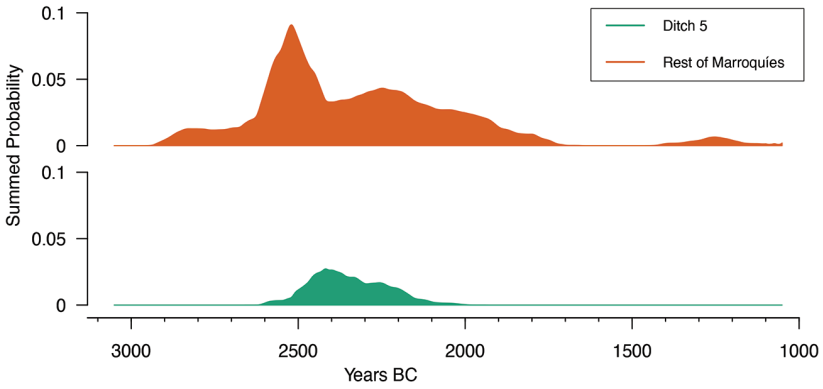

Fig. 12. The human remains deposited in Ditch 5 are concentrated in the centre of the distribution.

The secondary depositions of selected human remains brought to light during this last fieldwork appear to correlate with a final chapter of a key funerary ritual marked by ancestor worship. This practice replaced family cults by a newer, more general rite dedicated to anonymous forebears representing the whole community, a phenomenon observed in other areas of Marroquíes (*Cámara* et al. *2016; Nicas, Cámara 2017; Díaz-Zorita* et al. *2020*). In this sense, the social role of individuals would have not been lost after their death. They continued to be relevant ancestors in all the long process of manipulation and removal of bone remains. The bones selected for transport and deposition took on a new ontological status, transforming themselves into an original entity bearing new social significance and capacity of action (*Thomas 2002; Harrison 2004; Barley 2005; Fowler 2004; 2013; Rob 2013*).

This study also highlights the importance of the physical deposition of these symbols of the community along the settlement's edges. In this sense, these depositions took on the role of relics (*Delibes* et al. *2019*) or ancestors presumably forgotten as individuals, but venerated as members of a former group, perhaps of high status, regardless of their sex and age. In either case, at the moment of their secondary deposition, these disarticulated corpses in all probability assumed the role of symbols for the entire community (*Sánchez* et al. *2005; Pérez 2010; Cámara* et al. *2016; Nicás, Cámara 2017*) in the framework of rites serving to promote social cohesion.

Another key issue worth highlighting is the coexistence of different funerary rites at Marroquíes (*Camára* et al. *2012a; Beck 2017; Díaz-Zorita* et al. *2020*), in part as a result of the referred long time funerary practice. Since this aspect is shared by several other Chalcolithic sites, it now can be considered to be characteristic of late prehistoric societies in southern Iberia (*Vílchez* et al. *2023; Santana* et al. *2024*).

The chronology of the end of Ditch 5 as a real physical barrier and its relationship with the abandonment of the site requires recognizing that the radiocarbon dates place the death of the individuals in the second half of the 3rd millennium cal BC. However, their demise, as noted, does not necessarily correspond (not even closely) to the moment of their final deposition at SU 10 at SUNP-1/RU-9-1:1-2-3, a layer in the ditch deriving from a voluntary action of taking them from nearby features. The fact that the dates refer to several episodes of death and coincide with those of other excavated segments of ditches characterized by the same ritual appears to support the notion that Ditch 5 began to be used for the final phases of funerary rites in a late phase of the Late Copper Age, probably in its last century. This area of the ditch therefore came to embody the continuation of an older burial zone present since the second third of the 3rd millennium cal BC in the space between Ditches 4 and 5 (*Cámara* et al. *2012b; 2016*).

Taking into account the issues cited above related to events between death and final deposition, the human remains placed in Ditch 4 or in its immediate vicinity (*Nicás, Cámara 2017*) would take place later, between the end of the 3rd and the beginning of the 2nd millen-

nium cal BC. It is for this reason that the defensive role of Ditch 4 could have endured well beyond that of Ditch 5, due to more direct ties to the domestic space of the settlement.

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Ditches in focus: geomagnetic research on a Vučedol site of Szilvás in southeast Transdanubia (Hungary)

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ABSTRACT – *This paper presents and discusses the results of geophysical and archaeological prospections at the site of Szilvás in southeast Transdanubia (Baranya County, Hungary). The multiperiodic site was used from the Late Copper Age to the Migration Period, but the vast majority of the pottery sherds relate to the Vučedol pottery style. The find of a possible wheel model highlights the role of technological innovations. We identify a complex enclosure system with five ditches and a large number of pits, suggesting that we deal with a densely built, fortified settlement connected to the Vučedol complex. This complex is to be seen in the context of important social and economic transformations in southeast and Central Europe in the early 3rd millennium BCE, during the Late Copper and Early Bronze Ages. However, only a few Vučedol settlements have so far been excavated and published. Thus, the site of Szilvás opens up the possibility of gaining a better understanding about the domestic activities, subsistence economy, the layout and structure of the settlement, and its complex spatial organization.*

KEY WORDS – *Carpathian Basin; southeast Transdanubia; Late Copper Age-Early Bronze Age; Vučedol pottery style; ditch system; geomagnetic survey; wheel fragment*

Osredotočeni na jarke: geofizikalne raziskave na najdišču vučedolske kulture Szilvás v jugovzhodni Transdanubiji (Madžarska)

IZVLEČEK – *V članku predstavljamo in analiziramo nove geofizikalne in arheološke raziskave na najdišču Szilvás v jugovzhodni Transdanubiji (okrožje Baranya, Madžarska). Večperiodino najdišče sodi v čas od mlajše bakrene dobe do obdobja preseljevanja ljudstev, vendar velika večina lončenine pripada vučedolski kulturi. Najdba domnevnega modela kolesa poudarja vlogo tehnoloških inovacij. Identificirali smo zapleten sistem ograd s petimi jarki in velikim številom jam, ki nakazujejo gosto pozidano, utrjeno naselbino vučedolskega kulturnega kompleksa. Kompleks je umeščen v kontekst pomembnih družbenih in gospodarskih premen v jugovzhodni in srednji Evropi v zgodnjem 3. tisočletju pred našim štetjem; v času pozne bakrene in zgodnje bronaste dobe. Doslej je bilo izkopanih in objavljenih le nekaj vučedolskih naselbin. Najdišče Szilvás tako odpira možnost boljšega razumevanja domačih dejavnosti, samooskrbnega gospodarstva, postavitve in strukture naselja ter njegove kompleksne prostorske organizacije.*

KLJUČNE BESEDE – *Karpatski bazen; jugovzhodna Transdanubija; pozna bakrena–zgodnja bronasta doba; vučedolski lončarski slog; sistem jarkov; geofizikalna raziskava; fragment kolesa*

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Introduction

The Vučedol archaeological culture is distributed in present-day northwest Croatia (Slavonia and Syrmia; Croatian Slavonija and Srijem), northeast Bosnia and Herzegovina, and northwest Serbia (Syrmia; Serbian Srem), as well as partially in southeast Hungary (south-Transdanubia; Hungarian Dél-Dunántúl), and it dates back to the Late Copper Age and Early Bronze Age periods (3000/2900–2500/2400 cal BCE) (*Durman* et al. *1989; Forenbaher 1993; Della Casa 1995; Primas 1996; Kulcsár 2009; Kulcsár* et al. *2013; Rajković* et al. *2016.74–75*). This archaeological culture is associated with tremendous social transformations, as shown by changes in the material culture and the settlement structure *(Forenbaher 1994; Balen 2006; Zavodny* et al. *2021*). It is particularly known for its early fine copper production, sophisticated pottery and recurring symbols (*Durman 1983; Ecsedy 1999; Kulcsár 1999; Pásztor 2015; Miloglav 2018*). While the early (Late Neolithic and Early Copper Age) copper production centres were located in the eastern and central parts of southeast Europe, in the context of Baden, and followed by Vučedol, centres were established in the northwest Balkans and southwest Carpathian Basin (*Roksandić Vukadin, Bošnjak 2024.19–26*). In the context of Vučedol, copper production was based on increasingly elaborate production technologies with the use of two-part and multi-purpose casting moulds. For the first time serial production is indicated by the standardization visible in the large hoards (*Greenfield 1999; Roksandić Vukadin, Bošnjak 2024.39*). The copper production was presented in standard metal items like flat axes with broad cutting edges (like the Griča-type axes), awls, daggers and shaft-hole axes – especially Kozarac-type axes – were produced in large numbers *(Durman 1983.59; Pravidur 2014.139; 2018; Roksandić Vukadin, Bošnjak 2024.39; Roksandić Vukadin* et al*. 2024.23–24*). Most of the metal finds belong to chance or single finds and finds from hoards (primarily axes) (*Roksandić Vukadin* et al. *2024.23*). On the settlements, however, several objects, such as clay moulds, crucibles, and blowers, provide archaeological evidence of various metallurgical processes from the domestic context of Vučedol settlements.

In this regard, significant changes are evident in the settlement structures and locations. The previous Baden communities in the Carpathian Basin preferred flat settlements in the lowlands and shoreline, while a few hill-top sites are known further to the north in Bohemia and Moravia, south Poland and Lower Austria (*Bukowska-Gedigowa 1980; Kruk* et al. *1990; Zastawny 1999; Procházková* et al. *2001; Furholt 2008; 2009*). The Vučedol fortifications were positioned in elevated places, and several were protected with ditch-palisade constructions, making them harder to access. The increased number of these fortifications, such as the eponymous Vučedol and Zók sites, suggests that this form of settlement became more prevalent in the context of Vučedol (*Bóna 1964; Dimitrijević 1979; Ecsedy 1982; Bankoff* et al. *1990; Forenbaher 1994; Tasić 1995.76–78*). The fortified settlements were perhaps an integral part of an intensive spatial production and distribution network (*Roksandić Vukadin, Bošnjak 2024.40*).

This shift in settlement strategies, alongside the steps towards high-quality material production, demonstrates that the Vučedol phenomenon is associated with a remarkable social, economic, and cultural transformation in the north Balkans and southeast Central Europe, especially the south Carpathian Basin and its surroundings in the 3rd millennium BCE.

In this paper, we provide information about a newly measured Vučedol settlement of Szilvás with a complex ditch system situated on an elevated plateau, suggesting it is a fortified settlement. The geographical settings are similar to the few comparable Vučedol fortifications and the spatial dimension and the elaborated surface pottery material indicate a uniquely important site, which is the southernmost Early Bronze Age fortified settlement in the Baranya Hills, Hungary (Fig. 1).

Szilvás site and its research history

The site of Szilvás is situated to the south of Szőke and Szilvás villages, 15km to the south of Pécs (the administrative and economic centre of Baranya County and the south-Transdanubian region). The site and its microregions are geographically connected to the Baranya Hills, which are characterized by Neogene-Quaternary unconsolidated sediments, Pleistocene loess deposits and loamy and clayey soils, dissected by streams flowing north-south into the River Drava (*Lovász 1977; 1997; Újvári* et al. *2008*). The Mecsek Mountain is to the north of the site, providing excellent lithic raw material sources (Mecsek type of radiolarite, alkaline basalts, alkaline gabbro, alkaline dolerite, phonolite), for chipped grinding, and polished stone artefacts *(Lovász* et al*. 1974; Szilágyi 2018; Sági* et al*. 2022; Szilágyi* et al*. 2022*). The Danube runs 40km to the east

while the River Drava is 18km to the south, and both rivers played an important role in connecting the Baranya Hill region with the Balkans. The surveyed area is situated on the southern edge of a loess plateau, bordered by the Szőkei ditch to the west and the Szilvási-mellékág stream to the east (Figs. 3–4). The eponymous site of the Vučedol culture (previously called the Zók-Vučedol culture) is Zók-Várhely, which is 10km to the northwest of Szilvás (*Ecsedy 1982; Mitrović* et al. *2017*). The geographical locations of the Szilvás and Zók sites are very similar, as both are situated on a formation bordered on two or three sides by steep slopes, which continue southwards into a large plateau. They are composed of Pliocene Pannonian sediment and overlying clayey loess of Pleistocene origin, with a thin layer of brown forest soil (*Lovász* et al. *1974.103–104; Ecsedy 1982.59; 1999*). In Figure 2, we present all the Vučedol settlements recorded in the Archaeological Archives of the Janus Pannonius Museum and the Early Bronze Age ditch systems, which can be viewed as fortifications associated with the Vučedol period. However, these two different categories may overlap quite a bit, as identifying the pottery styles on the sites or dating the ditch systems requires further study. In the transition period between the Late Copper Age and the Early Bronze Age, not only did the Vučedol communities create fortifications, but also the groups associated with Kostolac/Kosztolác and Somogyvár-Vinkovci cultures (*Bándi 1979; 1984; Bertók* et al. *2009; Kulcsár 2009.236–240; Kulcsár* et al. *2013.69–77*). Many of the Early Bronze Age fortifications may belong to the Vučedol type, and some Vučedol settlements could still prove to be fortified. All sites are situated on an elevated plateau, and many are clearly positioned on the edge of the higher plain and steep stream valley meeting zone, potentially providing a good overview of the local landscape.

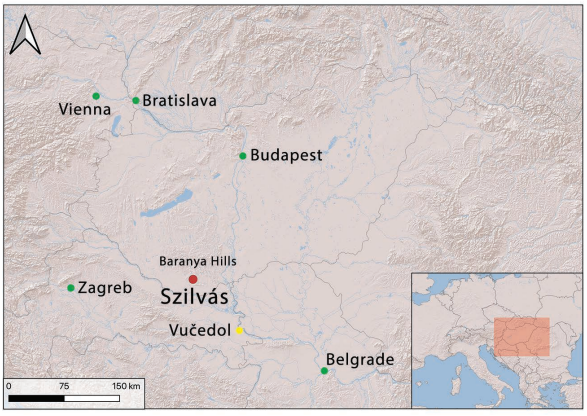

Fig. 1. The site is located at Szilvás in the Baranya Hills (southeast Transdanubia, Hungary). The red dots show the Szilvás site, the green dots refer to the capital cities, and the yellow dot displays the eponymous Vučedol site.

The Szilvás site has a relatively brief research history. The first aerial archaeological prospection was carried out by Gábor Bertók in 2007, who observed an enclosed area with several ditch-like anomalies. In 2008 and 2009, colleagues of one of the authors from the Janus Pannonius Museum (henceforth JPM) field walked in the area and identified Neolithic, Early and Late Bronze Age sherds (*Bertók* et al. *2014.118–119*). The site was reported and registered in the site catalogue of the Cultural Heritage Office (site registration id: KÖH 600/3973/2010, site id: 75983) in 2010.

In March 2024, colleagues of the authors from Kiel University (in German: Christian-Albrechts-Universität zu Kiel; henceforth CAU) and JPM organized a field campaign in Baranya County to examine enclosure ditches and investigate how these were related to settlement structures during prehistory, one site being Szilvás-Ó-szeg. We integrated geomagnetic surveys and surface find-collecting activities to examine the spatial and temporal dimensions of the enclosure ditches and settlement features. Before the fieldwork, the satellite and aerial images were analysed. The Szilvás site is visible in Google Earth satellite, Bing, and ESRI satellite imagery, and the Orthoimage Coverage dataset (Orthophoto) from 2005. The Google Earth satellite image captured in August 2013 shows two circular anomalies. The eastern part of them is obscured by forest, preventing further identification of their continuation. The western section of the two concentric circular anomalies seems to be linked to two linear features running nearly parallel, yet their coeval position remains entirely uncertain. The two linear anomalies are oriented northeast-southwest and extend into the forested section of the western half of the plateau, making them undetectable beyond this point (Figs. 3 and 4).

Geomagnetic prospection

The survey was conducted using a GPS-supported 8-probe SENSYS® magnetometer (towed Magneto® MX V3 Survey System; manufacturer: SENSYS) in an 8-sensor setup (FGM650/3, Fluxgate Gradiometer with 0.2nT resolution), a sensor distance of 50cm, a driving speed of around 12 to 16km/h and a 100Hz measuring frequency. The measurement image has a resolution of 0.2m, and GPS measurements were provided by a

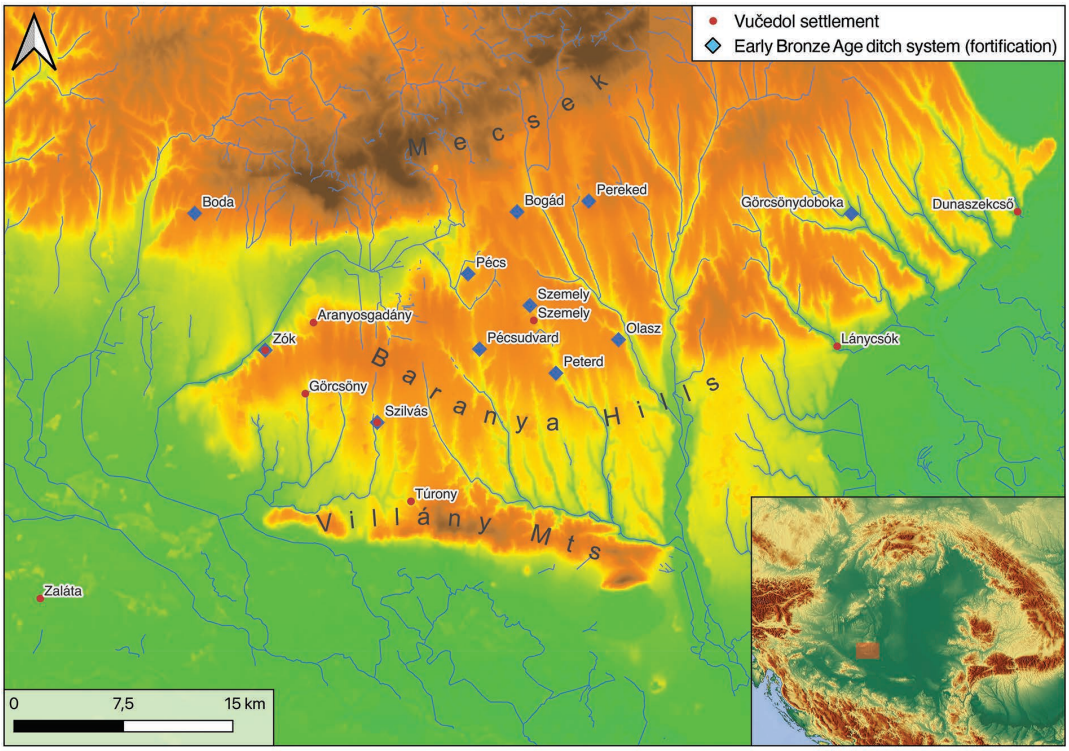

Fig. 2. ***The locations of Vučedol settlements (red dots) and Early Bronze Age ditch systems (blue rhombus) in Baranya County. The bigger map is provided by http://www.agt.bme.hu/cgi-bin/eu_dem.wms, and the smaller map by https://maps-for-free.com/layer/relief/z{z}/row{y}/{z}_{x}-{y}.jpg. The projection is in EPSG:23700; HD72/EOV for both maps. (Map made by Kata Furholt.)***

mounted Emlid® Reach RS2 with GPS/GNSS correctional data. The setup used during the fieldwork was towed by a quad bike, which, depending on the field conditions, allows for surveying an area of between 5 and 15ha per day. The data was recorded with MonMX, the manufacturer's software. Afterwards, the surveyed lines were prepared in DLMGPS and then the data was processed in the SENSYS® software MAGNETO to create a raster (20cm density and a search radius of 150cm) using the bilinear algorithm for interpolation. Final modifications, like the colour scale, were made in GIS software. The interpretation of the results was made by the scientists involved following the 'six-eyes-principle' (*Müller-Scheeßel* et al. *2020.4–5*), the GIS-based workflow (*Hofmann* et al. *2016.166*) was used to identify anomalies of certain strengths, and apply some quantitative methods for modelling (*Neubauer 2002; Medarić* et al. *2016; Winkelmann* et al. *2020; Buthmann 2021*). After the field survey, the research included data processing, visualization, physical interpretation and archaeological interpretation (*Medarić* et al. *2019.113–115; Buthmann 2021.293–295*). The coordinates shown in the magnetic plans refer to the UTM coordinate system, zone 34N in the World Geodetic System 1984 (EPSG 32634).

Fig. 3. The visibility of the Szilvás site on Google Earth in August 2013, and the map includes data from Airbus (© Kiel University; modified after the Google Earth image by Kata Furholt).

The vegetation in the focal area allowed for the survey of 9ha out of the approximately 14ha that were planned. The entire eastern bank of the loess plateau runs into the Szilvási-mellékág stream, which aligns with the visual characteristics observed in the aerial and satellite images. Altogether, five ditches are visible. To the north, two roughly parallel linear anomalies representing possible ditches extend in a southwest-northeast direction, spaced 20 to 30m apart and measuring 5 to 6m in width; however, they terminate on the eastern side where other anomalies also seem to end. These anomalies are detectable over a length of 150m. Two ditches are visible in the middle of the surveyed area. The northern one is almost a straight line running in a northwest-southeast direction, while the southern ditch shows a curve, though the orientation is more or less the same (Figs. 5 and 6).

Fig. 4. Aerial photograph of the elevated loess plateau, where the ditches of the Szilvás site are visible. The photo was taken from the northeast direction (© Janus Pannonius Museum; photo made by Gábor Bertók as part of the ArchLand project and modified from the original image by Kata Furholt).

Both ditches show a gate-like structure on the eastern part, where they have a break at the same position, both measuring 5 to 6m wide (Figs. 5 and 6). The gate-like structures are formed in a way that ditches widen towards the gap, forming an L (Fig. 7.3 and Fig. 7.4). These middle ditches are visible for the length of 200m. The southernmost ditch is the largest, measuring 10 to 13m in width and 345m in length in the measured area. However, based on its circular or oval shape, a 520m long ditch (covering an area of 10.3ha) can be reconstructed from the uncovered part of the loess plateau. A gate-like structure is identifiable in the

Fig. 5. Geomagnetic survey results overlaid on Bing Maps Satellite Imagery (data projected in EPSG:3857) (© Kiel University; map made by Fynn Wilkes).

northwest part of this ditch, creating a 10m wide free space that serves as an earth bridge for entering the inner part of the ditch system. The western part of this gate-like structure has an L-shaped wider part (Fig. 7.5). From the gate towards the southeast and northwest, an empty space of about 20m wide without detectable anomalies, either within or outside the circular ditch, indicates the presence of a road-like structure and was probably used for entering or leaving this gate. A similar 5 to 10m wide empty space is observable in the case of the double middle ditches between the two smaller gates (Fig. 7.3,4). Free spaces are visible along the inner side of the circular and curved double ditches, which could be interpreted as the space taken up by ramparts (Fig. 7.1). Ditch-rampart earth-wood constructions were used since the Late Neolithic and in all subsequent prehistoric periods in order to make an earthwork more prominent (*Convertini 2012; Jiráň 2013; Zápotocký 2013; Bátora 2018; Krenn-Leeb* et al. *2023*). The northernmost double ditches, oriented southwest-northeast, also exhibit free spaces, but the potential for a rampart seems unlikely due to the low intensity of anomalies and the differing orientations of the ditches compared to the middle and southern parts of the measured area.

Over 100 roundish pits and pit-like structures were found within the spaces enclosed by the ditches and in the 30m outer zone beyond the northernmost ditch (Figs. 5–8). These round anomalies were found on both sides of the road-like empty area inside of the circular ditch (Fig. 8.6), in the areas defined by the two successive ditches in the north, as well as, less densely, in the area north of the third ditch. These anomalies are also concentrated in the northern end of the measured area, to the north of the two short ditches, although they seem to have a different structure there. The roundish anomalies with diameters mostly between 1 and 4 m most likely represent pits based on their shape and dimension, which seems to be very similar to the comparable excavated Vučedol settlements (*e.g.*, Zók-Várhegy, Vučedol- Streim's Cornfield and Vučedol-Vineyard). However, similar features can also be found at other Bronze Age sites across Europe. These features have been identified as pits, cooking stone pits, hearths, or pits inside the houses at sites such as Mang de Bargen in Germany (*Schaefer-Di Maida 2022.Figs. 4 and 5*), as well as Maňa-Veľká Maňa, Bešeňov-Žitavský hon, Hul-Kratiny, and Vráble-Fidvár in Slovakia *(Bátora* et al. *2012; Müller-Scheeßel* et al*. 2016*). It is striking how evenly these pits are

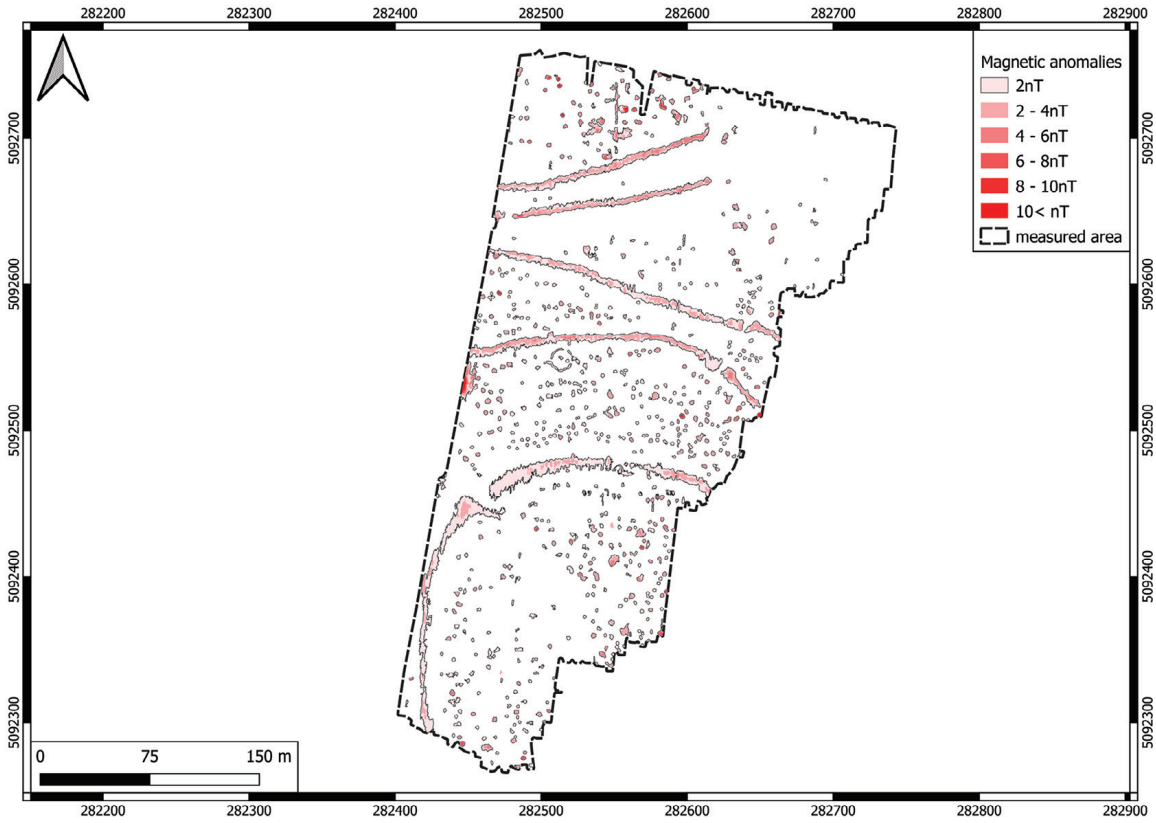

Fig. 6. Result of the geomagnetic survey of Szilvás. Magnetic anomalies are represented by (red) colour gradients, with varying nanotesla values, showing the intensity of anomalies across the site (data projected in EPSG: 32634) (© Kiel University; map made by Fynn Wilkes).

distributed in space. They seem to fill out the whole space while at the same time leaving free what was described above as road-like areas, which coincide with the ditch entrances. They also leave free the areas along the ditches, which were referred to as possible rampart areas. The pits are finally grouped along and around smaller free spaces that again cover the spaces between the ditches relatively regularly.

Circular pit-like structures can be classified into two categories according to their size, shape, and magnetic susceptibility values. The smaller anomalies (1 to 2m in diameter) are primarily represented between 2 and 4nT, while those larger than 2m often exhibit non-symmetrical forms and are shown between 4 and 6nT (Fig. 8). These small anomalies with low nT values are found within the ditches and in the 30m zone of the northernmost ditch. Additionally, these anomalies cluster around the ditches and the L-shaped gates arranged in a linear structure (Figs. 7.3–5 and 8). Moreover, these small anomalies form rectangular and oval-shaped structures around empty places, which could indicate houses, and some of them can be inside as documented in construction phases 2 and 3 in unburned house contexts at Vučedol-Streim's Vineyard site (*Forenbaher 1994.312–315*). The non-symmetrical anomalies with higher magnetic values suggest a looser arrangement without any clear clusters. There are some anomalies with non-symmetrical forms with higher 6 to 8nT values, but they do not show any spatial pattern except one cluster close to the curved ditch on the western edge and the central part of the surveyed area (Fig. 8). The vast majority of the ditches are shown between 2 and 6nT, similar to the circular and non-symmetrical pit-like anomalies. Slightly higher values of 6 to 8nT only appear at the L-shaped gate structure and some parts of the curved ditch in the middle of the surveyed area, and in the eastern part of the northernmost ditch, a nd it is still questionable as to whether this relates to the Vučedol enclosure construction.

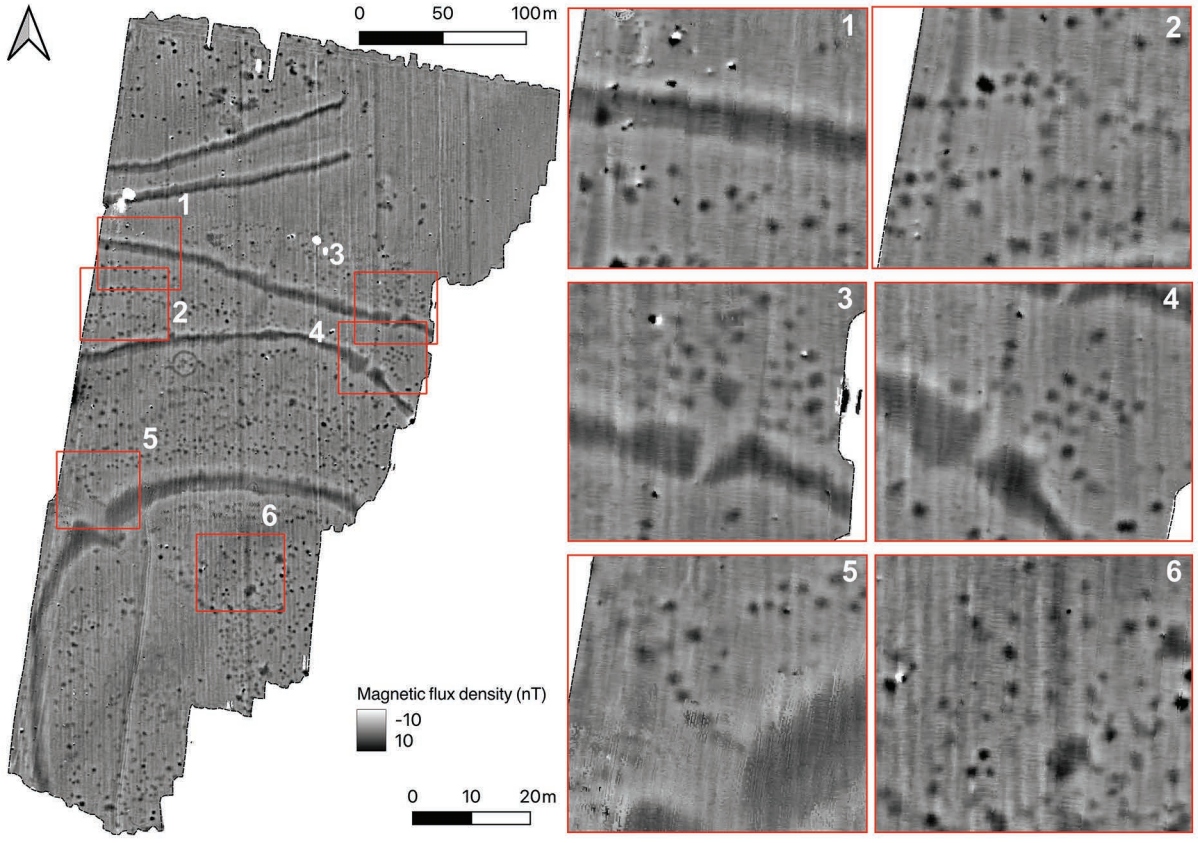

Fig. 7. Examples of different anomalies encountered in the magnetic survey data at Szilvás.* 1 *a potential rampart and pit-like circular anomalies alongside the ditch;* 2 *pit-like circular anomalies arranged in a rectangular manner;* 3–4 *L-shaped gate structures with circular anomalies at the outer side of the ditch;* 5 *pit-like circular anomalies arranged in one line at the outer side of the L-shaped gate structure of the circular ditch;* 6 *different sized pit-like circular anomalies inside the circular ditch (data projected in EPSG: 32634) (© Kiel University; map made by Kata Furholt).

In Figure 9, we chose to interpret those regularly placed open spaces between pits as areas for houses to which these pits belong, be it as refuse pits, storage pits or pits with other functions. It is important to note that the visibility of house structures in magnetic imagery largely depends on the building materials used and the condition in which the structures were preserved. Burned wattle-and-daub houses are typically highly visible, whereas unburned structures or those primarily constructed from wood – for instance the basket-like wattle work unburned houses at Vučedol-Streim's Vineyard – are much less distinct. Taking into account the shapes, architectural structure and spatial dimensions of houses found in other Vučedol settlements, our tentative reconstruction of house areas shown in Figure 10 seems to well represent a possible settlement plan (Fig. 10.5), including oval-shaped houses with a length between 8 and 18m and width between 6 and 8m (Fig. 10.1–3). For this reason, we consider that the empty spaces between the pit-like structures could be unburned houses, as supported by the fact that we did not find a large quantity of burned clay and daub on the surfaces, only smaller pieces weighing a few grams.

The eponymous Vučedol fortified settlement was reconstructed and has become a key location for public education in the Vučedol Museum near the site close to Vukovar, Croatia. Stašo Forenbaher analysed the house structures at Streim's Vineyard, part of the Vučedol site, where complete house floors were excavated, suggesting that every house form, layout, and construction technique is either the same or very similar. The average dimensions of a Vučedol house ranged from 7 to 9m in length and 4 to 6m in width, characterized by an oval-shaped or rounded rectangle divided into two or three rooms (*Forenbaher 1994. 311–317*). These houses were made using a light construction technique, which is only partly visible archaeologically, and thus the wattle and daub work with a few rather slim wooden posts functioned as the static frame of the house. This applied basketry technique has the advantage that the entire wall structure is homogeneous and structurally sounder. This also leads to the oval-shaped or rounded rectangle form of the houses and the light construction, as found in Vučedol. In Figure 10, we have presented the house structure and settlement layout as it is reconstructed for the Vučedol site in

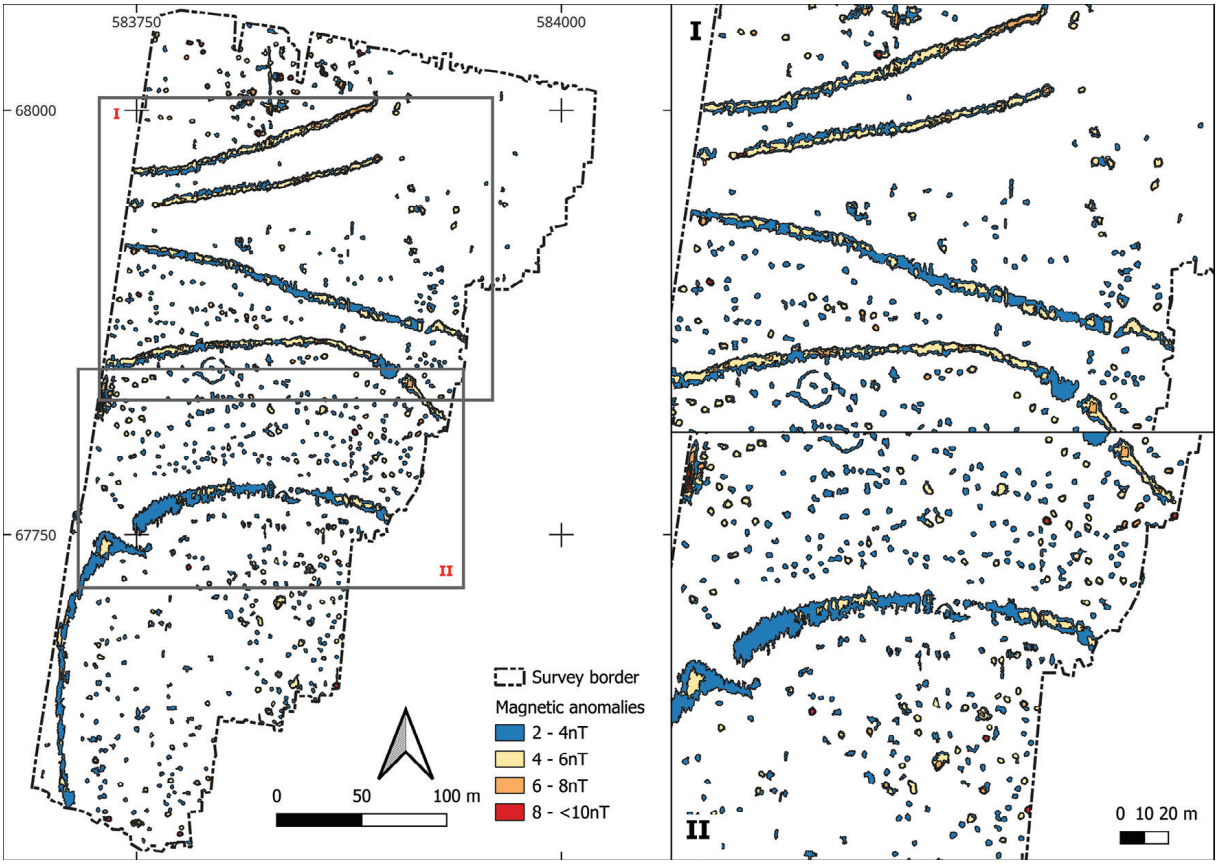

Fig. 8. Result of the geomagnetic survey of Szilvás. Magnetic anomalies are represented by different colours associated with varying nanotesla values, showing the intensity of anomalies and the potentially similar archaeological structures across the site (data projected in EPSG: 32634) (© Kiel University; map made by Fynn Wilkes).

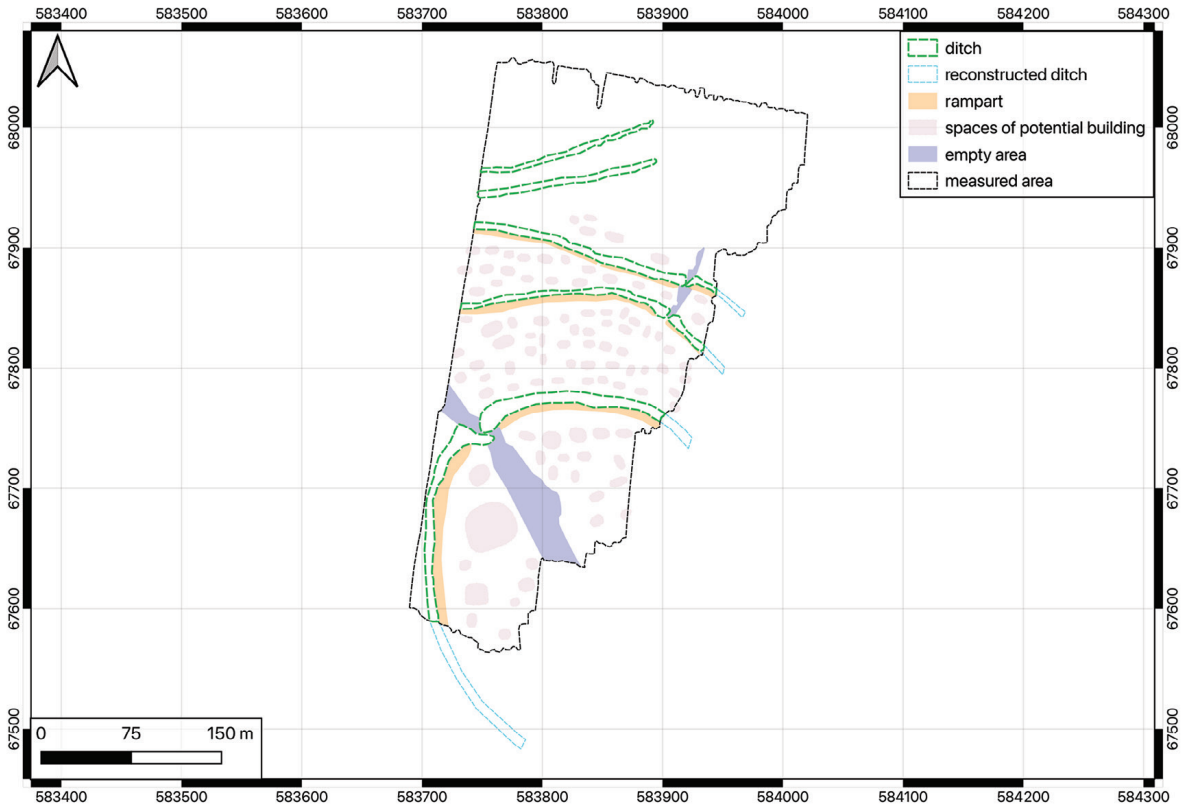

Fig. 9. Interpretation of geomagnetic survey results highlighting archaeological anomalies at Szilvás (data projected in EPSG:3857) (© Kiel University; map made by Martin Furholt, Erik Riese and Kata Furholt).

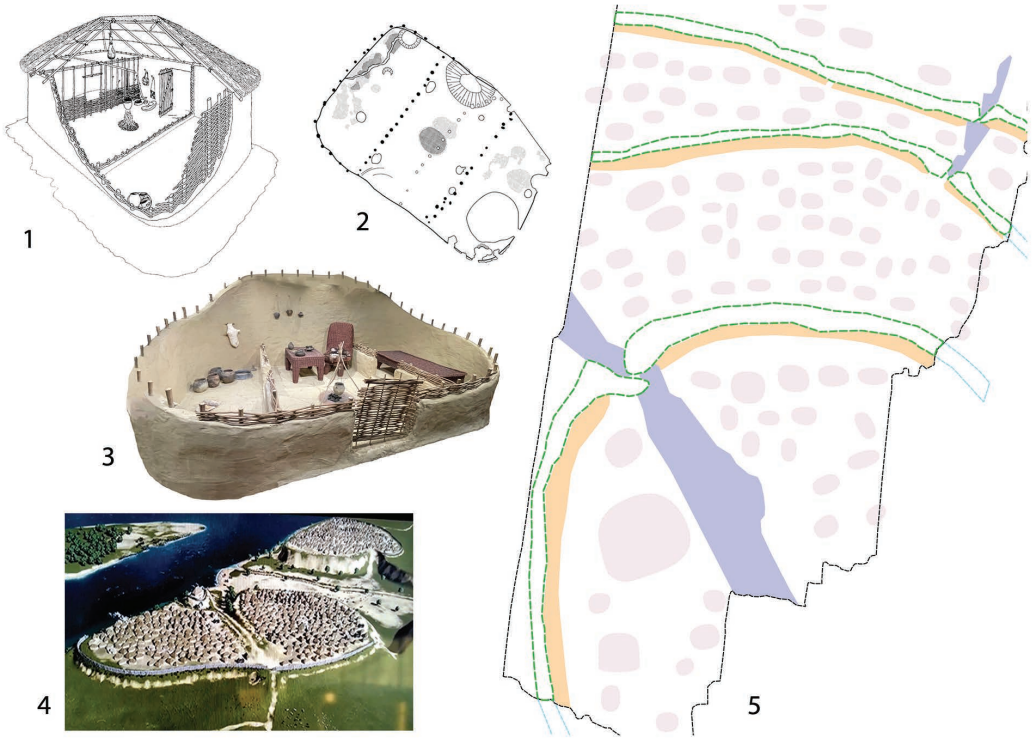

Fig. 10. The feature interpretation of the Szilvás site (5) with a compilation of house reconstructions (1–3) and settlement reconstruction of the Vučedol site (4). Source of the images: 1 *Forenbaher (*1994.316, Fig. 7*);* 2 *Forenbaher (*1994.315, Fig. 6A*); 3 photo taken and modified by Kata Furholt in the Vučedol Culture Museum near Vukovar, Croatia;* 4 *Original publication: Vučedol Culture Museum video display. Immediate source: https://www.youtube.com/watch?v=7YcGWtGwvFM. (Made by Kata Furholt.)*

comparison to our interpretation of the geomagnetic anomalies at Szilvás.

The above-ground house structures are similar to those connected to the Baden and Kostolac/Kosztolác complexes. Very similar to our approach to Szilvás, archaeologists exploring these sites have used the spatial arrangement of pits and, if possible, postholes to identify the potential places of above-ground buildings, such as in Đakovo-Franjevac, Balatonkeresztúr-Rétidűlő and Balatonőszöd-Temetői-dűlő (*Balen 2011; Fábián 2013; Horváth 2014*).

Obviously, this model has to be tested via excavations, and it is also clear that not all the indicated open spaces would have been occupied by houses, but could also have represented open courts, especially large ones like those in the southwest of the measured areas at Szilvás.

Collection of surface finds

We consistently applied a grid system based on 50m squares and limited collection times to 30 minutes per grid for collecting surface finds. Our goal was to collect every find from all periods to gain a comprehensive overview of the entire site's history and size. The finds were documented by grids, except for diagnostic sherds or special finds (*e.g.*, shaft-hole axes or clay figures), which were piece-plotted individually with a differential GPS system. The documentation contains a short description, drawings and numbering of the grids, with the GPS coordinates for each corner of every grid. We documented the archaeological material by grid, differentiated by materials (*e.g.*, pottery, metal, stone, and other organic and inorganic materials). Pottery was sorted and recorded according to fine, middle and coarse ware categories. Undiagnostic sherds were recorded and left on the surface. In the case of diagnostic sherds or other object types, we recorded as much information as possible (*e.g.*, dimensions, weight, raw material, technological characteristics, *etc*.) in our database and brought them to the museum for further analysis. Our aim was to compile all information about the recognizable periods on the site and the identifiable types of spatial distribution, which may enhance our understanding of the potential periodization of the measured geomagnetic anomalies (Figs. 11 and 12, Tab. 1).

The surface collection is associated with the Early Bronze Age Vučedol pottery style, dated to 3000/2900 to 2500/2400 cal BCE, which is classified as part of the Late Copper Age from the southern region of the Drava River (*Forenbaher 1993; Benkö* et al. *1989; Durman* et al. *1989; Bulatović* et al. *2017; 2020*). The most characteristic diagnostic pottery sherds from the collected surface assemblage include bowl fragments featuring

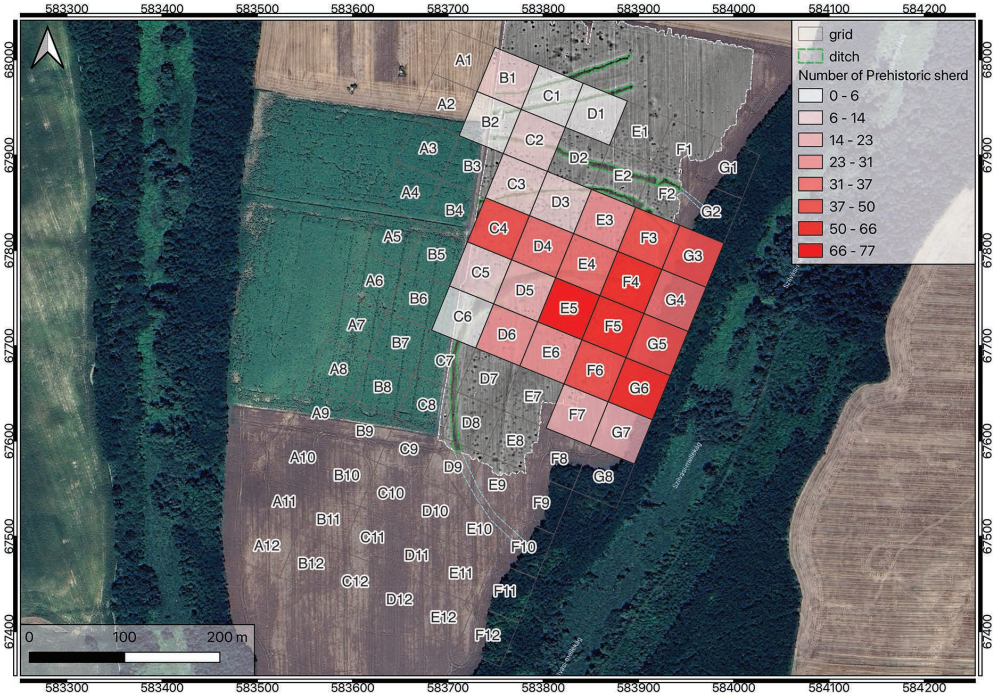

Fig. 11. The number of prehistoric pottery fragments in the applied grid system on Google Satellite Imagery (data projected in EPSG:3857) (© Kiel University; map made by Kata Furholt).

interior decorations adorned with white encrusted motifs, which are typical for the Vučedol pottery style (Fig. 13). Several inner decorated bowl fragments with white encrusted motifs were discovered besides undecorated coarse and fine ware pottery fragments, which indicates different food processing, consumption and storage activities. Altogether, 21 chipped stone items, three polished stone artefacts, and three grinding stones were discovered, which confirm local food preparation.

However, the most prominent item in the surface collection was undoubtedly a clay wheel fragment, which is possibly connected to a wagon model. It was discovered between the circular and curved ditches near the potential building structures in grid D4 (Fig. 14). The wheel fragment is 10cm in diameter, the axis of the wheel is 7cm long, and the perforation of the axis is 15mm in diameter. The surface of the wheel fragment is relatively smooth, but some minor cracks are visible. Based on the dimensions of the wheel fragment, we can assume that this is part of a bigger wagon model.

Numerous parallel clay wheel fragments and wagon models from the Late Copper Age and Early Bronze Age in the Carpathian Basin are known. Most of them comprise various components, such as wagon boxes and solid wheels, which reinforce the dating to the Early Bronze Age. A close parallel find can be mentioned from the Early Bronze Age clay wagon model from Börzönce-Temetői-dűlő (Zala County). This clay item consists of three identical solid wheels with

Grid id	Period	Pottery style	Number of fragments (n)	Total weight (g)
C3	Bronze Age	Vučedol	1	2
C4	Bronze Age	Vučedol	8	108
G3	Bronze Age	Vučedol	6	390
F3	Copper Age	Baden	3	96
F3	Bronze Age	Vučedol	1	8
F3	Roman	Roman	1	14
F4	Bronze Age	Vučedol	5	120
E4	Bronze Age	Vučedol	3	50
E4	Roman	Roman	1	2
G4	Bronze Age	Vučedol	9	50
C5	Bronze Age	Vučedol	1	20
C5	Bronze Age	Vučedol	1	no data
D5	Bronze Age	Vučedol	2	22
E5	Bronze Age	Vučedol	15	244
D4	Bronze Age	Vučedol	2	12
D4	Bronze Age	Vučedol	1	no data
F5	Bronze Age	Vučedol	12	230
G5	Bronze Age	Vučedol	7	404
D6	Bronze Age	Vučedol	2	24
F6	Bronze Age	Vučedol	10	228
F6	Copper Age	Baden	1	16
G6	Bronze Age	Vučedol	12	200
B1	Bronze Age	Vučedol	3	82

Tab. 1. The information regarding the quantity and pottery style of the diagnostic sherds by grid.

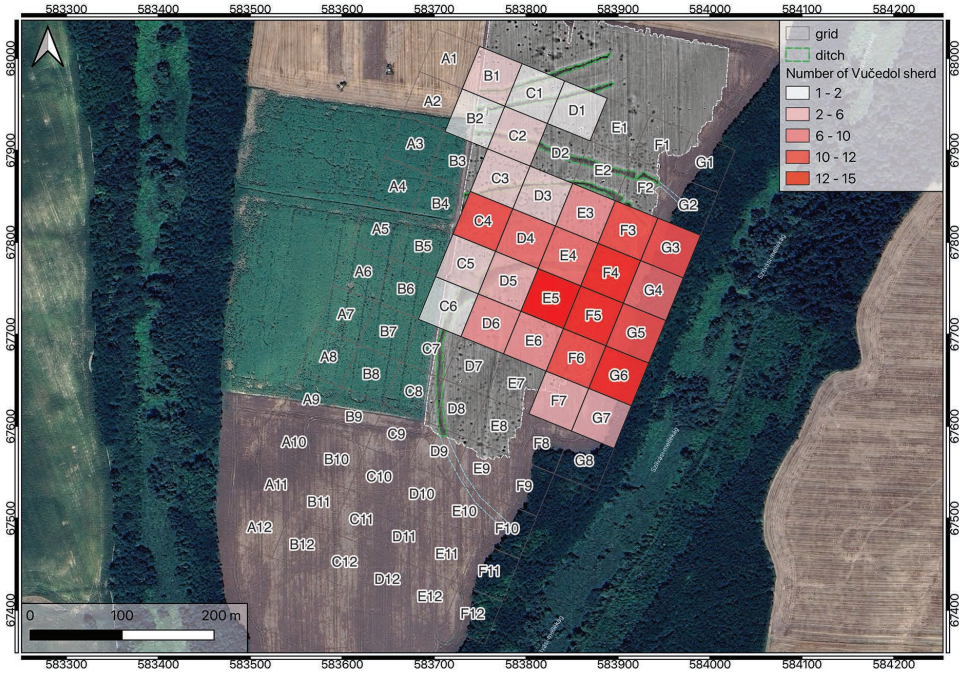

Fig. 12. The number of Vučedol pottery fragments in the applied grid system on Google Satellite Imagery (data projected in EPSG:3857) (© Kiel University; map made by Kata Furholt).

perforations for an axle (*Bondár 1992; 2012*). The reconstruction drawing of the Börzönce wagon model suggests the depiction of a simple, unadorned wooden cart with solid wooden wheels on an axle. Similarly, the other wagon models presented in Figure 15 feature solid wheels with a perforation in the centre. Wheels with perforations in the centre and conical shape indicate that they rotate around the axle. This style of representation is associated with the Early and Middle Bronze Age wagon models found in contexts within the Carpathian Basin (*Bóna 1960; Boroffka 2004; Maran 2004; Bondár 2012*). The solid clay wheel fragment and its clay tunnel-like structure around the perforation suggest that this find from the Szilvás site could be part of an Early Bronze Age wagon model, even though the wagon box was not discovered. Although numerous Bronze Age wagon models and wheels have been discovered in the Carpathian Basin, only a few finds have been recorded from Transdanubia, which makes the Szilvás find significant.

Summing up the new information about the Szilvás site

The potential ditch and rampart structure of the settlement of Szilvás, along with its location on the elevated plateau, enables us to interpret the site as a fortified settlement. Considering the diagnostic pottery

Fig. 14. Fragment of a clay wheel from a possible wagon model at Szilvás (© Kiel University; the photo taken by Victoria-Luise Boensch; the figure made by Kata Furholt).

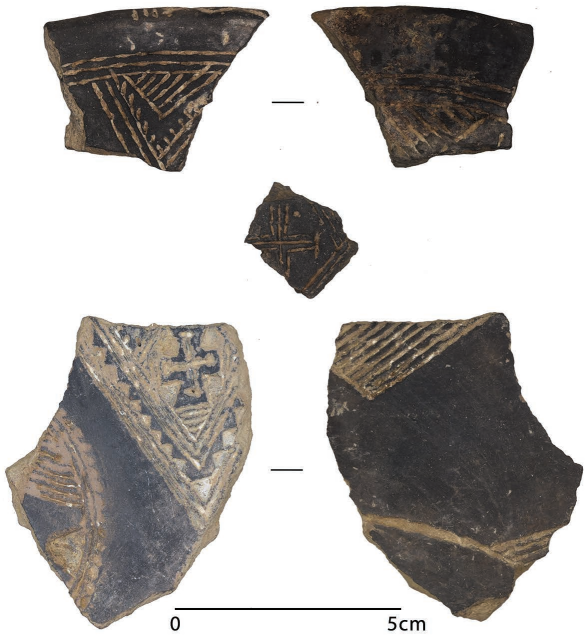

Fig. 13. Selection of white encrusted Vučedol pottery style at Szilvás site (© Kiel University; the photo taken by Victoria-Luise Boensch; the figure made by Kata Furholt).

sherds, it seems plausible that the site may have been a Vučedol settlement. Our work, which has to date only involved surface find collection and geomagnetic prospection, has so far not yet provided an answer to the questions of (1) how the northern ditches related to the entire settlement structure, and (2) whether some or all of the empty spaces between the dense distribution of pit-like anomalies could indicate potential aboveground buildings. These open questions, and especially the second one, can only be answered by excavation.

The significance of the Szilvás site on a broader regional scale

Szilvás can be better understood when it is embedded into a larger regional context. As mentioned above, we know of several Vučedol settlements without a confirmed enclosure ditch, and of a number of sites that are classified as early Bronze Age fortified hilltop settlements without a confirmed Vučedol association close to Szilvás and further to the north. The number of confirmed Vučedol settlements in Baranya County is low, and altogether nine sites have been recorded in the archaeological site catalogue of the Janus Pannonius Museum Archives and the Hungarian Cultural Heritage Office (previously the Kulturális Örökségvédelmi Hivatal, currently the Forster Gyula Nemzeti Örökséggazdálkodási és Szolgáltatási Köz-pont in Hungarian) (Figs. 2 and 16, Tab. 2). The sites are posi-

tioned on elevated locations in the landscape, which are either close to water bodies, mainly smaller streams, or the edge of hills and plateaus, thus intentionally seeking out the geographical benefit of a difference in elevation. The site of Zaláta seems to be the only exceptional case, as it is located far from the natural elevations of the Baranya Hill and Villány Mountain (Fig. 2). Zaláta site is situated 5km to the north of the Drava River, and the traces of several meanders suggest that the Drava River or its former tributary ran in the vicinity of the Zaláta site. The sites were reported after the field walking activity in 1964 (Archives of JPM).

Altogether, nine Early Bronze Age fortifications without explicit reference to the Vučedol context are known from Baranya County. These fortifications were primarily investigated through aerial photography, satellite imagery, and field walking, which led to the conclusion that they were all Early Bronze Age fortifications, although some of them could have been used in the Middle and Late Bronze Age (*e.g.*, Pécs, Pécsudvard, Pereked) (Figs. 2 and 16, Tab. 3). Further field surveys and radiocarbon dating are necessary for these Early Bronze Age fortifications to study the settlement patterns and the relationship between these fortifications and the surrounding settlements from a social archaeological perspective. Based on this information, we can

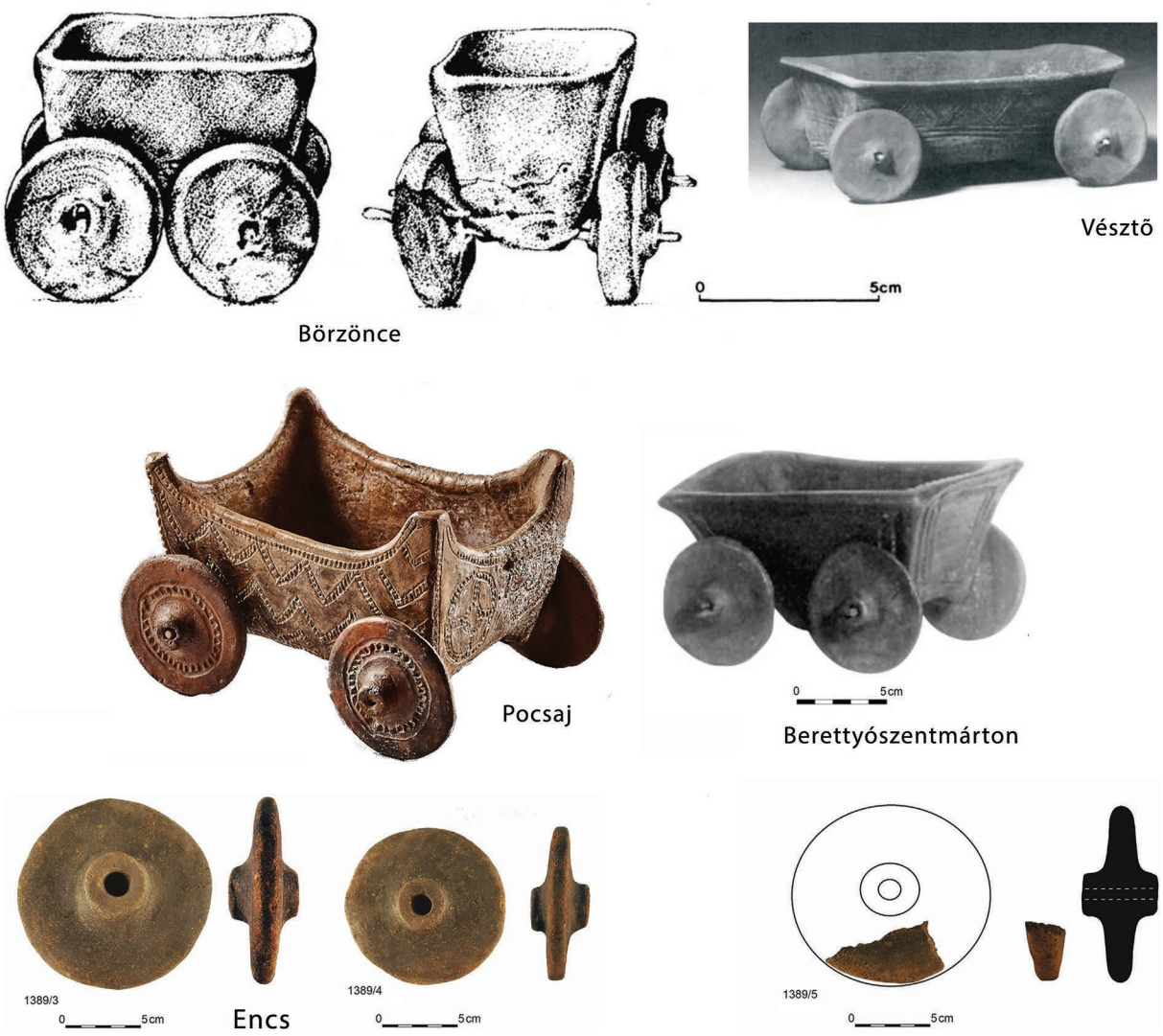

Fig. 15. Some wheel and wagon models from the Bronze Age context in Hungary (source of the images: Börzönce (Somogyvár-Vinkovci culture, EBA,* Bondár 1992.123, Fig. 5*); Pocsaj (Ottomány culture, EBA-MBA, © Déri Museum, photographer Ákos Jurás); Vésztő (Gyulavarsánd culture, EBA-MBA,* Bondár 2012.61, Fig. 21.3*, after* Kovács 1994.76, Fig. 38*); Encs (Füzesabony culture, EBA-MBA,* Mengyán *et al.* 2023.208, Fig. 7*); Berettyószentmárton (Gyulavarsánd culture, EBA-MBA,* Bondár 2012.61, Fig. 21.4*, after* Kovács 1994, Cat. no.33*) (© Kiel University; made by Kata Furholt).

conclude that not every Vučedol settlement was fortified. However, those sites where excavations and other systematic investigations were conducted – for instance, at Zók, Vučedol, and potentially Szilvás – show evidence of domestic activities within the fortifications. The Szilvás site represents the southernmost fortification in the southeast Transdanubian region.

Site name	Subsite name	Site id	X coordinates	Y coordinates
Aranyosgadány	Házságyi-hegy	20065	74611	579338
Dunaszekcső	Kálvária hegy	24638	82212	627610
Görcsöny	Leventelőtér	24662	69735	578773
Lánycsók	Égettmalom-dűlő	24849	72985	615239
Szemely	Szemely II	24529	74754	594442
Szilvás	Ó-szeg	75983	67761	583704
Túrony	Hosszúföldek-Kosaras	25220	62349	586017
Zaláta	Hetenye-dűlő	24409	55691	560607
Zók	Várhegy	25261	72718	576025

Tab. 2. Information on the recorded Vučedol settlements in Baranya County, Hungary (source: Archaeological Archives of JPM). The projection of all coordinates is EPSG: 23700 and CRS: HD72/EOV.

The closest fortified Vučedol settlement is Sarvaš, and the distance from the Szilvás site along the Drava River is approximately 70km, while towards the Danube this could be roughly 80 to 90km. Altogether, 16 fortifications are known from Slavonia and Syrmia, and two sites are published from Bosnia and Herzegovina (Fig. 16, Tab. 4). Except for the Đurđevo site, all Vučedol fortifications are situated on the right bank of the Danube. A smaller fortification cluster is identifiable around Vinkovci in the Croatian Syrmia, and another site cluster is located on the eastern fringe of the Fruška Gora Mountain (related to the Serbian Syrmia) (*Dimitrijević 1956; 1979; Tasić 1995; Miloglav 2018.120*). These fortifications are situated in elevated locations, similar to the Transdanubian sites, and thus we conclude that the Vučedol communities intentionally sought out those high places. The subnames or toponyms of the sites frequently reflect this elevation. In Slavonic languages 'Grad' and 'Gradac' signify city or castle (*e.g.*, Bapska-Gradac, Vučedol-Gradac), while in Hungarian 'Vár', 'Várhegy', and 'hegy' refer to a castle (*e.g.*, Zók-Várhegy, Dunaszekcső-Kálvária hegy), mountain castle, or simply a mountain (*Tasić 1995. 77*). Furthermore, the inhabitants constructed ditches and palisades that protected the entire settlement, which, besides them being protected from attacks or raids, also rendered them more visually striking as living and meeting places.

Site name	Subsite name	Site id	X coordinates	Y coordinates	Period	References
Boda	Alsó Kaposi úttól északra	90139	82096	571187	EBA	*Bertók-Gáti 2014*
Bogád	Krúdy Gyula utca vége	unknown	82202.99	593288.03	EBA?	*Bertók-Gáti 2014*
Görcsönydoboka	Erdő-föld	63224	82076	616215	EBA (Somogyvár-Vinkovci?)	*Bertók-Gáti 2014*
Olasz	Olaszi-hegy	75987	73434	600249	EBA?	*Bertók-Gáti 2014*
Pécsudvard	Bab-föld	25050	72791	590715	EBA, LBA	*Bertók-Gáti 2014*
Pereked	Alsó-mező	76079	82931	598205	EBA, MBA (Transdanubian Encrusted pottery style)	*Bertók-Gáti 2014*
Peterd	Bakaszó	76071	71140	595952	EBA	*Bertók-Gáti 2014*
Pécs	Nagyárpád	59397	77945	589931	EBA (Vučedol B2–C, Somogyvár-Vinkovci, Kisapostag), MBA, LBA	*Bándi 1979; Bándi 1984; Bertók-Gáti 2009; Kulcsár 2009*
Szemely	Felső-rét	unknown	75780.35	594170.64	EBA (Somogyvár-Vinkovci)	*Bertók-Gáti 2014*
Szilvás	Ó-szeg	75983	67761	583704	EBA	*Bertók-Gáti 2014*

Tab. 3. Information regarding the recorded Early Bronze Age fortified settlements in Baranya County, Hungary (sources: Archaeological Archives of JPM;* Bertók-Gáti 2009; 2014; Bándi 1979; 1984; Kulcsár 2009*). The projection of all coordinates is EPSG: 23700 and CRS: HD72/EOV.

Conclusion

Our investigations at the site of Szilvás in Transdanubia have enabled us to reconstruct the site as a densely settled Vučedol fortified hilltop settlement very similar to the structure known from the eponymous site. Our surface collection has reinforced the notion of the importance of wheel and wagon technology in Vučedol, as well as the idea of those sites as a main hub for the spread of innovative technologies. Although further work is needed to confirm and specify many of our propositions, we have shown the potential for our combination of non-destructive prospection methods to gain a better understanding of the Late Neolithic and Early Bronze Age settlement landscapes in the region.

Site name	Country	Y coordinates	X coordinates	References
Debelo Brdo	Bosnia and Herzegovina	5537061.6	2019014.9	*Tasić 1995.76-77*
Zecovi	Bosnia and Herzegovina	5607199.6	1854716.2	*Tasić 1995.76-77*
Bapska	Croatia	5652642.5	2144357.4	*Tasić 1995.76-77*
Borinci	Croatia	5670610.7	2090386.8	*Miloglav 2018.116-119*
Damića gradina	Croatia	5666250.5	2065919.7	*Miloglav 2018.116-119*
Ervenica	Croatia	5666877.1	2093129.33	*Miloglav 2018.116-119*
Sarvaš	Croatia	5704472.5	2097633.2	*Miloglav 2018.116-119*
Vinkovci	Croatia	5666489	2093208	*Miloglav 2018.116-119*
Vučedol	Croatia	5675291.1	2120813.9	*Miloglav 2018.116-119*
Belegiš	Serbia	5624898.9	2263859.2	*Tasić 1995, 76-77*
Đurđevo	Serbia	5672586.6	2233597.7	*Tasić 1995, 76-77*
Gomolava	Serbia	5605665.2	2199817.2	*Miloglav 2018.116-119*
Jasik	Serbia	5467526	2328389	*Tasić 1995.76-77*
Neštin	Serbia	5657046.1	2165381.1	Tasić 1995.76-77
Pećine	Serbia	5640914.1	2202969.8	Tasić 1995, 76-77
Sot	Serbia	5646481.4	2150482.2	Tasić 1995, 76-77
Vizić	Serbia	5648690.2	2165679.2	Tasić 1995, 76-77

Tab. 4. Information regarding the fortified Vučedol settlements in present-day Bosnia and Herzegovina, Croatia and Serbia. The projection of all coordinates is EPSG: 3857 and CRS: WGS 84/Pseudo-Mercator.

The Vučedol complex is very much appreciated by archaeologists for its elaborated material culture, high standard of crafts, metallurgy and rich symbolic expressions. Its densely settled, fortified hilltop settlements speak of complex social organization. This shift in settlement strategies, alongside the steps towards high-quality material production, demonstrates

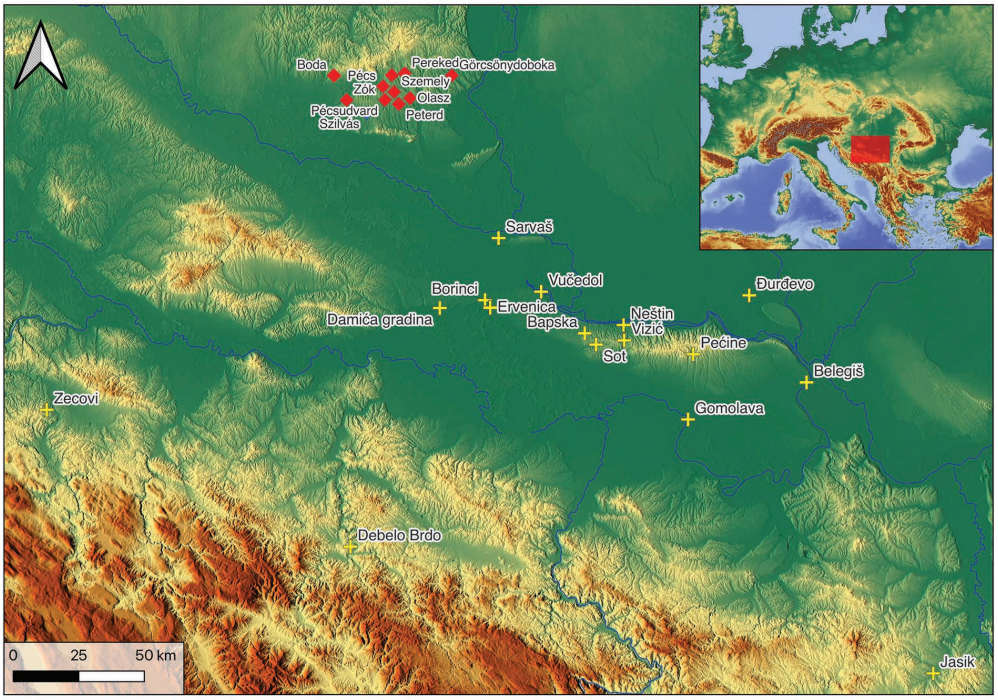

Fig. 16. Vučedol fortifications in Baranya County (Hungary), northwest Croatia, northeast Bosnia and Herzegovina, and northwest Serbia. The red rhombuses show the Hungarian sites, and the yellow crosses show the Croatian, Serbian, and Bosnian sites. (Map made by Kata Furholt.)

that the Vučedol phenomenon is associated with a remarkable social, economic, and cultural transformation in the north Balkans and southeast Central Europe, especially the southern part of the Carpathian Basin and its surroundings at the start of the 3rd millennium BCE (*Roksandić Vukadin, Bošnjak 2024*).

However, there is still much to learn about the underlying subsistence strategies and the specifics of the related socio-economic developments, such as the relation between hilltop sites and unfortified, flatland ones. The Vučedol sites should be much more prominent in discussions about the 3rd millennium BCE as a period of profound and continental-scale social change, mobility, migration and innovation, as they seem to play a multitude of potential roles: a node for interregional communication and innovation transfer, a fortification of 'Old European' ways of life, while at the same time integrating steppe migrants – see Luka Papac *et al.* (*2021*), which reports that one person buried in Vučedol is closely related to Corded Ware from Bohemia.

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Carved in stone: exploring the petrification phenomenon of late 3rd millennium BC in southern Portugal

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ABSTRACT – *The late 3rd millennium BC petrification phenomenon in southern Portugal challenges traditional interpretations, and invites us to explore the complex interplay between prehistoric memory and identity. Found at key mnemonic sites, like the ditched enclosures of Perdigões, Santa Vitória, and Bela Vista 5, these non-funerary stone agglomerations – comprising recutting infillings and a cairn – extended beyond mere functionality. They likely embodied powerful symbols, either by preserving cultural traditions amidst societal transformations or by deliberately and socially erasing past identities. Ultimately, this study examines these agglomerations as ideological tools that reshaped collective memory during the transition between the Chalcolithic and Bronze Age, shedding light on the more intangible behaviours of past communities.*

KEY WORDS – *petrification phenomenon; late 3rd millennium BC; southern Portugal; mnemonic sites; cultural preservation; social forgetting*

Vklesano v kamen: raziskovanje fenomena petrifikacije v poznem 3. tisočletju pr. n. št. na jugu Portugalske

IZVLEČEK – *Pojav petrifikacije v poznem 3. tisočletju pr. n. št. na jugu Portugalske predstavlja izziv za tradicionalne interpretacije in vabi k raziskovanju zapletenih medsebojnih vplivov med prazgodovinskim spominom in identiteto. Najdeni so bili na ključnih mnemoničnih najdiščih, kot so ograde Perdigões, Santa Vitória in Bela Vista 5. Ti negrobni kamniti skupki, ki vključujejo ponovno vkopana polnila in megalitske strukture, so presegli zgolj funkcionalnost in so verjetno predstavljali močne simbole, bodisi z ohranjanjem kulturnih tradicij sredi družbenih premen bodisi z namernim in skupnim brisanjem preteklih identitet. Nenazadnje, študija preučuje skupke kot ideološka orodja, ki so preoblikovala kolektivni spomin na prehodu med bakreno in bronasto dobo in poudarja nematerialna vedenja preteklih skupnosti.*

KLJUČNE BESEDE – *fenomen petrifikacije; pozno 3. tisočletje pr. n. št.; južna Portugalska; mnemonična najdišča; ohranjanje kulture; družbeno pozabljanje*

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Setting the scene: old challenges and fresh perspectives in the study of the 3rd and 2nd millennia BC transition in Southern Iberia

The transition from the Late Chalcolithic to Early Bronze Age – the end of the 3rd and beginning of the 2nd millennium BC (approx. 2200–1800 BC) – is a key theme to better understand a set of simultaneous sociocultural adaptations and declines throughout Europe (*Chapman 2008; Valera 2015; 2021; Lillios* et al. *2016; Blanco-González* et al. *2018; Hinz* et al. *2019; Almeida, Valera 2021; Díaz-del-Rio* et al. *2021; Weinelt* et al. *2021; Aranda Jiménez 2023; Schirrmacher* et al. *2024*). In this subject's intermittent and cyclic research history, Iberia has always stood out. This is mainly due to the early recognition of the different rhythms and responses to change, which caused acute social asymmetries that are depicted in archaeological records from the relatively restricted Iberian territory.

The best examples, and the most opposite ones with regard to the available archaeological knowledge, come from southern Iberia. On the one hand there is the southeast, which is known among researchers as the territory of the 'El Argar Culture' (*Lull* et al. *2013; 2015; Blanco-González* et al. *2018; Díaz-del-Rio* et al. *2021; Díaz-Zorita Bonilla* et al. *2022; Aranda Jiménez* 2023). The groups that make up this culture have been intensively studied, developed at the end of the Chalcolithic (around 2200 BC) and underwent a rapid increase in their social hierarchization and funerary differentiation in the first half of the 2nd millennium BC (*Lull* et al. *2013; 2015; Blanco-González* et al. *2018; Milesi, Aranda Jiménez 2019; Díaz-Zorita Bonilla* et al. *2022; Aranda Jiménez 2023*).

On the other hand there is the southwest of this region, in which this period of transition from the Chalcolithic to Early Bronze Age corresponds to perhaps one of the biggest unknowns in Iberian prehistory. Here, the changes seen at end of the 3rd and beginning of the 2nd millennia BC, from 2200 BC onwards, are incredibly abrupt, archaeologically speaking. Possible fragmentation of the existing communities is suggested, alongside what seems to be a social structural crisis (*Valera 2015; 2021; Almeida, Valera 2021; Díaz-del-Rio* et al. *2021; Schirrmacher* et al. *2024*), due to the sharp archaeological contrast between the communities from these two historical moments.

The visibility of Chalcolithic remains is overwhelming in southern Portugal. Not only in terms of materials, architecture, the number of sites and buried individuals, but also the social complexity, practices, and networks in which the communities were involved (*Valera 2015; 2021; Almeida, Valera 2021; Díaz-del-Rio* et al. *2021; Schuhmacher 2022*). Besides, these groups also seemed to share a cosmological vision and representation of the world that was apparently maintained without fixed ruling classes (*Valera 2015; 2021; Risch 2018; Díaz-del-Rio* et al. *2021*). In contrast, the Early Bronze Age is characterized by the general invisibility of archaeological contexts, either funerary or not, materials, faunal remains and practices (*Valera 2015; 2021; Risch 2018; Díaz-del-Rio* et al. *2021*). Nevertheless, this invisibility is perhaps not only a reflection of adaptation processes that remain to be understood, but also partially caused by a generalized lack of extensive dating programmes, which mainly affect the contexts discovered in rescue archaeology interventions.

Stark differences between the two periods can also be seen in human-animal relations (*Almeida* et al. *2024*) and in the profound changes to settlement networks (*Valera 2015; 2021; Almeida, Valera 2021; Díaz-del-Rio et al. 2021; Schuhmacher 2022*). Chalcolithic gathering sites, such as ditched enclosures, with solid social and symbolic agency, are abandoned along with the habitats (*Valera 2015; 2021*). As such, it is possible to suggest that in the final moments of the Chalcolithic in southern Portugal there was a fragmentation of the existing communities that seemed to be simultaneously suffering structural crises in their symbolic and social identities (*Valera 2015; 2021; Almeida, Valera, 2021; Díaz-del-Rio* et al. *2021; Schuhmacher 2022; Almeida* et al. *2024*).

But if the Chalcolithic is well characterized and studied, significant questions remain unanswered concerning the transition phase, its chronology, and the subsequent invisibility of the Early Bronze Age. Who or what caused this abrupt sociocultural and ideological shift? What were the variables and factors involved? Is this cultural turnover the result of an internal unbalance of the Chalcolithic system, or a reflection of adaptations to exogenous pressures?

In recent years, these questions have rekindled the interest of the international scientific community, and a number of researchers have focused on the role of external pressures in the Chalcolithic/Early Bronze Age transition in southern Portugal (*Lillios* et al. *2016; Blanco-González* et al. *2018; Hinz* et al. *2019; Díaz-*

del-Rio et al. *2021; Weinelt* et al. *2021; Schirrmacher* et al. *2024*). Since archaeology is a social science in nature, many of today's social concerns end up influencing archaeological research agendas. As such, it is not surprising that human-environment relationships, alongside aDNA research, have been the principal target of these projects. More precisely, most of the studies want to measure how a global climatic event that occurred around 2200 BC might have dictated the end of the Chalcolithic way of life (*Lillios* et al. *2016; Blanco-González* et al. *2018; Hinz* et al. *2019; Weinelt* et al. *2021; Schirrmacher* et al. *2024*), and if populational inputs (through migrations or other demographic phenomena) might have also played a role in it (*Olalde* et al. *2018; 2019; Villalba-Mouco* et al. *2021*).

Nevertheless, a more local and archaeological perspective from southern Portuguese contexts has only recently been explored (*Lillios* et al. *2016; Blanco-González* et al. *2018; Hinz* et al. *2019; Weinelt* et al. *2021; Schirrmacher* et al. *2024*). With only a small community of locally active researchers who publish their results, and a notorious lack of funding, several possible significant variables in the cultural changes between the Chalcolithic and Early Bronze Age are being forgotten, while others are over characterized, like the artefactual variability. Still, factors connected to more ideological and intangible practices tend to be the most overlooked, with some rare exceptions (*Valera 2021; Almeida* et al. *2024*).

This seems to be the case with regard to an architectonical practice that has so far been identified in at least three ditched enclosures from southern Portugal: Perdigões (Reguengos de Monsaraz), Santa Vitória (Campo Maior) and Bela Vista 5 (Mombeja). In the later stratigraphic phases of these archaeological sites (the last quarter of the 3rd millennium BC and beginning of the following millennium) a 'petrification phenomenon' was detected. This is characterized by large stone accumulations with the decreased presence of materials, deposited in the form of cairns and recutting infillings. However, most of these expressions were studied and published independently, without ever being connected and read as one (*Valera 2014*; *Basílio, Cabaço 2019; Basílio, Valera 2022; Valera, Basílio 2023*). In this sense, there is a need to reevaluate the available data to check if they might belong to the same phenomenon. If so, in a moment in which everything was changing in these communities, why are these structures being built and what can they mean? Can this behaviour be used as an ideological proxy for the study of the transition between the 3rd and 2nd millennia BC in southern Portugal? Is it exclusive to this chronological phase? Before proceeding further, it is necessary to clarify precisely what comprises the petrification phenomenon that is studied here, through a multidisciplinary approach, with a literature review and case studies that strengthen the proposed ideas.

From stones to symbols: the scope of 'petrification' and its social application

Archaeology is one of the sciences that most often recycles concepts and methodologies from other disciplines, using them in an attempt to better understand past communities. The concept of petrification also reflects this phenomenon.

Originating from the Latin words *petra* (stone) and *ficare* (a form of the verb *facere* meaning to make or do), the word *petrifying* (or petrification – the act of petrifying) can be applied in a literal way, corresponding to a geology term that summarizes the process by which the organic matter of any organism is naturally replaced by mineral materials. This procedure explains the formation of fossils, and it can be seen in the preservation of dinosaur remains, as an example, but also in archaeological contexts, like the fossilized human bodies from Pompeii – turning perishable elements into durable ones, extending their material existence.

With more in-depth research, it is possible to recognize that the concept of petrification is a multifunctional idea that is also applied in other circumstances, and specifically in examples that enhance and sustain other meaningful social roles. The deposition of stones in Jewish tombs, hence forming a stony shell, is a contemporary petrification behaviour (*Levin, Oleshkevich 2024*). Decorating tombs, either through grave goods that accompany the deceased or the deposition of external elements to mark it, has been common practice for a long time (*Nadel* et al. *2013*). Among the most recurrent elements traditionally deposited in graves are flowers, mainly because they have long been read as a metaphor for life, emphasizing its beauty, but also how ephemeral it is (*Christensen 2023*). Jews also chose to deposit flowers at the beginning of their tradition, although there was a clear trivialization of this practice over time and across multiple religious expressions. This forced a shift in Jewish traditions, from valuing the earthly life of the deceased to stressing and celebrating their afterlife

(*Nadel* et al. *2013*). By laying stones at funerary ceremonies, Jews intend to show that their loved ones will be remembered eternally (as long as the stones shall last), while simultaneously ensuring extra protection to guarantee that their bodies are not desecrated, and their souls remain in the afterlife – by creating a physical barrier (*Nadel* et al. *2013*) (Fig. 1).

Other religious examples of the representative and meaningful character that stones and stone accumulations have are noted in the Bible. In Genesis 28:18, the first of many of the Bible's stone memorials appears, namely the 'Stone of Bethel'. Here, Jacob sets up a stone memorial that serves as a physical remembrance of God's presence, while also working as a gathering site. The same Jacob, in Genesis 35:20, once again turned to stones to mark his wife's Rachel tomb, making her memory endure through time – a memorial that intends to extend someone's action and agency in the living world, like several communities do today at their cemeteries (*Viljoen 2023*).

The same intention is also present in a recent example of petrification, illustrating the symbolic agency that stones can carry regardless of the historical era analysed – the memorial created in the mock grave of the fictional character Dobby, the house elf, from the Harry Potter saga. This much-loved character dies and is buried by Harry Potter on Freshwater West beach (Wales, United Kingdom), who marks his grave with stones. After the filming, fans converged on this Welsh beach to mimic Harry's actions, creating a large memorial made up of socks (one of the character's props) and stones with engraved messages. The high visitor numbers and the associated environmental risk led to a conflict between the local government and fans, as there were plans for the memorial to be moved. This led to a wave of protests, as fans stated that this was one of the most iconic sites related to Harry Potter. As a consequence the government left the memorial in place, albeit with a new set of stricter rules surrounding it and the fans' activities (check https://bbc.com/news/uk-wales-63462109, originally consulted at 2024, May 28).

A more practical example of petrification is its usage as a preservation strategy at the archaeological site of Santa Vitória (Campo Maior, Portugal). Since its last excavation in the late 20th century, the site has faced significant erosion, threatening the integrity of several existing features (mostly pits). To address this issue, it was crucial not only to preserve these structures, but also to maintain their visibility within the archaeological landscape, so that they could be actively integrated into the various narratives that would be presented to visitors. The solution was to fill the pits and mark them with stone depositions on the top layers, creating a 'mini petrification'. By transforming the pits into physical markers, they became prominent features in the landscape, thus preserving the remnants of past practices and extending their agency into the future of Santa Vitória.

In summary, the given examples combine, emphasize, and repeat most of the characteristics that should be looked upon when searching for petrification phenomena in archaeological settings. Firstly, the presence of durable elements, namely stones, that have an extremely long lifespan, particularly in an agglomerated and spatially visible way, marking and creating a physical barrier. Secondly, the presence of an underlying dichotomy between two realities – a subject (something or someone) whose memory, role, meaning and/or agency will be marked by the stone agglomeration. Through that, it will inherently be extended and endure through time, a structural change between originally fleeting realities that turn into permanent ones, avoiding oblivion. This action could also be interpreted as an act of condemnation, pre-

Fig. 1. Current examples of petrification, in which stones are used as symbolic elements:* 1 *pit preservation at the ditched enclosure of Santa Vitória;* 2 *Oskár Schindler's grave in Jerusalem;* 3 *Dobby's tomb on Freshwater West beach (Wales, UK).

venting access to something, that would have the opposite intention – leading to forgetfulness. Yet the forgotten element would still have some social agency or role, since it would still be visible in the landscape.

Some stones are, as shown in the examples and petrification phenomenon discussed here, a lot more than just normal stones. They are embedded and enriched with deeper and complex meanings, actions and roles, whose ultimate function seem to be structuring and shaping the present, using a past element (a practice or even just a memory), but also determining and framing the future.

Building a southern Portuguese *corpus*: examples of petrification from late 3rd millennium BC contexts at the complex of ditched enclosures of Perdigões

Identifying examples of petrification in archaeological sites can be a tricky task. Stone is one of the most abundant and used raw materials throughout history, meaning that stone accumulations are not at all scarce in southern Portuguese prehistoric contexts. The true challenge is to understand whether there are other meanings and intentions behind these accumulations, rather than an exclusively functionalist approach, and if patterns start to emerge.

With these constraints and questions in mind, the common elements detected in the analytical overview of petrification were used as a reference to identify non-funerary contexts, with an exploratory approach exclusively focusing on securely dated features from the last quarter of the 3rd millennium BC from the archaeological site of Perdigões (Fig. 2). This strategy allowed us to build an architectonical and contextual reference framework. Funerary contexts and possible petrifications inside pits were excluded from this analysis. Due to a generalized lack of radiometric information, including these contexts would weaken the validity of the study.

The complex of ditched enclosures of Perdigões, located in Reguengos de Monsaraz, 35km from Évora, in a natural amphitheatre, is one of the most – if not the most – characterized and studied archaeological sites in southern Portugal, with over 25 years of continuous research, more than 100 ^{14}C dates and 257 scientific publications (*Lago* et al. *1998; Valera 2008; 2015; 2022; Valera, Evangelista 2014; Valera* et al. *2014; Valera, Basílio 2017*). Perdigões exhibits a remarkable diversity of practices over its 1500 years of occupation, including astronomical alignments of the entrances, a consistent pattern of circular and concentric structures, and the presence of funerary monuments (*Valera, Godinho 2009; Valera* et al. *2014*). The overlap of structures (some made of stone) and materials at the central point of the complex (*Valera* et al. *2014*) underscores the ideological and cosmological continuity of the groups that converged at Perdigões, whose existence seems to have lasted until the transition between the 3rd and 2nd millennia BC (*Valera, Basílio 2017; Valera 2022*). The use of stone as a construction element is attested at this archaeological site, but it is important to highlight that Perdigões was severely ploughed in the 1990s, which affected the preservation of later contexts, among which there a perhaps examples of petrification (Fig. 3).

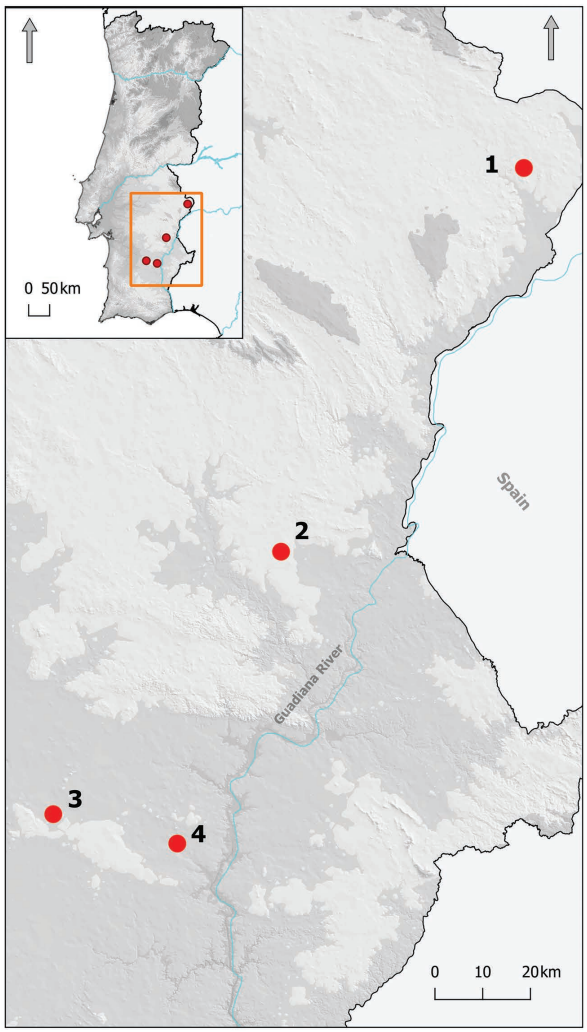

Fig. 2. Sites where the petrification phenomenon was noted:* 1 *Santa Vitória (Campo Maior);* 2 *Complex of ditched enclosures of Perdigões (Reguengos de Monsaraz);* 3 *Bela Vista 5 (Beringel);* 4 *Alto do Outeiro (Baleizão).

Structure 27 is between the most significantly altered features, with its original morphology greatly affected. This stone agglomeration, likely one of the last structures built, dates from the third quarter of the 3rd millennium BC, and is located at the heart of Perdigões, overlaying a sequence of timber circle constructions and the cremated human remains deposited in the central area of the site (*Valera 2023*). Currently under excavation, its exact nature remains unclear, with some ceramics, lithics and faunal remains appearing between the stones (*O.c.*). Nevertheless, according to the available data it appears that it once served as a physical marker signalling the end of the use of the central area of Perdigões, particularly the Bell Beaker occupation, imposing itself amid the remnants of earlier practices, hence its possible integration in the petrification phenomenon.

A second example, in the vicinity of Structure 27, is the combination of structures known as Cairn 1, the only one of its kind in the second half of the 3rd millennium BC in Alentejo (*Basílio, Cabaço 2019; Basílio 2022*). It is composed of a circular stone mound that covered two pits and the small depression in which they were excavated, allowing us to think about the existence of a normative, possibly orchestrated, set of practices (*O.c.*). This is mainly possible due to the infillings of both pits. Pit 77 illustrates how petrification can occur not only on larger scales, but also in smaller features (Pit 77 has a diameter of 58cm and depth of 40cm). This structure, securely ascribable to the end of the 3rd millennium BC, is infilled with two distinct phases of stone depositions, the later one visibly marking and differentiating it from the cairn that will cover it (*O.c.*). Pit 79 is the central and biggest structure. It is infilled with the remains of at least 20 animals, mainly wild specimens (deer and horses), with most of the bones showing signs of having been cooked and eaten during the last quarter of the 3rd millennium BC. These elements are complemented by a limestone idol, a sherd with solar motifs, and a bell beaker fragment (all associated with more intangible spheres of prehistoric communities) that, coupled with the apparent speed of the deposition (archaeologically speaking), have been read as the leftovers of a celebration or feast, in which food would play a central role (*O.c.*). Nevertheless, they appear to have not been discarded in a meaningless way, as suggested by the stone agglomeration that covers them. The monumental cairn gives visibility to this group of structures, giving them an agency and a symbolic meaning in the central area of the enclosure, where the overlapping and coexistence of practices would be overwhelming (*O.c.*). The physical and visual presence of this structure could extend a moment in time – the commensality ritual or festivity, but also the practices carried out, and the people present – stimulating and perpetuating its memory while shaping future narratives. It combines intangible social, cosmological, and ideological systems, materializing them in a tangible and enduring monumentality.

Lastly, another type of petrification: recuttings infilled with stone agglomerations on top of ditches 1 and 7. These reopening's follow the elongated shape and previously defined path drawn by the pre-existing ditches and are almost exclusively composed of depositions of medium and small stones, with a significant lack of sediment, suggesting a fast pace of deposition. Among the stones a few scarce material deposits were noted, clearly contrasting with the surrounding contexts, packed with ceramics, lithics and faunal remains (the absence of which was already noted in Cairn 1) (Fig. 4).

Ditch 1 is one of the largest and outermost ditches identified in Perdigões. It is 8.81m wide and has a maximum depth of 3.38m, with mostly horizontalized layers of material depositions dating from the second half of the 3rd millennium BC, possibly when it was also opened (*Márquez Romero* et al. *2022*). An interruption in its layout has been detected, forming an entrance that would condition access to the central space of Perdigões. Adjacent to this entrance, two pits (only separated by a plough mark) were excavated inside the final layers of Ditch 1, with a shallow depth ranging from 0.30 to 1m (*O.c.*). Infilling these pits (*O.c.*), which with the available information could be read as a single recutting (and not two individual features), there is a repetition of the petrification noted in Cairn 1 – an agglomeration of stones (medium and small), in this case with an elongated shape, with only a few sherds, faunal remains and a decorated beaker fragment included.

If any doubts remain regarding this type of petrification, Ditch 7 clarifies them. It corresponds to a 'V' section linear ditch possibly excavated and infilled during the second half of the 3rd millennium BC, with a maximum width of 3.90m, and a depth of 2.95m (*Valera 2015; Basílio, Valera 2022*). As in Ditch 1, Ditch 7 is also infilled with mostly horizontalized depositions, with its lower third corresponding to an intercalated deposition of stones, ceramic sherds and fau-

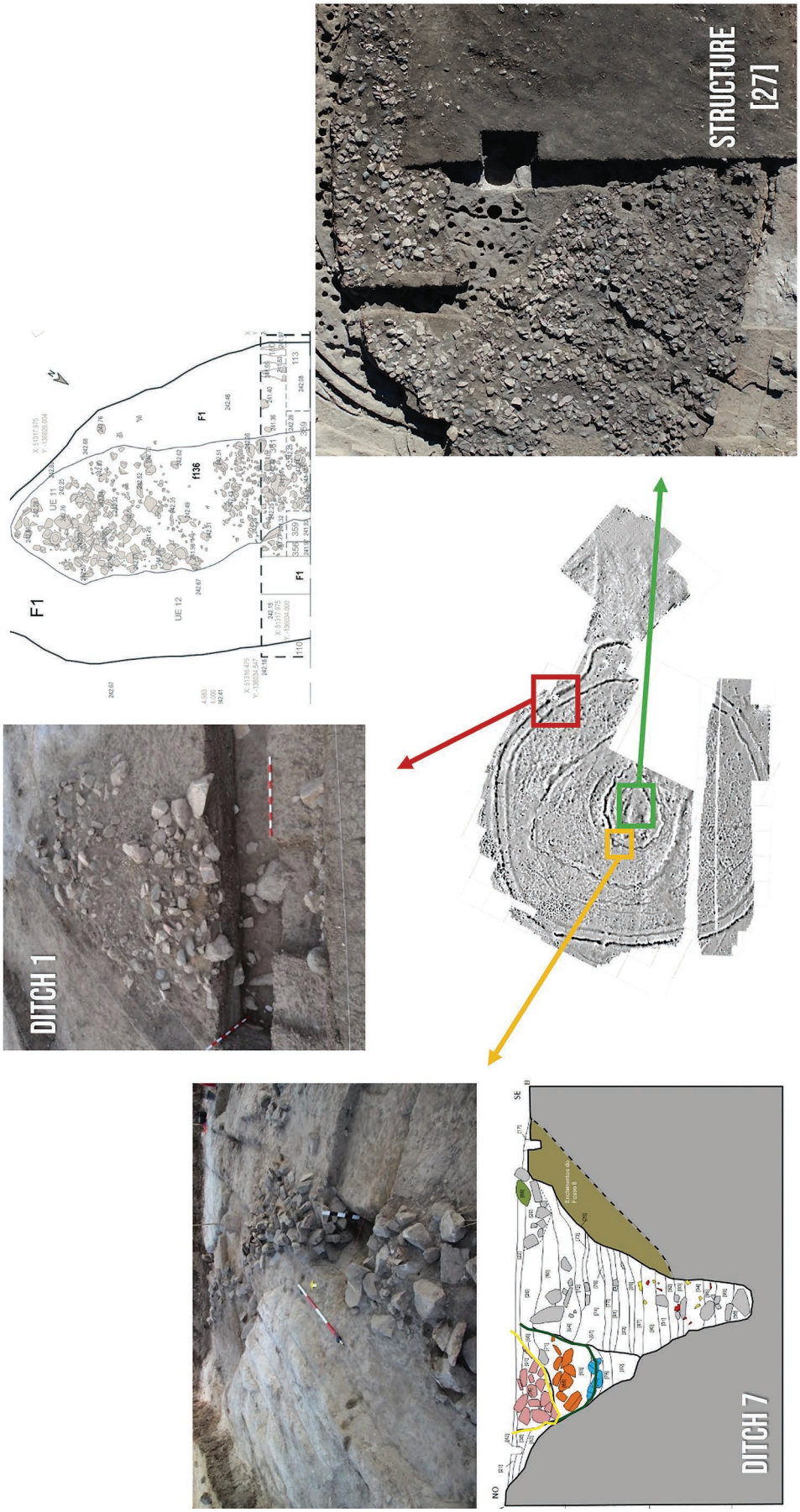

Fig. 3. Petrification context detected at the complex of ditched enclosures of Perdigões: Ditch 1 (Márquez Romero *et al.* 2022)*; Ditch 7* (Basílio, Valera 2022)*. The geophysical image was taken from Márquez Romero* et al. *(2011).*

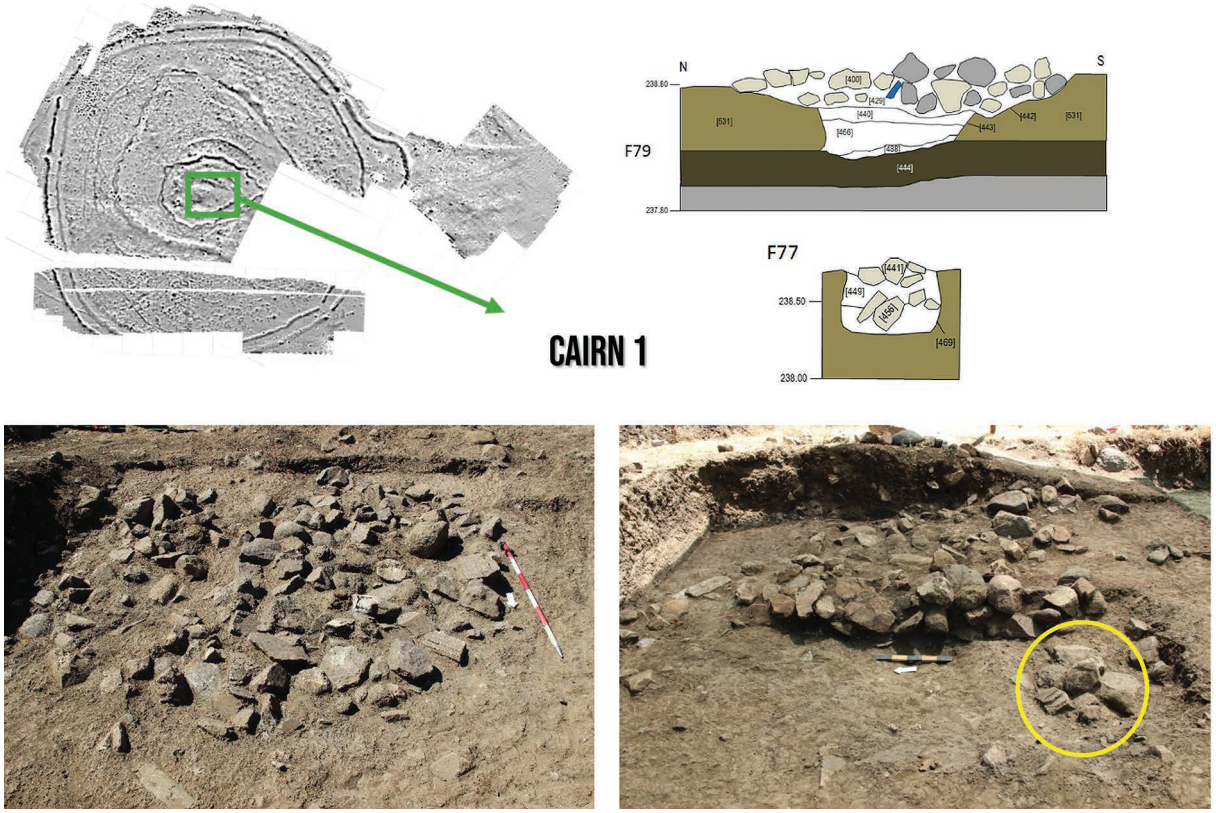

Fig. 4. Petrification context detected at the complex of ditched enclosures of Perdigões: Cairn 1 covering pits 77 (marked in yellow) and 79 (*Basílio, Cabaço 2019*).

nal elements that also integrate human remains (*Evangelista*, *Valera 2019*). The second phase in the life of Ditch 7 comes in the form of two moments of partial reopening (*Valera 2015*; *Basílio, Valera 2022*). An older recutting also presents two distinct moments of stone depositions that are separated by a deposit and some materials – similarly to Pit 77 (*O.c.*). The second reopening is narrower than the older stone depositions, with a depth of approximately 45cm (resembling Ditch 1) (*O.c.*). It was excavated inside the infilling of the previous recutting, slightly mismatching it, and is exclusively composed of an elongated stone concentration, with a hugely reduced material density, but with the deposition of an odd metallic element (*O.c.*). With these characteristics, these contexts justify the usage of the concept of 'phenomenon' to describe the focal social practice, since it can encompass the normal human variability and adaptations expected in any social and cultural behaviour.

Chronologically speaking, the opening and subsequent filling of both Ditch 1 and Ditch 7 occurred over extended periods, indicating a phased process of use, followed by the petrification. Both recuttings from Ditches 1 and 7 and Cairn 1 have an advanced chronology inside the 3rd millennium BC, inclusively covering the first years of the following millennium, matching the timeframe intended in the present research (*Valera* et al. *2014*). But if for Ditch 1 and Cairn 1 direct ^{14}C dates were obtained – ranging from 2300 to 2050 cal BC in Ditch 1 and from 2199 to 1977 cal BC in Cairn 1 (*Basílio, Cabaço 2019; Márquez Romero* et al. *2022*) – the chronological assignment of Ditch 7 is based in a *terminus post quem* analysis, which might undermine the results (*Basílio, Valera 2022*). Nevertheless, Ditch 7's petrification seems to have occured somewhere around the middle of the 3rd quarter of the 3rd millennium BC, or even at the beginning of the last quarter of the same millennium (*O.c.*). In support of these values, the petrification practices in Perdigões took place in the most indistinct phases in the life of this site, contemporaneously with ongoing regional acute social and structural changes (*Valera 2021*), accompanied by shifts in the faunal patterns (*Almeida* et al. *2024*).

To repeat, it was possible to identify two specific kinds of structures that apparently match and replicate the physical and ideological intentions behind the petrification phenomenon in the intended chronology: *stone round/oval concentrations (cairns)* that cover previous archaeological contexts, and *stone agglome-*

rations that mark recutting practices on already infilled ditches. With their contextual nuances, both expressions materialize intentional behaviours that, by resorting to locally available stones (gabbro-diorites), prevent (or at least make it harder) to access previous materials, contexts, and moments through a physical barrier, but that also reactivate previous narratives, creating new agents with the ability to influence the space's future biography.

Beyond Perdigões: understanding petrification regionally

The last quarter of the 3rd millennium BC is one of the least represented timeframes in the available ^{14}C charts of Alentejo, with scarce contexts and sites ascribed to it. This gap reflects both historical and archaeological invisibilities, but also a lack of radiometric projects, especially in sites detected in rescue archaeology interventions, often with significant time and financial constraints. This scenario limits the scope of this work, with only two other secure contexts with a petrification phase detected regionally: the ditched enclosure of Santa Vitória and the enclosure of Bela Vista 5. These enclosures allow us to attest that evidence of petrification should be sought not only in sites with long and complex histories, like Perdigões, but also in contexts with seemingly shorter biographies and simpler architectures.

The ditched enclosure of Santa Vitória, located in Campo Maior, 20km from Elvas, at a slight elevation of 312m high (*Valera*, *Basílio 2023*), was the first of its kind identified and excavated in Portugal, during the 1980s and 1990s (*Dias 1996*). It is composed exclusively of two lobulated ditches, and a minimum of 19 pits, with an interruption aligned with the summer solstice in Ditch 1, and the one from Ditch 2 facing north (*Valera, Basílio 2023*), without any other stone structures present. Most pits and nearly the entire infillings of Ditch 1 have been completely excavated, with its research reflecting the conceptual agendas of the time, which notably lacked understanding of negative structures and the dynamics of their infillings. This led to its original interpretation in the short published bibliography as a settlement, overlooking the infilling and depositional processes (*Dias 1996*). Fuelling this idea were the vast elongated stone agglomerations detected atop both ditches, interpreted as the remnants of destroyed huts (*O.c.*). However, with the development of the SANVIT research project, which conducted up-to-date field campaigns from 2018 to 2022 and critically reviewed the available data, it quickly became evident that the mentioned contexts might correspond to potential petrification moments, spread through the top layers of Ditch 1 (*Valera*, *Basílio 2023*).

Ditch 1, section 1, only preserved a small area of its original complete infilling, left as a testimony since the 1980s (Fig. 5). In this section, the major infilling phase mirrors what was observed for both Ditches 1 and 7 at Perdigões, featuring predominantly horizontalized layers, some material depositions ascribed to the mid/second half of the 3rd millennium BC, but also evidence of an earlier recutting (*Valera, Basílio 2023*). After this first reopening a new recutting was excavated, but this one is infilled with a large stone agglomeration, primarily of gabbros and diorites (*O.c.*). Due to the limited area that has been preserved, and the extent of alterations, having been exposed for a long time, little more can be determined about its original shape and role, beyond the possibility that it might correspond to a petrification phase.

Ditch 2, on the other hand, was only partially excavated by the previous research team, allowing the establishment of its full depositional sequence during the second half of the 3rd millennium BC (*Valera, Basílio 2023*). Four different surveys have been conducted in this structure, revealing a notable gabbro and diorite agglomeration in all the excavated sections (*O.c.*). This agglomeration exemplifies a 'by the book' petrification moment, infilling an elongated recutting excavated in the top layers of a previous ditch, following its path, almost exclusively including medium and small stones, with few archaeological artefacts. This petrification blocks access to the earlier infillings while visually marking them, creating a physical and visual barrier in the site's landscape.

In some instances, such as section 2, an earlier recutting already infilled with stones was noted, since it was misaligned with the previous one (*Valera, Basílio 2023*). This prompts reconsideration of whether the existence of double petrifications, like the one detected at Ditch 7 of Perdigões (*Basílio*, *Valera 2022*) might be more common than previously noted. Additionally, these practices seem to occur not only in linear ditches, such as those at Perdigões, but also in lobulated structures. These enclosures highlight that there is an additive constructive technique (*Valera 2014*) behind them, also seemingly corroborated by the petrification in Ditch 2 of Santa Vitória, which seems slightly interrupted in the transition between

the different lobes (*Valera*, *Basílio 2023*). However, the excavated area is still too small to fully support to this hypothesis.

Besides the additive construction that has been suggested for lobulated ditches, another distinct characteristic that brings them together is their late chronology inside the 3rd millennium BC. The available dates suggest that these sites began to be constructed in the second half of the 3rd millennium BC (*O.c.*). This is valid for both structures of Santa Vitória, with the possible petrification of Ditch 1 frameable within the last quarter of the 3rd millennium BC (2118–1894 cal BC), in contemporaneity with the one detected at Ditch 2 (with a *post quem* date of 2139–1957 cal BC). This chronology also aligns with the enclosure of Bela Vista 5, the second regional context in which petrifications were identified. However, if in size, chronology and planimetry Bela Vista 5 is closer to Santa Vitória, the presence of a funerary context sets them apart.

Bela Vista 5, located in Beringel, 13km from Beja, was identified through rescue archaeology and, unfortunately, only partially excavated (*Valera 2014*). The site comprises 84 possible pits, 26 of which are confirmed, that accompany three ditches. The smallest of these, Ditch 3, corresponding to just a small section, connected to Ditch 2, forming part of a 'crab claw' entrance (*O.c.*).

Ditch 1, the innermost structure, forms a small, circular 6–7m wide enclosure, which appears to be linked with the single pit that it surrounds (Fig. 6). This feature corresponds to the unique funerary structure of Bela Vista 5, containing the remains of a single adult individual, possibly a female, who exhibits signs of bone manipulation and body reconstruction (*O.c.*). Although this ditch's infillings show several recuttings, none corresponds to a petrification (*O.c.*).

Ditch 2 forms a significantly wider oval enclosure, measuring between 29 and 32m in width, closer to the one delimited by Ditch 1 at Santa Vitória (*O.c.*). Despite its width, Ditch 2 is not particularly deep, reaching a maximum depth of 1.20m. It was among the first contexts in southern Portugal where the segmented construction of ditches was securely attested (*O.c.*). Also segmented are the petrifications. The gabbro-diorite stone accumulations from Ditch 2 exhibit characteristics like those found at Santa Vitória and Perdigões. However, while the segmented nature of petrifications was only theorized for Santa Vitória, in Bela Vista it is now fully verified, alongside the existence of double petrifications, as proved in sector 5 of Bela Vista 5 (*O.c.*).

A third site that may exhibit evidence of late petrification is Alto do Outeiro, in Baleizão (Beja). Initially interpreted as a settlement (*Grilo 2007*), a detailed re-

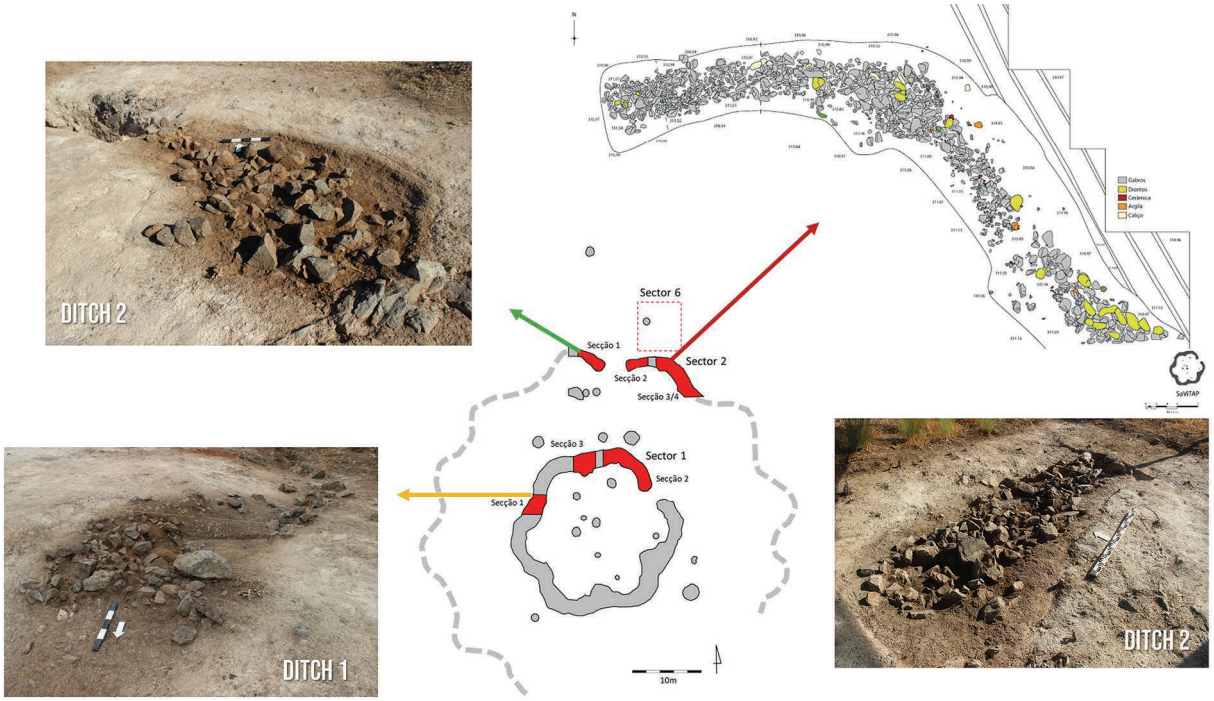

Fig. 5. Petrification context detected at the ditched enclosure of Santa Vitória: Ditches 1 and 2 (*Valera, Basílio 2023*).

view of the published data suggests it may be inscribed into the ditched enclosures phenomena. The site features two possibly lobulated ditches, the full plan of which remains unknown, and at least six confirmed pits (*O.c.*). Similarly to Santa Vitória, Alto do Outeiro is situated on a discreet hill with an elevation of 164m (*O.c.*), and it includes a final clogging layer interpreted as a 'positive stone structure' (*O.c.*). Upon closer examination of the available photographs and sections, this 'structure' appears to mimic the behaviours of other petrifications, suggesting it might correspond to an unidentified recutting section, later infilled with a stone agglomeration and some clay fragments (Fig. 7). Unlike the previous examples that have direct radiometric data, Alto do Outeiro lacks ^{14}C analysis, with only the materials suggesting a possible integration into the later stages of the 3rd millennium BC (*O.c.*). Nonetheless, this site exemplifies how re-evaluating previously excavated and already interpreted sites can shed some new light on ongoing social practices. It also emphasizes the need for increasing the existing chronological datasets, particularly regarding the late 3rd millennium BC contexts. The limited number of radiocarbon dates (as noted in Figs. 8 and 9) restricts our understanding of the timing and dynamics of petrification practices.

By expanding the geographical scope of the present study, new behaviours associated with the petrification phenomenon from the last quarter of the 3rd millennium BC in southern Portugal have been identified. This broader perspective allows for a better understanding of the diverse array of practices observed within the related prehistoric communities. The scarcity of artefacts, the occurrence of double petrifications, the use of local raw materials and their segmented nature can now be added to the previously recognized characteristics of this phenomenon. These new features emphasize the complexity and multiplicity of roles that these archaeological expressions could acquire in the final moments of the 3rd millennium BC, reaffirming the conceptual choice of the word 'phenomenon' to describe this petrification practices.

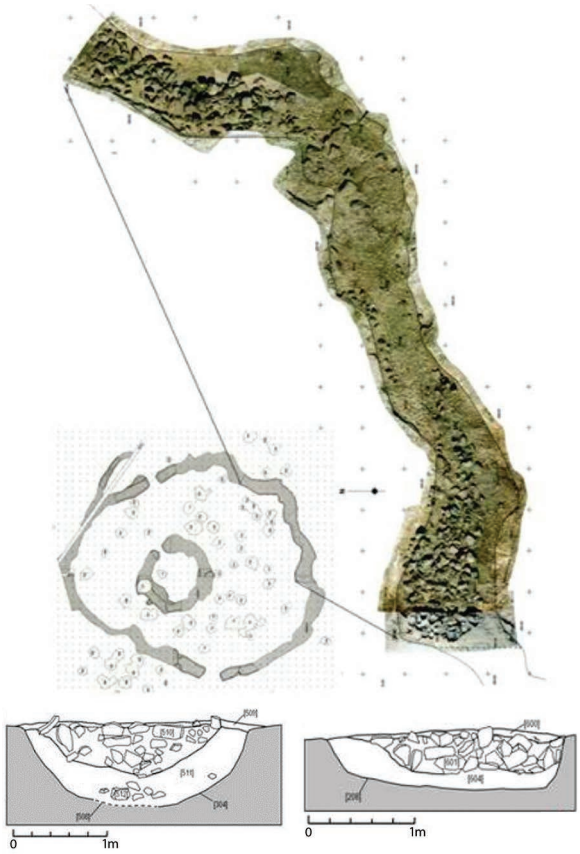

***Fig. 6. Petrification context detected at the ditched enclosure of Bela Vista 5: Ditch 2. The images and sections are taken from* Valera 2014.**

Discussion

From petrification to social agency: exploring space and architecture

Conducting a study focused on architectonical expressions dated from the end of the 3rd millennium BC requires recognizing that these structures need to be carefully analysed, as they may embody an additional layer of inscribed transcendent roles and agencies, especially given their construction, existence and use within an abruptly changing social context.

Architecture has a language of its own, it evokes emotions, creates sensorial experiences, has the ability to transcend time and is usually an identitarian token that includes more than just the final constructed product (*Erdinç 2023*). It embodies thoughts, and that materialization is the sum of a planning phase, all the prior and following alterations and modifications (the structure's biography), the pre-existing landscape and future events. It serves as a long-lasting memory, a monument – from the Latin *monumentum*, meaning something that reminds, a memorial, a record.

This is particularly true for prehistoric architecture. Despite often being constructed in a segmented manner, as noted in the examples of petrification given above, they rely on the strong visual and imaginative power that is needed to maintain the spatial cohesion and repetition of regional patterns, such as the generalized tendency for circularity, or even the final planimetry of lobulated enclosures.

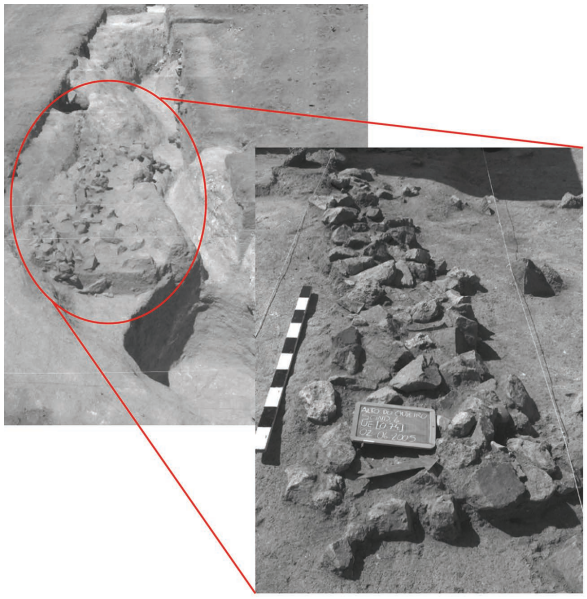

Fig. 7. Petrification context detected at the ditched enclosure of Alto do Outeiro. The images are taken from Grilo (2007).

The concept of architecture is intimately connected with that of space. In this case, space should also be understood as a social reality, that represents and materializes a collective thought and construction (*Durkheim 2002; Silvano 2010; Erdinç 2023*). This perspective creates multiple and mainly bilateral relationships between a space and the communities that inhabit it. Thus, in this line of interpretation, a space is the result of the symbiosis between the process of sensorial interpretation and the storage of experiences (social memory) by the communities that transform it (*Durkheim 2002*). In essence, it is the consequence of the anthropic capacity to create order in a heterogeneous reality, giving it meaning(s) and significance(s) (*Silvano 2010; Bradley 2012*). In other words, Space, as a social construction, can be segmented and divided into a material realm, usually occupied by architecture, both natural and anthropic, and the representations and ideas that are associated with it (*Lévi-Strauss 1979*), mostly spread and maintained through oral traditions and myths (*Kelly 2015*).

The organization of a space, whether on a micro or macro scale, will also reflect the social structure of the groups that give it meaning (*Durkheim 2002*), and the same applies to architecture. This means that planimetry, morphology, areas of implantation and the materials used are an integral part of the narratives created, incorporating and contributing to the physical materialization of visions, organizations and shared group beliefs (*Durkheim 2002; Valera 2008; Silvano 2010; Kelly 2015; Erdinç 2023*). One of the best examples of this materialization of intangible meanings is the system of organization defined by the Zuni, a North American native tribe. The Zuni divide their cosmos into seven regions, which are then physically applied to the organization of the clan (*Mauss 1903*). On the other hand, space also functions as an element of memory that encapsulates collective histories and milestones (*Mauss 1903; Halbwachs 1939*). Due to its physicality, this segmentation ends up fostering social processes of interchanging ideas, myths, rites and cosmogonies (*Halbwachs 1939*). This gives it a functional and symbolic plurality in maintaining, renewing and affirming shared identities daily (*Mauss 1903*), thus perpetuating ancestral meanings. On the other hand, it creates a weakness in the social system. By depending heavily on these spatial symbols and physical landmarks/structures (anthropic or natural), their eventual disappearance increases the risk of identity crises and social stress, but it can also instigate collective movements to counter change. These are not immediate responses, and have their own rhythms. Archaeologically visible physical changes, both in space and materials, have a delay in comparison to what may have been a metamorphosis in the social system (*Silvano 2010*). These changes, and their magnitude, also depend on the strength of possible impacts and the resilience, regeneration, adaptation and reconversion ability of the human groups affected. Collapse scenarios are only envisaged in rare situations. As such, the correlation between spatial and social changes will not be direct or synchronic, but asynchronous, and can be perceived on a generational or multigenerational scale, also depending on how much they affect the local non-material culture (*Kelly 2015*). Ultimately, although not that commonly, spatial metamorphosis can cause the obliteration of the collective mnemonics used to materialize shared meanings and beliefs (*Lévi-Strauss 1979; Valera 2008; Silvano 2010; Kelly 2015*), leading to social collapses.

This may be the phenomenon reflected in the petrifications presented in this study. With deep, ongoing social and spatial changes at the end of the 3rd millennium BC, revisiting previously existing architectures might have represented an attempt to rescue and reconnect with traditions, using them as a tool and means to oppose or delay shifting behaviours. By calling past narratives into present action, these communities were possibly invoking the ancient mythologic ancestors (*Kelly 2015*) who were believed to be responsible for constructing and infilling the ditches, as

also suggested by the local nature of the stones used, claiming a relational identity and establishing a connection between a constructed past and their present (*Milesi, Aranda Jimenéz 2019*). Human memory, however, is an unreliable collective phenomenon (*Halbwachs 1992*), meaning that maintaining earlier narratives through oral traditions is a challenge in which meanings are constantly being altered (*Connerton 1989*). Traditions are composed of previous knowledge that is updated with present experiences (*Kelly 2015*), combining a mix of natural memories from actual events, and artificial ones from instilled and learned ideas (*Yates 1966*). Different oral technologies were available to keep this cultural memory alive in groups that did not have written records. The most common ones correspond to social performances, presented in the form of songs, dances and histories, that are usually carried out and shown to the community at large social gatherings, which were the ideal settings for spreading traditional knowledge (*Connerton 1989; Kelly 2015*). Another, more permanent, technique is the development of mnemonic structures (*Connerton 1989; Assman 2011; Kelly 2015*). Their durability can lead to constant processes of social reinterpretation (*Rogers 1983; Connerton 1989*), in order to give them alternative meanings that match the existing narratives, practices and myths.

Spatial mnemonics: perpetuating traditions and practices through petrifications

Mnemonic structures are integral parts of an architectonical communication strategy that encapsulated inscribed memories in pre-literate communities (*Connerton 1989; Meusburguer* et al. *2011; Kelly 2015; Van Dyke 2019*). By repeating the same spatial features, alignments and patterns, mnemonic architecture is a tool for the dissemination of traditional knowledge, aiding in the construction of a cohesive and common social identity. Since human experience is predominantly spatial (*Meusburguer* et al. *2011; Van Dyke 2019*), the longevity observed at certain sites, namely in those interpreted as gathering sites, like the archaeological site of Perdigões, but also other natural features, like hills (*Basílio 2022*), is unsurprising. These 'memory theatres' work as relational leverages that enhance the effectiveness of the enacted practices, due to their performance in spaces where there are visual and physical remains of previous events (*Tilley 1994; Meusburguer* et al. *2011; Zerubavel 2012*).

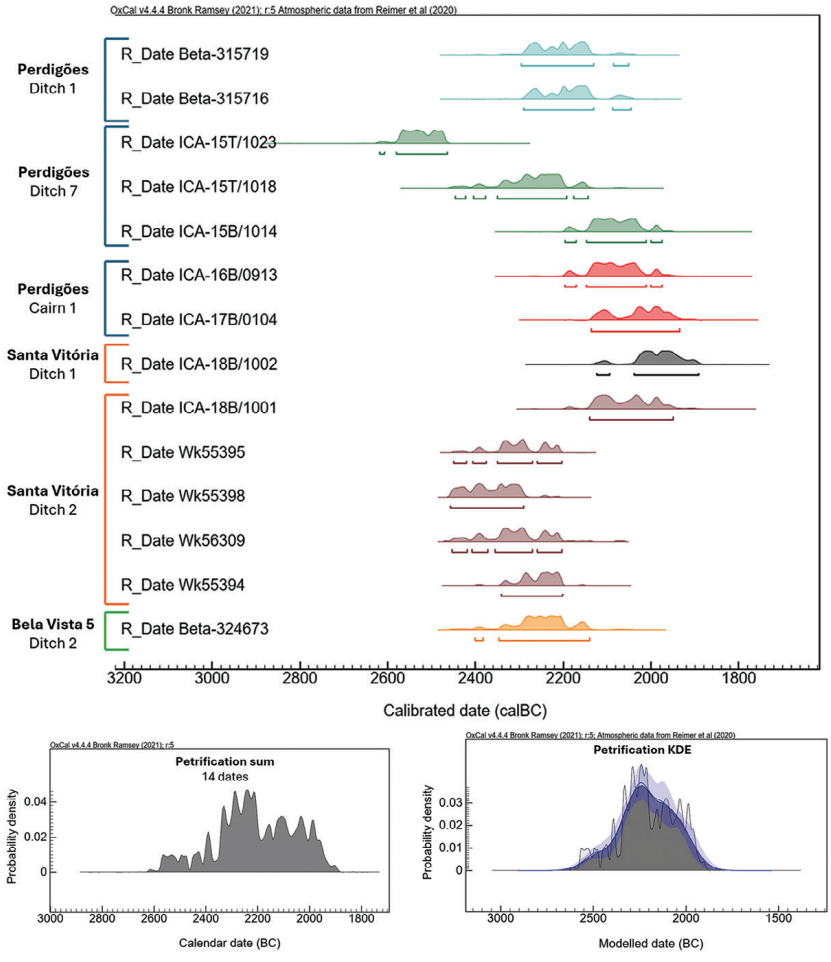

Fig. 8. Calibrated Radiocarbon dates from petrification contexts. KDE and SPD from the same contexts.

In this sense, the petrifications considered here might acquire a new layer of symbolism. By taking advantage of previously existing contexts, at socially meaningful sites, the 'parasite' petrifications work as a new chapter that was added to the structure's biography, extending and monumentalizing it. An intentional discursive and future-looking practice at the turn of the 3rd millennium BC, that would possibly aim to construct a new past, visually marking it, but simultaneously thinking about the perpetuation of the structure's meanings in the future (*Holtorf 1996; 1997; Bradley 2002; Basílio, Cabaço 2019; Van Dyke 2019*).

Radiocarbone dates from petrification contexts						
Sites	Lab.	Date	Cal BC 2σ	Context	Sample	Bibl.
Perdigões - Ditch 1	Beta-315719	3780±30	2297-2132 (91,2%) 2085-2051 (4,2%)	SU 116 - Pit 194	Teeth (*Sus* sp.)	*Márquez Romero* et al. *2022*
	Beta-315716	3770±30	2291-2131 (87,2%) 2088-2047 (8,3%)	SU 11 - Pit 194	Bone (*Sus* sp.)	
Perdigões - Ditch 7 **	ICA-15T/1023*	4010±30	2618-2609 (1,4%) 2581-2465 (94,1%)	SU 92	Mandible (Human)	*Basílio, Valera 2022*
	ICA-15T/1018	3820±30	2447-2424 (1,9%) 2405-2378 (4,2%) 2350-2193 (82,5%) 2177-2144 (6,8%)	SU 86	Bone (*Sus* sp.)	
	ICA-15B/1014	3690±30	2197-2171 (5,7%) 2147-2012 (83%) 2001-1975 (6,7%)	SU 63	Bone (*Sus* sp.)	
Perdigões - Cairn 1	ICA-16B/0913	3690±30	2197-2171 (5,7%) 2147-2012 (83%) 2001-1975 (6,7%)	SU 500 - Pit 79	Bone (*Cervus elaphus*)	*Basílio, Cabaço 2019*
	ICA-17B/0104	3650±30	2137-1936 (95,4%)	SU 488 - Pit 79	Bone (un-determined	
Santa Vitória - Ditch 1	ICA-18B/1002	3620±30	2123-2095 (5,6%) 2040-1891 (89,8%)	SU 101 - Phase 2	Bone (un-determined	*Valera, Basílio 2023*
Santa Vitória - Ditch 2**	ICA-18B/1001	3670±30	2141-1951 (95,4%)	SU 202 - Phase 2	Bone (un-determined	*Valera, Basílio 2023*
	Wk55395	3846±15	2451-2421 (3,7%) 2406-2377 (9,1%) 2351-2271 (54,7%) 2260-2204 (27,9%)	SU 274 - Phase 1	Bone (*Sus* sp.)	
	Wk55398	3873±15	2457-2291 (95,4%)	SU 276 - Phase 1	Bone (*Cervus elaphus*)	
	Wk56309	3848±20	2454-2419 (7,1%) 2408-2373 (12%)	SU 273 - Phase 1	Bone (un-determined	
	Wk55394	3825±15	2341-2201 (95,4%)	SU 234 - Phase 2	Bone (*Sus* sp.)	
Bela Vista 5 - Ditch 2	Beta-324673	3810±30	2401-2383 (2%) 2346-2141 (93,4%)	SU 202	Bone (*Sus* sp.)	*Valera 2014*

* outlier date ** *Post quem* dates

Fig. 9. Detailed chronological information about the petrification contexts.

Similar behaviours and intentions can be proposed for revisitations detected in other types of petrifications. One of the oldest examples of meaningful petrification is the stone shells, *tumuli* or cairns, created around megalithic monuments. These architectonical elements would carry the multiple purposes already noted for the later petrifications, but on a much earlier chronology. On the one hand, a more practical function to protect the earthen mound that covered the megalithic structure, stabilizing it and, on the other, contributing to a temporal extension of the monument's biography and agency, by visually emphasizing their presence in the landscape – a spatial mnemonic (*Tilley 1994; Bradley 1998; Meusburguer* et al. *2011; Kelly 2015*). The indirect chronological range of use, mostly inferred from the votive sets, suggests that dolmens seem to maintain their ability to attract gatherings over time, even when the social environment was shifting, with communities continuously re-registering into a shared communal identity embodied in dolmens, claiming an identity as also noted for southern Spanish monuments (*Chapman 2008; Milesi, Aranda Jimenéz 2019; Aranda Jimenéz* et al. *2021*).

Reactivating and reconnecting with an already abandoned site is also noted in some Chalcolithic walled enclosures of Portuguese Estremadura. Due to the abundance of raw materials, most of their structures were built using a large number of locally available stones. Over time, through reformulation and abandonment processes, both natural and anthropogenic,

these sites transformed into indecipherable stone agglomerations, whose previous contexts and practices become inaccessible, while simultaneously generating and imposing new ways of experiencing and perceiving space. Nevertheless, later funerary depositions indicate that, despite being in ruins, these enclosures could still function as active memory theatres in the social landscape, exemplifying the ongoing cognitive reorganizations of space (*Valera 2003*), even in historically distinct moments, as materialized by the Bronze Age depositions (*Sousa 2021*). Furthermore, parallels can also be found with what occurs in the walled enclosures from northeast Portugal, where the structures are read as living elements that integrate a network of ongoing space construction and monumentalization/patrimonialization processes (*Jorge 2003; Cardoso 2007*). In sites like the enclosure of Castelo Velho de Freixo Numão, where structures and passages seem to have been condemned/closed, during the transition between the 3rd and 2nd millennia BC, becoming, in some cases, large stone agglomerations (*Jorge* et al. *2005*), alternative interpretations have been suggested. Changing the architectures, or creating new features (as with the noted condemnations), has an impact in the surrounding environment, and in the previously ascribed meanings and representations (*Jorge 2003; Cardoso 2007*).

Additionally, a few other contexts and practices could be associated with the petrification phenomenon, as they generically mimic the possible intentions behind the focal practice, but without resorting to stones. Here the elongated depositions of clay detected at Ditch 1 in Santa Vitória can be included, alongside the horizontalized laid 'cloaks' of ceramics, miniature stones and faunal elements identified in the central area of Perdigões, but also in Ditches 8 and 12. However, if in broad terms these depositions serve as a spatial marker for new biographic moments and as dividers that end the previous depositional behaviours, they do not seem to have a long-lasting action in the landscape, since they are usually followed/covered by other deposits, and do not seem to significantly shift the type of practices that follow it. In this sense, even with some common ground, due to the unclear nature of these and the previously presented practices, they were not considered or included in the specific petrification phenomenon discussed in this study. Nevertheless, what they highlight is that throughout Late Prehistory in southern Portugal there are different ways of 'petrifying' (in the sense of marking space), even without making exclusive use of stones.

These different expressions likely served as the cultural matrix that led to the late 3rd millennium BC petrifications, in a possible act of cultural appropriation of a previously existing practice. If those same communities used and perhaps gave new meanings to previous structures, the same might be theorized for the act of petrifying, assigning it a new role as a combative practice.

Ultimately, the petrifications serve as a small window to a time when the Chalcolithic communities seemed to be struggling to maintain the *status quo*, with clear attempts to reconnect with their more intangible past, bringing it to action. A swan song that, according to the existing records, did not prevent the profound social and spatial metamorphosis that followed, leading, it seems, to the loss of Neo-Chalcolithic knowledge.

What if...? Alternative readings for the petrification phenomenon

Archaeology, given its fragmented record and inherently social nature, allows for significant flexibility in interpreting past communities. This is also true for this research, where the presented hypotheses mainly focus on the possible role that the petrifactions could have, and how they might reflect an attempt to maintain the then current traditions. However, other valid intentions may also exist, such as the possibility that petrifications might aim to mark a clear break by metaphorically destroying and erasing previous practices and structures, thus preventing their accessibility and use in future narratives.

Forgetting and destroying are often perceived as intrinsically negative and violent concepts, mostly connected to societal declines and collapses. However, this connotation reveals more about our current societal prejudices than those of past communities, where the meaningful segmentation, amortization and destruction of materials and architectures seem more common.

Intentionally forgetting is a social behaviour that is well documented both ethnographically and archaeologically (*Connerton 1989; Kelly 2015; Bernbeck* et al. *2017; Valera* et al. *2019; Van Dyke 2019*). It is neither a linear nor a straightforward process, making it challenging to interpret and detect archaeologically. Generally, it materializes a complex struggle between materials, contexts, and practices that persist in the shared social consciousness and those that can be forgotten (*Forty, Küchler 1999*) or intentionally conceal-

ed and destroyed (*Hanson 1998; Van Dyke 2019*). Some of these dynamics occur organically, due to structural amnesia or natural oblivion (*Connerton 1989*). However, there are also phenomena of deliberate forgetting through planned events of destruction, often taking place at mnemonic sites (*Connerton 1989; Hanson 1998; Kyle 2015; Hadad 2018; Van Dyke 2019*).

These events likely functioned as memory management mechanisms, shaping the collective memory of past communities (*Connerton 1989; Kyle 2015; Hadad 2018; Van Dyke 2019*). They might also have also served as coping strategies to maintain social cohesion by selectively addressing uncomfortable occurrences, thus transforming them (*Freud 1914; Connerton 2008*). The intentional destruction of materials, monuments, or other mnemonic devices can, as such, reflect a deliberate effort to erase only specific memories or, on a broader scale, larger historical narratives (*Connerton 1989; Holtorf 2006*), thereby fabricating an artificial social memory (*Yates 1966*).

These socially powerful practices might initially seem intangible, but have become quite palpable in recent years through the social re-evaluation of colonial narratives. Colonial monuments have been questioned and, in some cases, destroyed, as a part of a broader movement to reassess and 'rectify historical injustices' (*Nora 1989; Bhaba 1994*). This is part of a larger ongoing trend, where societies actively engage in the process of reinterpreting their past, not only questioning physical expressions, but also critically reviewing the values and narratives these monuments represent. This is a conscious effort to reclaim history and align public spaces and collective memory with current ideals of justice and equality – a clear demonstration of how collective memory is continuously being constructed, renegotiated and reshaped in response to contemporary stimuli.

Ultimately, what these interactions between remembering and forgetting underscore is the fluidity of collective memory, illustrating how it evolves over time so that it can reflect the active perspectives of communities, involving a selective process of emphasizing certain events while downplaying others (*Halbwachs 1992; Nora 1989; Bhabha 1994; Assmann 2011*). This dynamic sometimes includes the physical destruction of remnants from the past.

Applying these insights to petrifications, it can be suggested that the stone agglomerations might correspond to the fragments of memory management events that metaphorically destroyed realities whose agency no longer aligned with ongoing narratives. Similar to the re-evaluation of colonial monuments, petrifications may have function as symbolic acts that challenged existing beliefs and questioned the relevance of previous practices, structures and identities (*Nora 1989; Halbwachs 1992; Bhabha 1994; Assmann 2011*). Archaeologically, dismantled structures, particularly huts, are known in the region under study (*Valera* et al. *2019*), reaffirming the conception of petrification events not as independent, but instead as connected to other memory management processes (*Valera*, *Basílio 2023*). Could condemnation practices, through dismantling, be occurring outside the ditches, with the remains being used to form the stone agglomerations? If so, there would be a differentiation between the stone agglomeration from Perdigões Cairn and the other depositions, the first ending a specific and orchestrated sequence (*Basílio, Cabaço 2019*) and the other ones with more versatile, and possibly periodical, functions (*Valera*, *Basílio 2023*).

By allowing communities to engage in such dynamic processes of remembering and forgetting (*Van Dyke 2019*), particularly within the final stages of the 3rd millennium BC, there is room for the emergence of counter-movements (*Bernbeck* et al. *2017*). These movements can utilize the same physical realities – the petrifications – not as signs of destruction and forgetting, but as preservation tools (*Hadad 2018*). In this line of thought, petrifications become artefacts that might not only challenge dominant narratives, but simultaneously preserve earlier traditions, structures (by including their remnants) and identities, embodying a choice to preserve aspects of cultural heritage that might otherwise be erased or overshadowed.

The processes of creating petrifications could also offer valuable insights into understanding this phenomenon. Hypothetically, considering the social role inherent to construction endeavours, petrifications might have been the result of a collective effort, where each stone could have been placed by a member of the community. While speculative with regard to the contexts examined in this study, ethnographic examples from indigenous cultures of the Americas illustrate similar rituals behind the creation of ceremo-

nial cairns throughout North America. In these contexts, the construction of such structures was not merely about the final form, but also about the construction process itself. Each stone would be placed in the agglomeration by a different member of the community, representing a profound symbolic gesture of participation and integration (*Chartkoff 1983*), affirming the individual's connection to the communal identity and belief systems (*Butler 1946; Muller 2003*). Among the Native American cultures, the act of adding a stone to a ceremonial cairn represented a moment of purification and spiritual cleansing, reinforcing the shared narratives and historical continuity (*Butler 1946; Chartkoff 1983; Muller 2003*).

If petrifications were indeed created through similar participatory memorialization rituals, they could be read as synecdoches that encapsulate the profound interplay between the individual and the collective within prehistoric societies. In the hypothetical scenario, where each stone is placed by a member of the community, petrifications transcend their physical form to symbolize the entirety of communal identity and memory (*Muller 2003*), with an even greater symbolism if the stones were from a previously existing structure. Each stone, individually contributed by a community member, becomes a microcosm of the group's collective history, beliefs, and aspirations. As these stones aggregate into larger structures, they metaphorically represent the amalgamation of individual narratives into a unified whole – a living testament to the shared experiences and values of both the present and the past (*Heidegger 1927; Merleau-Ponty 1945*).

This participatory aspect of petrifications underscores their potential to endure as markers of communal identity, resisting the pressures of societal change and ensuring the perpetuation of cultural practices and beliefs across time (*Tajfel 1979; Moscovici 1984*). They embody the dual nature of individual agency and collective identity, serving as tangible expressions of cultural continuity, social cohesion, and historical consciousness. This challenges the traditional narratives that are generally used in the study of prehistoric communities. These groups appear to be forging new paths by manipulating and shaping the past, possibly in response to the ongoing shifts in their contemporary world (*O.c.*). Therefore, far from being static monuments, and regardless of their interpretation, petrifications stand as vibrant testaments to human resilience.

Final remarks

The late 3rd millennium BC petrifications from southern Portugal have proven to be a multifaceted and complex set of structures, challenging conventional interpretations with their diverse and possibly ambiguous roles, but mostly complementary. These non-funerary agglomerations, which manifest as recutting infillings and a single cairn, are characterized by the use of locally available stones in sites where stone structures are not extremely abundant, and include a reduced number of artefacts (but generically in line with materials from other contemporaneous contexts). They have been found in mnemonic sites across southern Portugal, mostly connected to gathering events, like the ditched enclosures of Perdigões, Santa Vitória and Bela Vista 5. Based on the available data, their function/action appears more closely connected to their symbolic capacity, rather than any practical purpose.

On one hand, they could be seen as tangible expressions of cultural continuity and resilience. They can embody deliberate social efforts to preserve and perpetuate collective traditions and memories, serving as a tool to resist profound social and spatial transformations (*Silvano 2010; Erdinç 2023*). On the other hand, they may also represent acts of intentional social forgetting, where communities selectively obliterated past traditions to construct new social realities (*Connerton 1989; Van Dyke 2019*).

This dual possibility underscores their possible role in shaping and reshaping collective memory within the late 3rd millennium BC (*Nora 1989; Halbwachs 1992*), serving as ideological proxies for the ongoing socio-political dynamics and transformations, with the cairn appearing to be more connected to the ending of what seem to be specific and orchestrated practices in a feasting event (*Basílio*, *Cabaço 2019*).

Nevertheless, the limited number of radiometric studies across these sites prevents the establishment of a more comprehensive interpretation. Expanding the radiocarbon sampling would make it possible to clarify the tempo of this phenomenon, particularly the diachronic sequence of the opening, filling, and subsequent petrification of ditches. So far, and based on the current data, it seems that petrification might have corresponded to the last stages in the biography of the focal sites and contexts, prior to their abandonment as possible gathering sites.

Ultimately, the study of these petrifications challenges, with the available information, the static interpretations of such architecture and emphasizes the agency that these communities had in shaping their histories (*Kelly 2015; Bernbeck* et al. *2017*). It shows that even the study of seemingly smaller phenomena, which are quite difficult to be fully aware of while excavating, like petrification, provides insight into how ancient human communities navigated change, negotiated continuity, and constructed social and identitarian meanings. In the end, neither of these processes led to the temporal maintenance of the related communities, rendering such petrifications into marks of a significant shift that culminated in the stratified societies of the southern Iberian Bronze Age.

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Chalcolithic stamp seals from Tepe Gheshlagh, and a look into their application in ownership and exchange systems

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ABSTRACT – *Tepe Gheshlagh is one of the major sites with deposits of the Chalcolithic period in the east of the Central Zagros. The central question in the present study was the administrative system and ownership in the Chalcolithic period. With a descriptive-analytical method, an attempt was made to expound on Gheshlagh's glyptic assemblage that attest to the existence of an ownership system and commercial exchanges. A structural analysis of the glyptic iconography suggested that each of the linear, circular, or repeating patterns were less mere personal insignias intended to exclude the possibility of alteration or forgery than they were marks belonging to a pre-literate system where each sign/symbol stood for individual commodity types that were transported or exchanged as such. At the same time, the composition of these widely varying geometric motifs followed certain conventions.*

KEY WORDS – *Chalcolithic; stamp seal; cylinder seal; Central Zagros; Tepe Gheshlagh*

Bakrenodobni pečatniki iz Tepe Gheshlagh in njihova uporaba v sistemih lastništva in izmenjave

IZVLEČEK – *Tepe Gheshlagh je eno najpomembnejših najdišč bakrene dobe na vzhodnem območju osrednjega Zagrosa. Ključni raziskovalni vprašanji naše študije sta organizacija administrativnih sistemov in koncept lastništva v tem obdobju. S pomočjo deskriptivno-analitične metode podrobneje obravnavamo zbirko pečatnikov iz Gheshlagha, ki dokazujejo sistem lastništva in trgovinske izmenjave. Strukturna analiza ikonografije pečatnikov kaže, da linearni, krožni in ponavljajoči se vzorci niso bili zgolj osebni simboli, namenjeni preprečevanju ponarejanja ali spreminjanja, temveč so predstavljali znake v okviru določenega sistema pred vpeljavo pisave. Vsak znak ali simbol je verjetno označeval določeno vrsto blaga, ki se je prenašalo ali izmenjevalo. Kljub veliki raznolikosti geometrijskih motivov je njihova sestava sledila določenim konvencijam, kar nakazuje na standardizirano vizualno komunikacijo v skupnosti.*

KLJUČNE BESEDE – *bakrena doba; pečatnik; valjast pečatnik; osrednji Zagros; Tepe Gheshlagh*

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Introduction

As a highly prized category of the vestiges of prehistoric cultures that are rather infrequent in the archaeological record, glyptics evince trade and cultural interactions with other regions. In the 5th and early 4th millennia BC, the Central Zagros was pivotal to the regional and cross-regional trade given its location on the Great Road. The Late Chalcolithic period is believed to mark the onset of complex societies and chiefdoms, especially in Upper Mesopotamia and Anatolia, and the Near East is a major region as regards fundamental changes in social hierarchy (*Lovell, Rowan 2011; Matthews, Fazeli Nashli 2022*). In Mesopotamia, sealing is first attested in the Neolithic period (*Akkermans, Kim 1996; Denham 2013*), and various elegantly and skilfully engraved iconographies occur on glyptics (*Atakuman 2013; 2015*). Functionally speaking, apart from indicating ownership, seals and their imagery served as a primeval means of communicating information from one place to another, especially in preliterate societies (*Tala'i 2013.1*). Before writing was first developed in Mesopotamia in the late 4th millennium BC, a variety of objects were used to store information. The thousands of years preceding writing provide us with archaeological examples of precursors to writing, such as tokens, stamp seals, cylinder seals, and stone and sherd disks (*Costello 2011*). The practice of sealing would come into vogue from the Bronze and especially the Iron Ages onwards, demonstrating the turning of modest rural communities into the developed urban centres and complex societies of the 3rd millennium BC. The Chalcolithic period saw the popularity of sealing movable containers to safeguard their contents when stored in warehouses or sent as exports to other places. Such a system involved entrusting the consignment to a person or persons responsible for making a safe delivery to the destination, hence its being deemed part of a socio-economic system (*Alizadeh 1993.40*).

Excavations at Gheshlagh uncovered long-lasting occupation levels dating to the mid- and late Chalcolithic (*Sharifi, Motarjem 2014; 2018*). Some most conspicuous artefacts from Gheshlagh are a number of seals of various forms and clay sealing from the late Chalcolithic contexts dated to 3850±280/3600±220 cal BC. The types and functions of these glyptic objects will be addressed in this paper. Gheshlagh's glyptics hint at record keeping as well as private ownership. They find close parallels at Giyan (*Contenau, Ghirshman 1935*), Seh Gabi (*Henrickson 1988.9*) and Hissar (*Schmidt 1937*) as well as in Mesopotamia (*Gurdil 2005; Peyronel, Vacca 2020*) and on the Central Plateau such as Sialk (*Vidale* et al. *2018.32*), Ghabristan (*Madjidzadeh 2008*) and Tepe Sofalin (*Hessari 2017*).

A one of a kind 'quasi-cylinder' seal from Gheshlagh represents a rare example that may furnish insights into the transition from the stamp seal to the cylinder seal (for more information see *Matthews* et al. *2025*). Being among the earliest evidence on ownership across the region, the assemblage from this site points to an administrative system in the late 5th and 4th millennia BC (*Freikman, Garfinkel 2017*). The small community of Gheshlagh, thanks to its assemblages of glyptics and tokens (for the latter see *Motarjem, Sharifi 2015*) gives to us the very first indications of social complexity on the eastern slopes of the Central Zagros. In what follows, the glyptic material from Gheshlagh is introduced in an attempt to expound on its cultural attributes (Tab. 1).

Research questions

The central questions are as follows: What are the cultural characteristics of Gheshlagh's glyptics? And is it possible to propose a thematic relation to personal identity and administration, or were they intended to serve a different purpose? In our view, purposes other than administration and trade are unlikely.

Research method

Linear drawings of the iconography on the seals and the sealing from Gheshlagh were prepared before a comparative study was embarked on with the glyptic assemblages from coeval sites in Iran, Anatolia, and Mesopotamia.

History of research

Using seals in trade and ownership contexts marks a trailblazing achievement in human history. As trade tools, ownership markers, and apotropaic items, seals have always sparked interest in all cultures, which have recorded on them their thoughts and ideas via engraved imagery (*Lovell, Rowan 2011; Matthews, Fazeli Nashli 2022*). By categorizing and analysing the applied iconography, the glyptic stylistics of each individual period enable us to pin down the main reasons behind the creation of those visual images and, thereby, the interactions and reciprocal influences of different cultures (*Motarjem 1997.56*). The earliest seals were made from clay (*Gorelick, Gwinneth 1981.18*), and an examination of the material and cognitive properties of sealing practices and the changing functions of seals

in their transition from personal amulets to a means of labelling mass-produced goods helps to unpack the interlocking (pre)histories of quality control, authenticity, and ownership that make up the modern brand (*Wengrow 2008.7*).

In parallel with their use as amulets, the development of trade seals began in the Middle East. The earliest attestations of sealing arise in the late Neolithic Mesopotamia in the 6th millennium BC (*Buchanan 1967.265*) and spread out in the Chalcolithic period (*Bader 1993; Akkermans, Kim 1996; Schmandt-Besserat 1999; Carter 2010; Denham 2013*). A total of about 2000 sealings from Arslantepe provide copious and complex evidence on trade interactions in the Near East (*Marro 2010; Stein 2012*). The practice of sealing in the Balkan region was mainly inspired by that in Anatolia (*Budja 2003.117*). Rather few glyptic assemblages are currently known from earlier contexts, despite the fairly extended excavations in Iran. From Tepe Giyan come seals dating back to the Early Chalcolithic (*Contenau, Ghirshman 1935*). Stamp seals are known from the necropolises of Hakalan and Parchineh (*Haerinck, Overlaet 1996*), as are several examples marked by geometric patterns from Se Gabi (*Henrickson 1988.5*). As regards northeastern Iran, Tepe Hissar produced square and circular stamp seals with knob handles (*Schmidt 1937*), and clay sealings are reported from Tepe Khalese in Zanjan (*Valipour* et al. *2013*). At Tepe Sialk two stone seals of a mid-Chalcolithic date (4000/3700 BC) were recovered (*Vidale* et al. *2018.32*).

Regional trade in the Chalcolithic period

In Mesopotamia, the Chalcolithic period unfolded in the early 5th millennium BC. Marking a shift from small agricultural settlements to larger centres, the period is typified by technological advances, including advanced pottery making and copper metallurgy, and broad long-distance trade networks (*Sharp, Kaercher 2018*). The ubiquitous presence of obsidian is evidence of trade in numerous localities, as at Gheshlagh, where a large assemblage was found originating from the Lake Van Basin, Nemrut Dağ, and Meydan Dağ (*Saed* et al. *2023*). The question of trade ties between Iran and Mesopotamia has long been the subject of inquiry (*Algaze 1989; Potts 1993; Matthews, Fazeli 2004; Sharp, Kaercher 2018.233*). Beginning in the 6th millennium BC during the Halaf period (*Henrickson 1983; 1986*), such ties would continue in the 5th and 4th millennia BC, seemingly through the Great Road and the intermountain valleys and passes of the Zagros massif

Level	Period	Date (BC)
Gheshlagh I	Iron age III	800 BC
	Gap I	
Gheshlagh II	Late Bronze age	1600 BC
	Gap II	
Gheshlagh III	Late Chalcolithic	3600±220
Gheshlagh III	Late Chalcolithic	3850±280
Gheshlagh IV	Pisdeli/ Ubaid period	3915±270
Gheshlagh IV	Pisdeli/ Ubaid period	3960±290
Gheshlagh V	Early Chalcolithic (Dalma)	5000±305
Gheshlagh V	Early Chalcolithic (Dalma)	5500±250

Tab. 1. The stratigraphic sequence of Tepe Gheshlagh.

(*Sharp, Kaercher 2018.233*). Archaeological evidence points to ongoing extensive contacts from the Chalcolithic and the Bronze Age onwards between Upper Mesopotamia and the highlands of northwestern Iran (*Danti 2014a; 2014b; Zettler, Danti 2017a; 2017b; 2017c*).

Several major highways linked Mesopotamia and the Central Zagros. The most important of these, labelled as the Great Khorasan Road by Muslim geographers, ran from Mesopotamia to the Zagros region and whence to the central Iranian plateau and Central Asia, and has retained its prominence even today (*Henrickson 1983; 1986*). This ancient highway of the Central Zagros has been a focus of scholarship and was crucial to the cultural and environmental settings shaping regional civilizations (*Henrickson 1983.33; Levine, Young 1986.15*). Another noteworthy point is the indispensable role of geography in the natural environment of archaeological sites, as each region features distinct peculiarities that manifestly affect the spatial distribution of the sites, among them being the extent of tillable land, rainfall, temperate climate, fertile soil, average temperature, altitude, water resources, vegetation, and fuel resources, which combine to determine the carrying capacity (*Alden 1982*). One form of archaeological evidence for trade exchanges is the advent of the practice of sealing. Seals, sealings, and clay tokens deposited in the 5th millennium BC in from Tell Abada and Tell Brak contexts signal a growing social complexity (*Jasim, Oates 1986*).

Tepe Gheshlagh and personal ownership and trade in the eastern flank of the Central Zagros

Located on the River Talvar of the Sefid Rud Basin in Bijar County, Kurdistan Province (Fig. 1), the excavations at Tepe Gheshlagh brought to light a Chalcolithic site in the highlands stretching between the eastern

Central Zagros and the southern Lake Urmia region (*Sharifi 2023*). However, the already inferable cultural interactions of these two regions were yet to be backed by the recovery of any intermediary sites. Kurdistan Province and Bijar are lesser-known regions that, in light of the cultural evidence at hand, maintained contacts with remote regions. Fieldwork at Tepe Gheshlagh unearthed a surprisingly thick, over 14-metre deep, deposit representing different phases of the Chalcolithic period. Divided into five subperiods, the lowest deposit marks the Dalma culture, while the Godin VII material characterizes the uppermost level of the Late Chalcolithic, which is followed by a hiatus interrupted by the Late Bronze occupations, which in turn would give way to the Iron III settlements in the wake of a second break, providing a broader cultural sequence spanning at least two millennia for the eastern slopes of the Central Zagros (*Motarjem, Sharifi 2014; Sharifi, Motarjem 2018*). A complete continuity of settlement is attested in the Chalcolithic period. As regards cultural interactions, the Talvar Valley in 5500 BC possessed all the environmental factors that enabled permanent settlements on Tepe Gheshlagh (*Motarjem, Sharifi 2014; Sharifi, Motarjem 2018*). Gheshlagh is a trans-regional centre with both local and cross-regional contacts and ties. The glyptic objects from the site come from the late Chalcolithic contexts that in terms of other finds tally with the Godin Period VII, and were associated with the characteristic red-slipped ware and applied handles. Moreover, absolute dating places the pertinent contexts in 3850±280/3600±220 cal BC (*Sharifi 2020*). Nonglyptic small finds from the site show close affinities to the Central Zagros and strong inspirations from the Mesopotamian cultures (*Hall, Woolley 1927; Lloyd* et al. *1945; Kirkbride 1972; Jasim 1983; Oates 1983; Henrickson, Vitali 1987; Merpert, Munchaev 1987; Hijjara 1997; Stein, Alizadeh 2013; 2014*). Thus, rather unsurprisingly, the glyptics are closely paralleled in the coeval assemblages from both Iran and Mesopotamian. Such correlations were presumably communicated through the Great Road. The small, narrow valley of Talvar as a natural corridor connects parts of the eastern Central Zagros with the highlands and steppes encompassing the southern Lake Urmia Basin, and lies on the main route and close its arteries. Proximity to the Great Road possibly offered certain prerogatives to the nearby communities, among them being trade exchanges.

Gheshlagh's glyptics

The glyptic assemblage from architectural remains of Gheshlagh consists of five stamp seals, a quasi-cylinder seal, and a sealing as well as a fragmentary 'stamp' patterned in the linear style. The pieces are invariably made of terracotta, bearing a buff or grey slip. Deriving from a Late Chalcolithic context (Loc. 303), all were recovered from a refuse pit (Fig. 2), except the quasi-cylinder that lay within a bin. The seals split into several morphologies: square with a handle, rectangular with a handle, conical, amygdaloid, flat/stamp, quasi-cylinder, and lentoid.

Stamp seals

Seals 3 and 4 have a knob handle with a lanyard hole above the square flat side, which is patterned with parallel diagonal lines that form either a repeating chevron pattern, Seal 3, or a symmetrical quadrants, Seal 4 (Figs. 3–4). The conical specimen, Seal 5, shows another geometric design (Fig. 5). In the amygdaloid Seal 6 (Fig. 6), the design is longitudinally bisected by a central carved band flanked on both sides with engraved chevrons. Seal 7, a broken lentoid stamp, has a rather complicated design that makes it stand out from the entire assemblage. Here, the concentric circular panels outlined by patterned bands are spotted with irregularly positioned circles (Fig. 7).

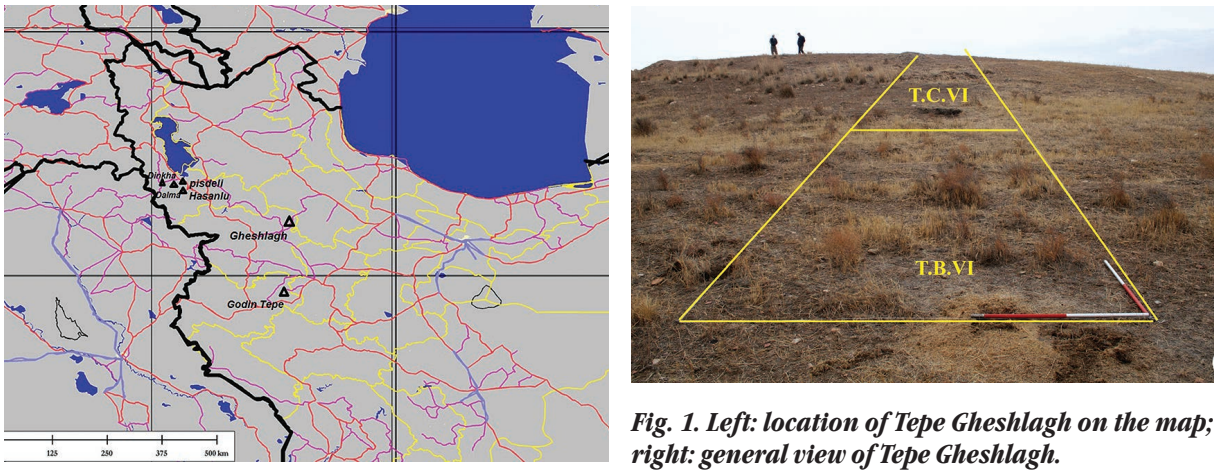


Fig. 1. Left: location of Tepe Gheshlagh on the map; right: general view of Tepe Gheshlagh.

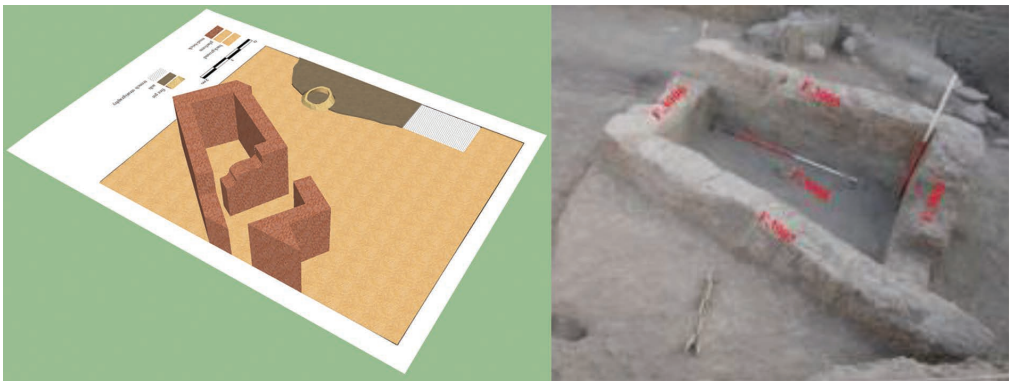


Fig. 2. Tepe Gheshlagh: findspot of the quasi-cylinder seal, Level III, Phase II.

Quasi-cylinder seal

With the key peculiarity of the geometric patterns engraved on the convex matrix (tubular body), this unique piece (Fig. 8) was probably a forerunner of later real cylinder seals. The local inhabitants had presumably a fleeting knowledge of the Mesopotamian cylinder seals of the Ubaid period, as is evidenced by a few examples of Ubaid-type pottery (*Sharifi 2020. 207–208*). The Gheshlaghi artisans perhaps wished to copy cylinder seals, yet the attempted replicas proved to be rather smaller than those commonly used in Mesopotamia and Susiana. Note that the cylinder seal was yet to become popular in the post-Late Chalcolithic and even Bronze Age Iran, and continued to be a mainly Mesopotamian phenomenon until it came into popular use in the first millennium BC and the Achaemenid period (*Motarjem 1997*). The considerably increased surface area for engraved marks compared to the stamp seal is thought to have been the main reason behind the origination of this new glyptic form.

Sealing

The sealing from Gheshlagh, impressed with a stamp seal and excavated from a Late Chalcolithic context, once sealed a jar. The impression is divided into four equal panels, each of which are decorated with parallel carved lines (Fig. 9). Weighing four grams, an interesting thing about this piece is that the clay it is made from is entirely different from the resources across the whole Talvar region. The fine-grained texture of this greyish clay appears to be of a Mesopotamian origin, given the absence of such soil from the Talvar Valley, where the micaceous soil tends to be red in colour. With this observation hinting at an extraneous provenance, one may expect to find evidence of extended trade relations in the region.

Fragmentary stamp seal

Clay objects, either unbaked or baked, form a significant part of the cultural material in the Chalcolithic deposits at Tepe Gheshlagh. For the large parts, such objects, including various figurines, tokens and indeterminate pieces, derive from the ash and refuse deposits of Level III. Setting standardized criteria for measuring daily life affairs appears to have been a basic need societies had to tackle before social complexities started to emerge. This became all the more important when the economy began to shift from subsistence to 'commercial' production.

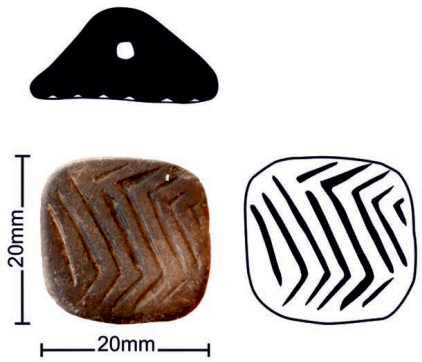


Fig. 3. Tepe Gheshlagh: Seal 1, with a handle and a chevron pattern.

Fig. 4. Tepe Gheshlagh: Seal 2, with a handle and quadrants carved from different angles.

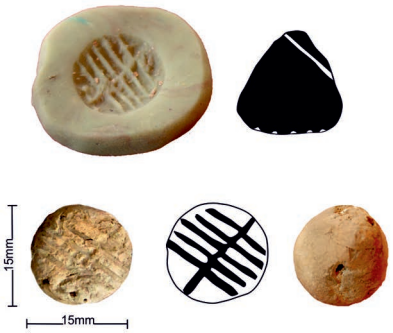


Fig. 5. Tepe Gheshlagh: conical seal.

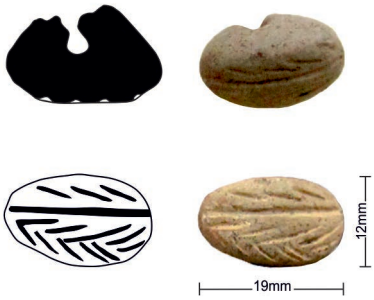


Fig. 6. Tepe Gheshlagh: amygdaloid seal with a geometric design.

Fig. 7. Tepe Gheshlagh: lentoid seal with a carved pattern.

The assemblage of small finds from Tepe Gheshlagh contains a fragmentary crescent-shaped clay stamp seal that bears a series of indefinite horizontal lines carved while the clay was leather-hard (Fig. 11). This piece can be interpreted as a sort of tally scored with geometric marks, which was used alongside and at the same time as the other seals and tokens. Thus, it can be interpreted in relation to the use of seals in trade exchanges. As with those on the items in the rest of the assemblage, the design consists of engraved lines, and finds parallels in later periods (*Schmandt-Besserat 2013*). Most scholars working on tokens have established a direct relationship between these counting tools and the subsequent emergence of writing (*Schmandt-Besserat 1992.6*). As is clear from Figure 11, the patterns making up these glyptic designs allow us to argue for a proto-written system, which in turn will evince trade exchanges.

Comparanda from neighbouring regions

Glyptic evidence points to trade interactions, and thus social complexity. The Late Chalcolithic material from Gheshlagh finds close parallels in the glyptic assemblages from other regions, indicating that regional and trans-regional ties prevailed at the time. For example, a similar square form (Seals 1 and 2) is known from Tepe Hissar in northeast Iran (*Schmidt 1937.Pl. XV*). Earlier evidence (Figs. 12–13) occurs at Domuztepe in Anatolia (*Carter 2010.Fig. 5:168; Denham 2013.75*), and at Tell Halaf with geometric patterns and a pierced handle for suspension (*Frangipane 2007.Fig. 4*). Such handled square seals were also in use at Arslantepe (*Frangipane 2016.12*).

The following studies include non-glyptic, simple conical clay objects (in addition to tokens) from these sites, Sarab and Çayönü, Hajji Firuz Tepe, Ekşi Höyük and near eastern regions (*Voigt 1983; Broman-Morales 1990; Schmandt-Besserat 1992; Bennison-Chapman 2014; Palka 2021; Niemi 2019; Yeşilbaş 2024*).

In the prehistoric glyptic art of Mesopotamia and Iran (*Voigt 1983.258*), geometric patterns are the most

Fig. 8. Tepe Gheshlagh: quasi-cylinder seal.

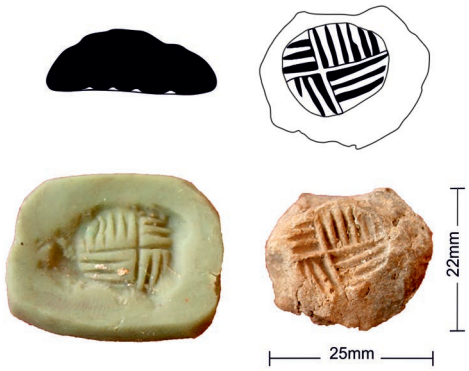


Fig. 9. Tepe Gheshlagh: sealing impressed with a stamp seal and excavated from a Late Chalcolithic context.

Fig. 10. Tepe Gheshlagh: seals from different views.

popular. In Iran, stamp seals with such designs have been reported from Tepe Giyan and Tall-e Bakun (*Langsdorfe, McCown 1932.Pls. 80–81*), and Chogha Mish (*Alizadeh 2008.Pl. 22*). The conical instance from Gheshlagh is paralleled at the Ubaid period site of Tell Zeidan in Syria (*Stein 2009.Fig. 11:131*). Similar examples equally marked with geometric designs occur at Çatalhöyük (*Wickede 1990.Abb. 24*), and in eastern Anatolia (*Gurdil 2005.347–348*).

With regard to Gheshlagh's sealing, an identical piece is known from Tepe Kalnan of Bijar (*Saed Mucheshi 2011.drawing 48*). Closely related instances come from the cemetery of Domgar (Parchineh) (*Vanden Berghe 1975.Fig. 9*) and further afield from the Ubaid period in Anatolia (*Gurdil 2005.348*). Comparanda for designs are attested in the glyptic collections of Se Gabi (*Henrickson 1988.5*), Hissar (*Schmidt 1937.Pl. XV*), and Giyan (*Contenau, Ghirshman 1935*).

Hence, the recorded material culture indicates extensive contacts during the focal periods with Mesopotamia, as is evidenced by both pottery (*Sharifi 2020. 207–208*) and glyptic comparisons.

Discussion

The period between the late 6th to early 5th millennia BC marked a new chapter of trade contacts and interactions with the arrival of sealing. Apart from securing property ownership, the sealing applied to goods, jars and other receptacles represented a sort of owner's signature (*Bayani 1973*).

Sealing in the Iranian plateau is most probably a practice of Mesopotamian derivation. An inquiry into the functions and contexts in which seals emerged will touch on complex issues with regard to the dynamics of glyptic art and the role that sealing played in the advance of preliterate societies in prehistory (*Tala'i 2013.36*). It should be admitted that the practice of sealing was invented and appreciated in village societies. The developments of the Village Period (the potter's wheel and metallurgy, *inter alia*) heralded incipient social complexities and chiefdoms, and steered village communities towards complex social and economic structures (*Tala'i 2013.71*), which called for record keeping and ownership marking. An increasingly growing trend culminated in the mid-4th millennium BC with the rise of the urbanized civilization and novel economic relations in the face of which the earlier stamp form proved inefficient, hence the superseding of the cylinder seal (*Moore 1940*). While the real reasons prompting this shift will continue to elude us, the larger surface of such seals, and thus ability to convey more information, was likely a deciding factor. Indeed, apart from seals' practical use in trade processes, their designs perhaps also communicated information on the owner's economic status and background (*Tala'i 2013.72*).

Regarding the geographical distribution of sealing practices, while in the Halaf period it was basically a prerogative of Upper Mesopotamia (*Carter 2010*), seals are fairly popular at the Chalcolithic settlements across Iran, assemblages from which share great resemblances (*Contenau, Ghirshman 1935; Haerinck, Overlaet 1996*). Morphologically, the seals from Gheshlagh tend to be either square with a handle or conical, with their flat side bearing engraved geometric designs, while the late Chalcolithic glyptic material from Upper Mesopotamia is dominated by animal figures in relief (*McMahon 2016.171*).

What is at stake in the present study is the possible correlation between a certain design iconography and a given trade item. In other words, we are trying to find an answer for the question of whether seals with similar designs were reserved for a specific category of commodities, as was the case with tokens where each form-factor represented a distinct item (*Schmandt-*

Fig. 11. Tepe Gheshlagh: fragmentary stamp seal.

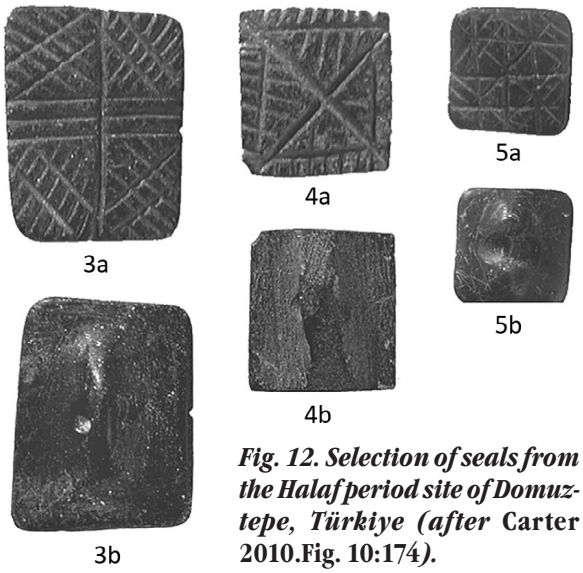


Fig. 12. Selection of seals from the Halaf period site of Domuztepe, Türkiye (after* Carter 2010.Fig. 10:174*).

Besserat 1992.6). It is argued here that, as with clay tokens, seals were possibly item-specific, in the sense that those with structurally the same design were likely applied to a single category of goods. For instance, Stamp Seal 2 and the sealing (No. 7) from Gheshlagh both bear designs consisting of motifs arranged in symmetrical quadrants. Considering the multiple related examples from other regions cited above, this particular design may convey a certain concept (*e.g.,* grains or livestock). The sealing in question, given its distinct soil type, was obviously once affixed to an imported item, while Seal 2 was presumably impressed on outgoing goods. It should be noted that the above tokens, which are linked by a similar function, are used in Schmandt-Besserat's token hypothesis to count or define the quantity of a good. At both centres, seals with the same design were possibly associated with the same item or service, and this might also be true for Seals 4 and 6.

Gheshlagh's regional and trans-regional contacts, fostered by its location on the natural corridor linking the three Iranian regions of the northwest, the Central Plateau and the west and going beyond Iranian borders, are clearly reflected in its material cultural, as we find unambiguous comparanda for the geometrically patterned designs in the glyptic assemblages from Se Gabi, Giyan, Hissar, and further afield in Mesopotamia and even Anatolia (Tab. 2). The climate and natural landscape of the region are quite similar to those of large parts of the nearby cultural spheres like the Lake Urmia basin to the northwest, the Zagros highlands, and Upper Mesopotamia. That is why the small finds from the site, including glyptics, reveal reciprocal impacts with the coeval cultures in such regions as Anatolia (*Denham 2013*) and the Halaf culture of Upper Mesopotamia (*Frangipane 2007*). It should be noted that the fragmentary stamp seal in linear style from Gheshlagh (Fig. 11) is as yet unreported from any other Chalcolithic context, though this patterning style was also widespread in Mesopotamian glyptics (*Englund 2006; Schmandt-Besserat 2009*).

Regarding the level of social and economic complexities, Gheshlagh held a privileged place in regional and cross-regional interactions, as is evidenced by the exotic Ubaid-type pottery and the profusion of obsidian items (*Saed* et al. *2023*). The widespread use of tokens of diverse types (*Motarjem, Sharifi 2015*) and seals testify to broad regional and long-distance trade ties. Furthermore, the uninterrupted sequence of respective occupations of the site covering a millennium, from the middle to the Late Chalcolithic period, is clear evidence of the relatively stable environmental and climatic conditions in the region. In was only in the Late Chalcolithic, *i.e.* the late Godian VII, that a change affected the distribution pattern of the regional settlements, probably due to the arrival in the region of bearers of the Yanik culture (Early Transcaucasian Culture). As result of this shift, most Chalcolithic centres were deserted, and the new sites began to form sparsely within the foothill belts.

Conclusions

Indications of a rise in the number of settlements during the 5th and 4th millennia BC are attested in surveys over most parts of western Iranian plateau, with the eastern flanks of the Central Zagros and the plateau's margins being no exceptions.

A remarkable recently excavated site in the region is Tepe Gheshlagh, which contains numerous evidence on trade ties with coeval centres, particularly in the

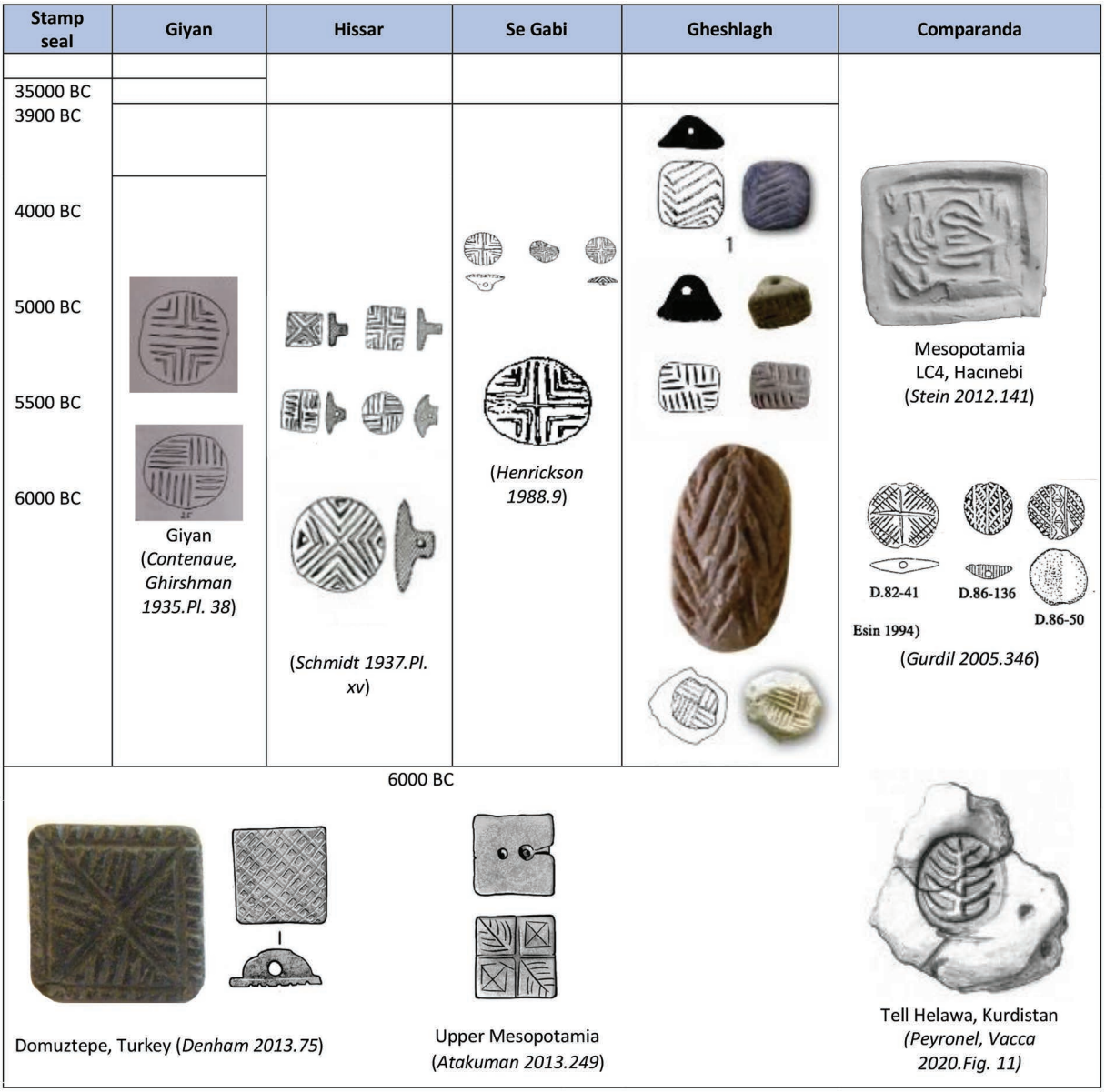
Fig. 13. Seals from Domuztepe (after* Denham 2013.75*).

Chalcolithic period, including various types of glyptics, Ubaid-type pottery, and an abundance of *in situ* tokens.

These all clearly indicate the significance of Gheshlagh as a major trade centre, to which many goods were probably directly imported via the regional exchange network. While reliable direct proof eludes us at the moment, some circumstantial evidence from the site, like the so-called Ubaid-type ceramics and an exotic sealing discarded in a refuse pit, hints at such a network.

The glyptic assemblage from Gheshlagh points to a kind of social stratification (personal ownership and an aristocratic class) and the rise of rudimentary forms of social and economic complexities. The material culture and the fairly long sequence recorded at Gheshlagh suggest promising conditions for human settlements in the region in the Mid-to-Late Chalcolithic, thanks to which the local inhabitants were able to attain initial social complexity.

Ties with regions as remote as Upper Mesopotamia are evident in the small finds, among them being a clay sealing. This piece was found to have been formed from a type of clay totally at odds with the known resources all through the Talvar region. Originating from an uncertain source in Upper Mesopotamia, the fine-grained texture and light grey colour of this sealing starkly contrast the micaceous and red soils of the Talvar Basin, suggesting that the exotic piece made its



Tab. 2. Comparanda and evolution of the designs of the stamp seals between the 6th and 4th millennia BC.

way to the site through trade. The quasi-cylinder seal from Gheshlagh might shed some light on the presently enigmatic transition from the stamp to the cylinder seal. Technically qualifying as a cylinder seal, similar pieces still remain unreported from any other region. The Gheshlagh glyptics bear geometric designs. Iconographical analysis of these designs revealed a certain pattern consisting of repeating symmetrical motifs that have been reported from multiple contemporary centres like Se Gabi, Giyan, Sialk, and Hissar. An interesting point about the geometric designs of the glyptic assemblages from Gheshlagh and the neighbouring regions is the shared iconography of several clusters of seals that bear closely related designs. Drawing on this observation, one may safely argue that seals with similar designs were dedicated to the same commodity all across a given trade network. This being the case, Tepe Gheshlagh furnishes the first evidence on social complexity in the focal period. All these are indications that Gheshlagh was the main administrative centre in the Chalcolithic period, engaged in intensive cultural and commercial ties. The claim is further supported by the large assemblage of obsidian items from the site. If a site's situation on a major obsidian trade route throughout the Village Period can be an acceptable measure of its prominence and central place as conceived of by nearby rural settlements, then the abundant obsidian pieces and the practice of sealing will bear testimony to the obvious location of Tepe Gheshlagh at the crossroads of trade routes that extended from northwest Iran through the foothills of the Central Zagros to Upper Mesopotamia.

Therefore, archaeological evidence indicates that Gheshlagh was not a simple but rather a complex society actively engaged in commercial contacts with northwest Iran and Anatolian regions on the one hand, and Mesopotamia on the other. This observation attests to the social and economic activities of the residents. Notwithstanding its location within a steppe, apart from trade, the site served as a hub for a series of ancient routes. Despite its limited extent, Gheshlagh's small community practiced commercial administration, and was in contact with the further eastern swathes of the Zagros and Mesopotamia. It was this regional centrality that made possible sustained occupations over an extended period of time, despite the severe pasture scarcity in the environs.

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Late Neolithic and Early Chalcolithic lids from Damyanitsa, southwestern Bulgaria

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ABSTRACT – *This paper examines 190 ceramic lids from the Late Neolithic (second half of the 6th to beginning of the 5th mill. BC) and Early Chalcolithic (first half of the 5th mill. BC) layers of the settlement of Damyanitsa in Southwest Bulgaria. Damyanitsa offers a range of lid types, allowing for a detailed typology and tracing their development from the Late Neolithic to the Early Chalcolithic periods. A detailed typological division is offered in order to facilitate comparisons with lids from contemporaneous sites in Bulgaria and within the broader context of southeastern Europe. The majority of the lids have small sizes with a base diameter of up to 15.0cm (89%). No significant differences in the shape and technology of lids are observed between the two periods. A particular type of lid, distinguished by its grooves, suggests that some of these lids may have been utilized for the purpose of sealing vessels for long-distance transport or storage of liquids or foodstuffs. The function of these grooves is to hold the lid to a specific vessel type, representing an evolutionary development in the functionality of the lids.*

KEY WORDS – *Late Neolithic; Early Chalcolithic; Damyanitsa settlement; Southwest Bulgaria; lids; storage of liquids and food*

Pozno neolitski in zgodnje halkolitski pokrovi iz Damjanice v jugozahodni Bolgariji

IZVLEČEK – *V članku preučujemo 190 keramičnih pokrovov iz pozno neolitskih (druga polovica 6. do začetka 5. tisočletja pr. n. št.) in zgodnje halkolitskih (prva polovica 5. tisočletja pr. n. št.) naselbinskih plasti v Damjanici v jugozahodni Bolgariji. Različne vrste pokrovov omogočajo podrobno tipološko analizo in sledenje njihovemu razvoju od poznega neolitika do zgodnjega halkolitika. Predstavljamo podrobno tipološko razdelitev, ki omogoča primerjavo s sočasnimi pokrovi v drugih delih Bolgarije in širše v jugovzhodni Evropi. Večina pokrovov je majhnih, s premerom do 15,0 cm (89 %). Med obema obdobjema ni opaznih večjih razlik v obliki in tehnologiji izdelave pokrovov. Posebni so pokrovi z utori, ki nakazujejo, da so morda služili za zapiranje posod za transport ali shranjevanje tekočin. Narejeni so za zapiranje določenih vrst posod in predstavljajo napredek v uporabi pokrovov.*

KLJUČNE BESEDE – *pozni neolitik; zgodnji halkolitik; naselbina Damyanitsa; jugovzhodna Bolgarija; pokrovi; shanjevanje tekočin in hrane*

Introduction

The Late Neolithic (approximately 5200–4900 BC) in the Balkans is marked by the initial experimentation with copper metallurgy (*Radivojević* et al. *2010*) and the development of new technologies, such as the graphitized surfaces as decoration of pottery (*Vandova 2004*). Towards the end of the 6th millennium BC, the number of settlements in the Struma Valley increased significantly. Large settlements emerged in proximity

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to the river on the second or third terraces (such as Damyanitsa and Topolnitsa). This emphasized a deep change in agriculture (cultivation of more fertile soil) and breeding system (dominance of cattle), followed by the increase in population (*Grębska-Kulova 2004.137*). These transformations may be indicative of and impact economic changes, including an increase in the scale of production and the necessity for the storage of larger quantities of food.

The lids are indicative of the level of food storage 'technologies', and storage is important in the study of scales of production (household organization of production). Better lids may reflect more advanced food storage technology.

Lids have been found in a significant number of settlements from the Early Neolithic to Late Chalcolithic across Bulgaria (Fig. 1).

The paper aims to examine in detail the Late Neolithic and Early Chalcolithic lids found on the prehistoric settlement of Damyanitsa (Fig. 1.6), and present their detailed typological and technological characterization and development during this time. The functional interpretation of a particular type of lids – with a groove – will also be presented.

Lids means better storage technology

With the cultivation of plants and the domestication of animals, the need for food storage increased. It is likely that perishable materials such as wood, hides, and fabric were used to cover and protect provisions from contamination, acting as a prototype lid. Several well-preserved wooden vessels with tight-fitting lids, representing rectangular and oval-shaped boxes, have been found at Çatalhöyük East, in buildings in horizons VIA and VIB, dated to the mid-7th millennium BC (*Mellaart 1967.Pl. 105–108; Cessford 2001.721, Tab. 3*). According to Keightly, the use of perishable cover materials is not a compromise on efficiency–such lids can provide an excellent seal (*Keightley 1987.110*) as well as aesthetic effect. The same author emphasizes that well-made lids, especially those that fit tightly to the mouth of the vessel, suggest care, careful storage, and

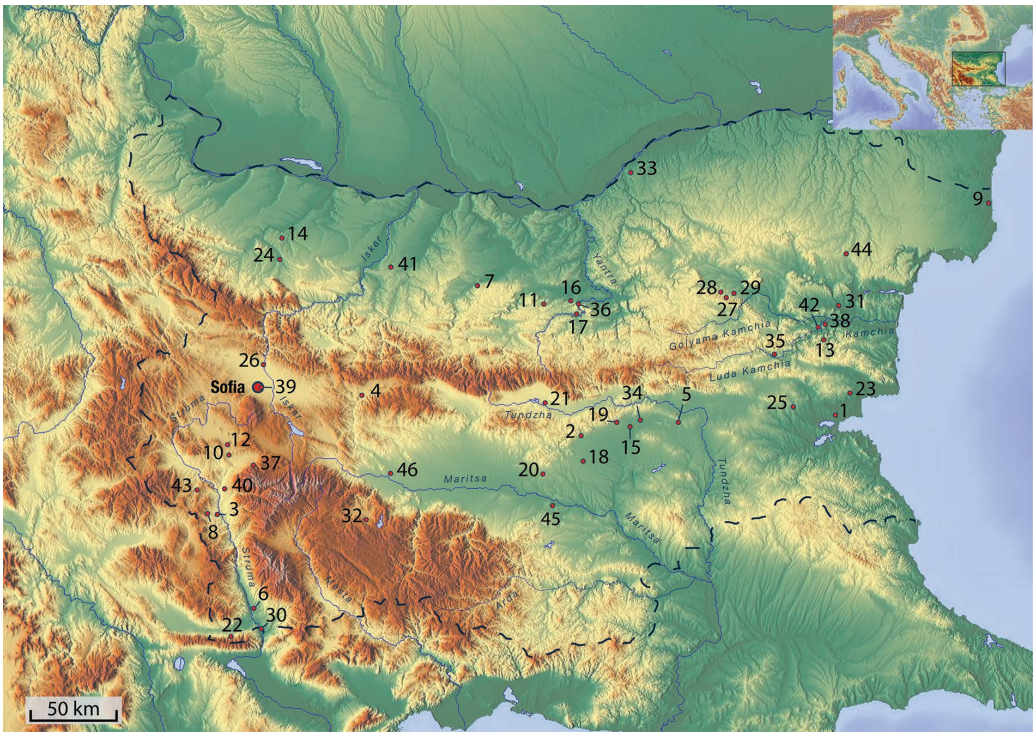

Fig. 1. Map of Neolithic and Chalcolithic sites from Bulgaria: **1** ***Atanasovsko Lake;*** **2** ***Azmashka Mound;*** **3** ***Balgarchevo;*** **4** ***Chavdar;*** **5** ***Chokoba;*** **6** ***Damyanitsa;*** **7** ***Devetashka Cave;*** **8** ***Drenkovo;*** **9** ***Durankulak;*** **10** ***Dyakovo;vo;*** **11** ***Emenska Cave;*** **12** ***Galabnik;*** **13** ***Golyamo Delchevo;*** **14** ***Gradeshnitsa;*** **15** ***Hlebozavoda, Nova Zagora;*** **16** ***Hotnitsa;*** **17** ***Kachitsa;*** **18** ***Kaloyanovets;*** **19** ***Karanovo;*** **20** ***Karasura;*** **21** ***Kazanlak;*** **22** ***Kolarovo;*** **23** ***Kozareva Mound;*** **24** ***Krivodol;*** **25** ***Krushaka;*** **26** ***Kurilo;*** **27** ***Ovcharovo;*** **28** ***Podgoritsa;*** **29** ***Polyanitsa;*** **30** ***Promachon-Topolnitsa;*** **31** ***Provadia Solnitsata;*** **32** ***Rakitovo;*** **33** ***Rousse;*** **34** ***Sadievo;*** **35** ***Saedinenie;*** **36** ***Samovodene;*** **37** ***Sapareva Banya;*** **38** ***Sava;*** **39** ***Slatina;*** **40** ***Slatino;*** **41** ***Telish Lîga;*** **42** ***Usoe;*** **43** ***Vaksevo;*** **44** ***Valchi Dol;*** **45** ***Yabalkovo;*** **46** ***Yunatsite (https://maps-for-free.com/).***

cleanliness of the food, which is an indication of higher standards for stored foods and liquids. With the improvement of pottery technology, the form of ceramic lids changed. At the same time, ceramic bowls were inverted over the mouths of other vessels, serving as lids (*ibid.*), a practice that persists to the present day.

In a significant number of prehistoric settlements on the territory of Bulgaria, lids have been found (Fig. 1). Their form developed over time and thus certain lids are significant chronological markers, but not so strong cultural indicators. Clear over-regional unifications are observed in the frame of one period (Fig. 2).

The lids from the Early Neolithic period (6200/5900–5500/5450 BC) have cylindrical or slightly conical bodies (Fig. 2.1–13) and these forms continue until the end of the Chalcolithic period. During the Middle Neolithic (5500/5450–5200/5100 BC), lids continued to be conical and cylindrical in shape (Fig. 2.14–15). At the Late Neolithic (5200/5100–4900/4850 BC) in parallel with the use of lids with conical and cylindrical shapes (Fig. 2.16,19,26,29,30), flat lids appeared *en masse* (Fig. 2.17–18,20,21–25,27–29,31–33). However, it should be noted that this type of lids is already attested in the Early Neolithic at Yabalkovo (Fig. 2.5) (*Leshtakov* et al. *2006.11,Fig. 9.1–3*). At the end of Late Neolithic and during the Early Chalcolithic (4900/4850–4600/4550 BC), in addition to the preceding shapes of the lids (Fig. 2.34,35,37,38,41,43), a new form appears, namely domed lids (Fig. 2.36,38–39,40,42–45). During the Middle Chalcolithic (4600/4550–4500/4400 BC), and the use of cylindrical, conical, flat and domed lids (Fig. 2.46–50) continue until the end of the Late Chalcolithic period (4500/4400–4100/3800 BC) (Fig. 2.51–59).

The prehistoric settlement near Damyanitsa

Location and geography

The settlement of Damyanitsa is located in the Sandanski-Petrich Valley (Fig. 1.6), which is the most extensive in the Struma River basin. The valley is surrounded by several mountain ranges: to the east and south, the Pirin Mountains, the Sengel Mountains and the Slavyanka Mountains; and to the west and southwest, the Ograzhden and Maleshevo Mountains and the Osogovo-Belasitsa Mountain range. The Sandanski-Petrich Valley is accessible to the Strumitsa Valley to the west and the Serres Valley to the south (*Michev* et al. *1980*). The prehistoric settlement is located near

Fig. 2 (opposite page). Neolithic and Chalcolithic lids from Bulgaria (different scales): **1 *Sapareva Banya (after* Nikolov 2002.37, Tab. 20*3);* 2 *Slatina (after* Nikolov, Takorova 2018.Nos. 106,82*);* 3 *Galabnik (after* Pavúk, Bakamska 2021.193-194, Abb. 106*);* 4 *Chavdar (after* Todorova, Vajsov.1993.Fig. 96*);* 5 *Yabalkovo (after* Leshtakov *et al.* 2006.11, Fig. 9.1-3*);* 6 *Rakitovo (after* Raduncheva *et al.* 2002.113*);* 7 *Kazanlak (after* Nikolov 2002.30, Tab. 169*);* 8, 15, 26, 38 *Karanovo I, II, II-III, IV, V (after* Nikolov 2002.27, Tab. 154; 1998.74; 2006.6; Schlor 2005.106-107, Taf. 58*);* 9 *Saedinenie (after* Nikolov 2014.Fig. 9.7*);* 10, 56 *Azmashka Mound (after* Nikolov 2002.29,Tab. 161; Petrova 2004.Fig. 1*);* 11 *Emenska Cave (after* Elenski 2004.Fig. 2.5*);* 29 *Samovodene (*Suvandzhiev 2019.Fig. 4.3,7-8*);* 12 *Ovcharovo Plateau (*Todorova 1983.Tab. 1.12*);* 13 *Ovcharovo Zemnika (after* Todorova 1983.Tab. 2.13-14*);* 14, 19 *Balgarchevo II, III (after* Pernicheva-Perets *et al.* 2011. Fig. 4.71, Fig. 4.107*);* 16 *Vaksevo IV (after* Čochadžiev 2000.254-255, Abb. 4.5*);* 17, 35 *Damyanitsa; 18 Kurilo (after* Petkov 1960.46, Fig. 6*);* 20 *Drenkovo (after* Grębska-Kulova 2004.133; Vandeva 2024.66*);* 21 *Hlebozavoda, Nova Zagora (after* Kănčeva-Ruseva 2000.117-124, Taf. I-V; Todorova, Vajsov 1993.Fig. 112*);* 22 *Atanasovsko Lake (after* Klasnakov 2011.216-218, Fig. 3.1-3*);* 23 *Karasura (after* Todorova, Vajsov 1993.124, Fig. 110*);* 24 *Krushaka (after* Leshtakov 2018.21-25*);* 25 *Chokoba (after* Petrova, Leshtakov 2009.143,Fig. 2*);* 27, 39 *Kachitsa (after* Suvandzhiev 2019.Fig. 7.1-2; Leshtakov 2010.44, Fig. 8*);* 28, 57 *Hotnitsa (after* Suvandzhiev 2019.Fig. 7.6; Angelov 1958.Abb. 12.1*);* 30 *Durankulak Nivata (after* Todorova, Vajsov 1993.Fig. 127*);* 31 *Usoe I (after* Todorova, Vajsov 1993.145, Fig. 126.6*);* 32 *Podgoritsa (after* Todorova, Vajsov 1993.Fig. 121a.5*);* 33 *Valchi Dol (after* Petrova 2020.241,245, Fig. 2.9*);* 34 *Slatino (after* Chohadzhiev 2006.Fig. 66,20,86,11*);* 36 *Gradeshnitsa (after* Nikolov 1984.45; Danov 2019.42, Fig. I.13.7*);* 37 *Kozareva Mound (after* Georgieva 1998. 155, Fig. 5*);* 40, 48 *Sava II, III, IV (after* Todorova 1986.Figs. 36-38,40*);* 41 *G. Delchevo (after* Todorova 1975. 11-12, Tabs. 13.2,14.4*);* 42, 59 *Durankulak Necropolis (after* Todorova *et al.* 2002.Abb.113*);* 43 *Durankulak Golemija ostrov (after* Vajsov, Slavchev 2020.283*);* 44 *Ovcharovo (after* Todorova.1983.Tab. 35*);* 45, 49 *Polyanitsa III, IV (after* Todorova 1986.Fig. 27-28*);* 46 *Dyakovo (after* Chohadzhiev 2007.Fig. 35*);* 47 *Maritsa IV (after* Todorova 1986.Fig. 24*);* 50 *Provadia Solnitsata (*Leshtakov 2008.Tab. 4*);* 51 *Krivodol (after* Georgieva 2012.Fig. 47*);* 52 *Kolarovo (after* Pernicheva 2001.33, Tab. 42.1,2,5,6*);* 53 *Telish Lîga (after* Merkyte 2005.Pl. 16.20,23*);* 54 *Devetashka Cave (after* Georgieva 2012.Fig. 47*);* 55 *Sadievo (after* Kancheva-Ruseva, Petrova 2014.Fig. 5.8; Todorova *et al.* 2003.Fig. 15.6-8*);* 58 *Rousse (after* Popov 1998.192, Fig. 11.5; Chernakov 2009. Cat. No. 57*).***

Cal. BC (Boyadzhiev 1995)
Region / Period
West Bulgaria
Thrace, Southeast Bulgaria and the Rhodopes
Central Northern Bulgaria
Northeast Bulgaria
4500/4400 4100/3800
Late Chalcolithic
4600/4550 4500/4400
Middle Chalcolithic
4900/4850 4600/4550
Early Chalcolithic
5200/5100 4900/4850
Late Neolithic
5500/5450 5200/5100
Middle Neolithic
6000/5900 5500/5450
Early Neolithic
51 Krivodol
52 Kolarovo
53 Telish Liga
54 Devetashka Cave
55 Sadievo
56 Azmashka Mound
57 Hotnitsa
58 Rousse
59 Durankulak Necropolis Varna culture
46 Dyakovo
47 Maritsa IV
48 Sava IV
49 Polyanitsa IV
50 Provadia Solnitsata
34 Slatino
35 Damyanitsa
36 Gradeshnitsa
37 Kozareva Mound
38 Karanovo V
39 Kachitsa
40 Sava II, III Necropolis
41 G. Delchevo
42 Durankulak Golemija Ostrov
43 Durankulak 44 Ovcharovo
45 Polyanitsa III
16 Vaksevo IV
17 Damyanitsa
18 Kurilo
19 Balgarchevo III
20 Drenkovo
21 Hlebozavoda Nova Zagora
22 Atanasovsko Lake
23 Karasura
24 Krushaka
25 Chokoba
26 Karanovo IV
27 Kachitsa
28 Hotnitsa
29 Samovodene
30 Durankulak Nivata
31 Usoe I
32 Podgoritsa
33 Valchi Dol
14 Balgarchevo II
15 Karanovo II–III
11 Emenska Cave
12 Ovcharovo Plateau
13 Ovcharovo Zemnika
1 Sapareva Banya
2 Slatina
3 Galabnik
4 Chavdar
5 Yabalkovo
6 Rakitovo
7 Kazanlak
8 Karanovo I, II
9 Saedinenie
10 Azmashka Mound

the village of Damyanitsa, in the Osmanitsa locality (N: 41°30"58.0847, E: 23°16"17.8190), on the left bank of the river, on the third terrace about 1km east of the river bed (Fig. 3).

History of excavations

The prehistoric settlement was discovered during the construction of the railway between 1941 and 1943, where plaster and fragments of vessels were found (*Dremsizova-Nelchinova 1987.62*). The settlement was registered in 1982, during the Bulgarian-Polish 'Struma' archaeological expedition (*Domaradski* et al. *2001.5–7*).

The first excavations of the settlement began in 1985, conducted by Lilyana Pernicheva-Perets and Małgorzata Grębska-Kulow, who opened three test trenches in the northwestern part of the site, encompassing a total surface area of 60m2 (*Pernicheva, Grębska-Kulova 1986.24).* Two additional campaigns were carried in 1988 and 1989 around the Trench 1, covering an area of 250m2 (Fig. 3) (*Pernicheva* et al. *1989.9; Pernicheva, Grębska-Kulov 1990.16*).

The archaeological investigations were resumed in 2016 and 2017, due to the construction of the Struma highway, which passes through the site, to the east of the test trenches. The excavation of 65 test trenches was undertaken, encompassing an area of 7ha (Fig. 3) (*Grębska-Kulow* et al. *2017b.75; 2018a.30–33*).

Stratigraphy

The settlement at Damyanitsa was founded in the Late Neolithic period (around 5300/5200 BC) and developed until the end of the Chalcolithic period (the first half of the 4th mill. BC). It is a flat settlement with rather complex stratigraphy, both vertical and horizontal, resulting from spatial development during occupation (*Grębska-Kulowa, Kulow 2007.283*). The site covers a huge area of approximately 100ha. The cultural layers are between 0.50m and 3.00m (in the ravines) thick. The chronological frame of the Late Neolithic is approximately 5300/5200–4900 BC. A detailed analysis of the pottery and ornamentation have enabled the identification of three distinct Late Neolithic occupation phases. The first two phases are closely associated with the Vinča culture, specifically the South-East variant identified in Anzabegovo IV (*Gimbutas 1974*), while in the third phase the dominance of Akropotamos-Topolnitsa culture (*Todorova, Vajsov 1993; Koukouli-Chryssanthaki* et al. *2007; Vajsov 2007*), developed in the Northern Aegean is observed.

In the test trenches from 1985, 1988 and 1989, the earliest phase, Damyanitsa I, was attested only in test trench 2 at a depth of 1.30m to 1.80m, recovered from dug-in features with a grey fill (Fig. 4.a). The pottery is black, grey-black, grey-brown and brown, which is typical of the Late Neolithic in the area. The forms were often simple, biconical and truncated-conical vessels with flat handles attached to the rim or immediately below it, and spherical, low-necked vessels also occurred. Vessels with a slightly thickened inner mouth appeared, but still lacked the typical Late Neolithic sharp profiling. The most characteristic is the decoration of rippling, plastic knobs, punctation along the middle rib, nail patterned impresso along the middle rib, barbotine, and red engobe. The earliest manifestation of the black-topped decoration in the variant grey and black is also typical for this phase (*Pernicheva 1995; Grębska-Kulow* et al. *2017a.17*).

The second phase, Damyanitsa II, is recorded in test trenches 1 and 2 at a depth of 0.50m to 1.30m (Fig. 4.a). It ends in both test trenches with a burnt layer. The material from the burnt layer fills three pits in Trench 1. The pottery is grey, black, beige and brown. The typical forms of the pottery include S-shaped profiled vessels with a thickened inner mouth and rounded handles (*Pernicheva 1995; Grębska-Kulow* et al. *2017a.18*). The most characteristic features are the rippling, black-topped technique and lugs, which are often combined together. The bitumen-drawing and isolated sherds of painted pottery of the Akropotamos type are registered in this phase.

The last Late Neolithic phase, Damyanitsa III, was recorded in all trenches at a depth of 0.00m to 0.50m. A new ceramic group appears, with new forms and decorations. In terms of colour, the pottery is homogeneous-red or brownish-red, almost brick-like. The new forms encompass spherical vessels with a thickened interior mouth, as well as amphora- and kantharos-shaped vessels. Long, banded handles are characteristic. The vessels are well-fired, but the surface is without slip. Painted pottery is closely related to this pottery complex. The painting is black or brown on a red background, and the absence of slip (a local evolution of the original Akropotamos style) (*ibid.*).

In the area excavated in 2016 and 2017, the site is conventionally divided into three sectors: southern, central, and northern, with one central test trench (Fig. 4.b). The cultural layers gradually increase in the western and southern directions, exceeding 3.00m (Fig.

4.c). The Late Neolithic settlement extends across the northern, central, and southern sectors within the study area, making it larger than the Early Chalcolithic occupation, which is located only in the central and northern sectors (Fig. 4.b). Compared to other sites, Damyanitsa is the largest Late Neolithic settlement known in Southwest Bulgaria.

The presence of Late Neolithic dwellings has been recorded on the slopes, as well as in the ravines formed by the paleotributaries of the Struma, which were already dry during this period. Several buildings surrounded by numerous pits have been discovered (*Grębska-Kulow* et al. *2018a.30*). In the southern sector, only the last Late Neolithic phase of Damyanitsa

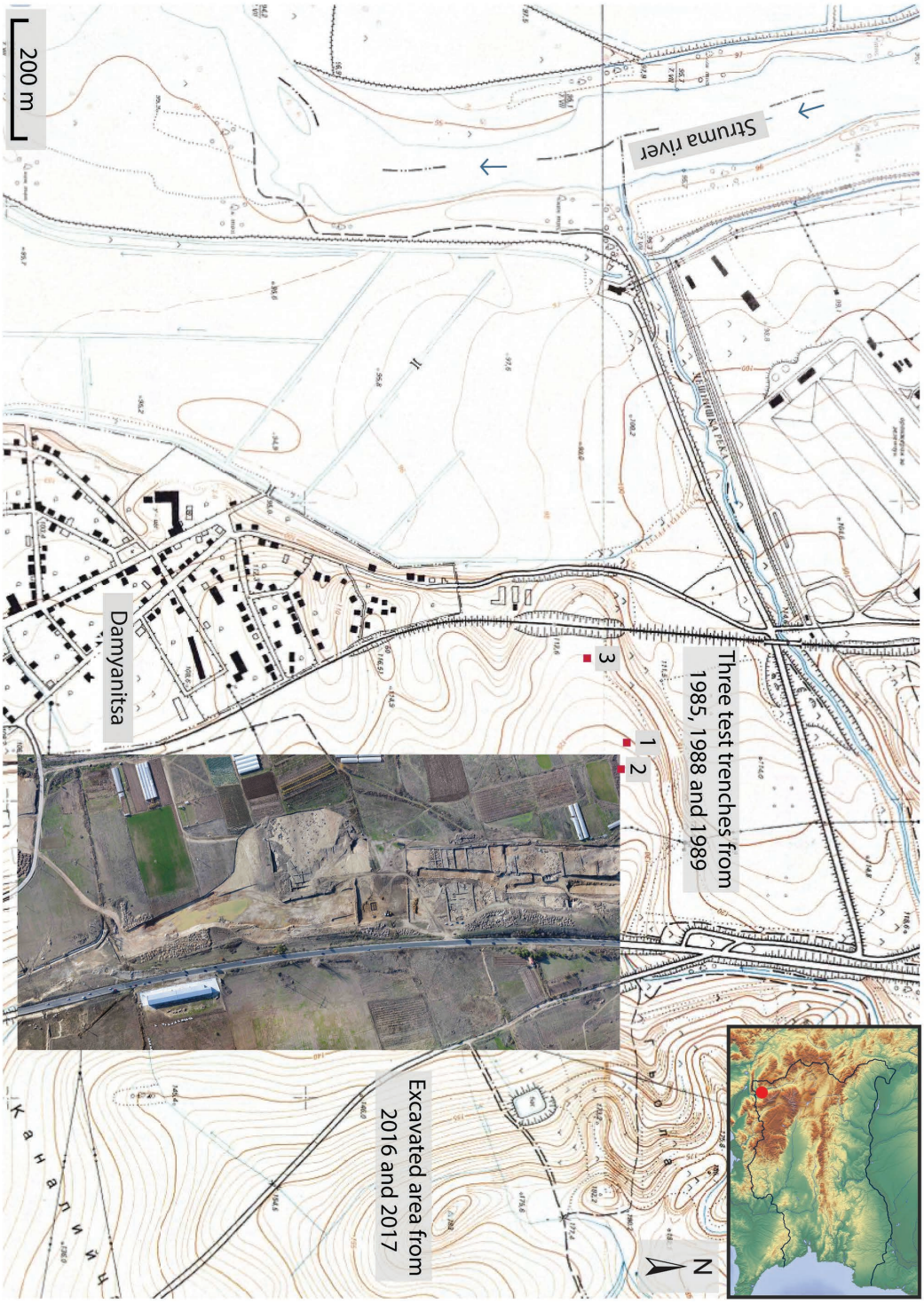

Fig. 3. Site location map with test trenches in 1985 and the excavation area from 2016 and 2017 (after **Grębska-Kulow *et al.* 2018b.Fig. 1;** ***aerial photograph © Ivan Vajsov) (https://kade.si; https://maps-for-free.com).***

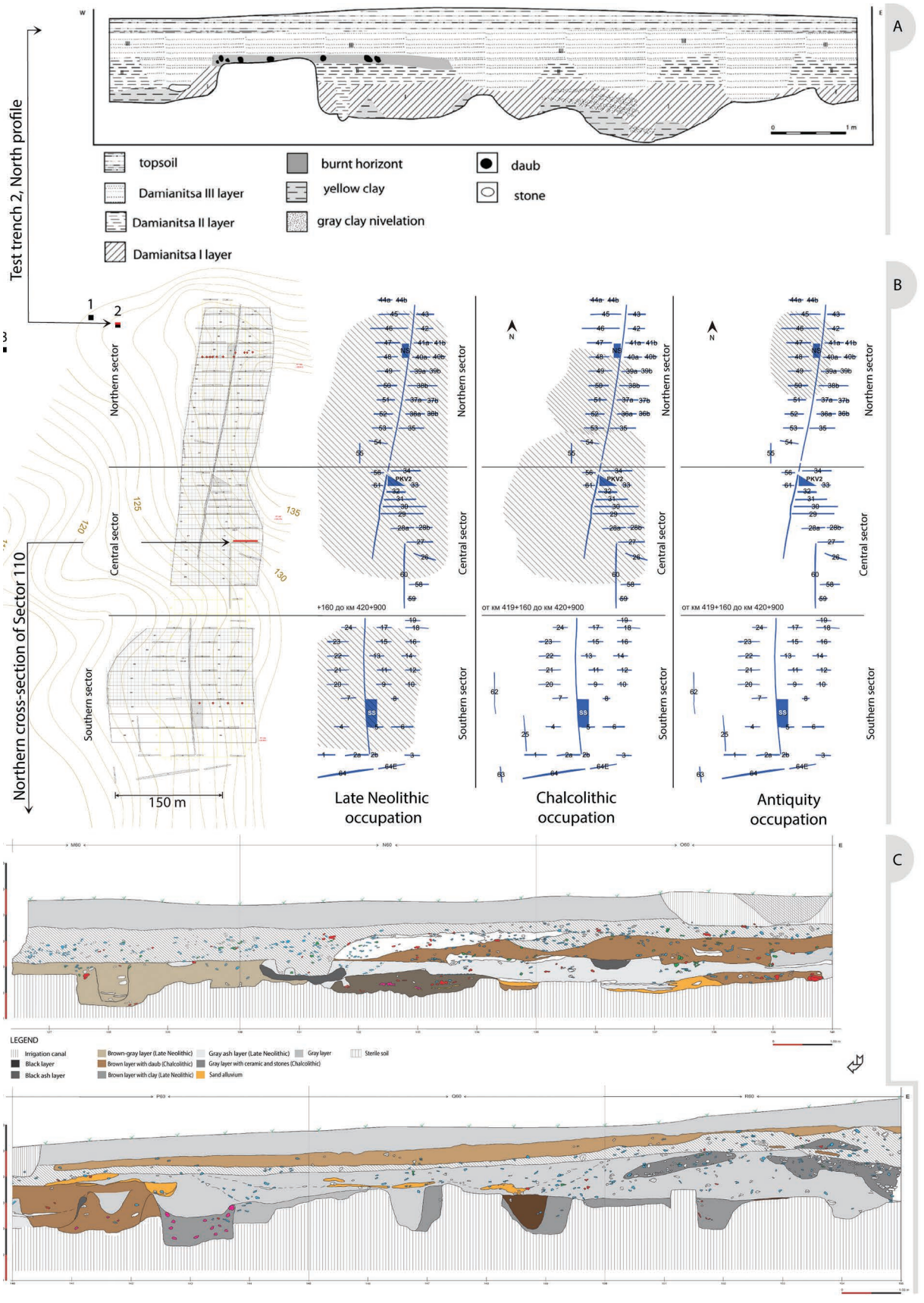

Fig. 4. Plan of the Damyanitsa, cross-sections of test trench 2 and sector 110 and the settlement during the various periods (after* Gręboska-Kulow *et al.* 2017a.Fig. 4; 2017b.Fig. 2; 2018a.Fig. 2*).

(phase III), characterized by the Akropotamos-Topolnitsa culture, was documented.

During the Early Chalcolithic, the buildings were of a non-compact arrangement in the central and northern sections of the settlement. The Late Chalcolithic settlement of Damyanitsa is characterized by the presence of dwellings, stone clusters, a stone circle, and a distinct economic zone comprising a considerable number of hearths (*Grębska-Kulow* et al. *2018a.30–33*).

The final phases of habitation, along with the subsequent sudden depopulation, are associated with climatic changes that transpired during the first half of the 4th millennium BC. Subsequently, the periodic inundation of the settlement by streams flowing into the Struma, in conjunction with the rise of groundwater levels, resulted in the loss of habitable areas and the eventual departure of the population in the 4th millennium BC (*ibid.*).

Traces of occupation dating back to the Bronze Age have been uncovered. A villa rustica and a necropolis existed here between the 1st to 4th centuries AD (*Grębska-Kulow* et al. *2018a.30; 2018b.35–36*).

The lids from Damyanitsa

Clay composition, modelling and shaping

The majority (168) of the Late Neolithic and Early Chalcolithic lids from Damyanitsa are made of well-refined clay. A minimal quantity of mineral inclusions (quartz sand) is registered in 98 lids, and there are also those with almost pure clay (70)–almost without inclusions. Only 22 lids have clay with inclusions and large dimensions (more than 5mm) of inclusions. Inclusions of carbonized organic material are found in 14 lids (7%), and chamotte in only one.

The surfaces can be categorized into three distinct types: polished (32 objects), smoothed (109) and partially smoothed (49). One of the lids from Damyanitsa exhibits indications of an imprint, which is consistent with the presence of a tool, most likely a bone spatula, given the similarity in marks and texture observed on the surface of the lid and those characteristic of bone. The lid's deformation in the impression suggests that it may have been inadvertently pressed over during the manufacturing process, potentially going unnoticed by the maker (Figs. 5 and 13.7).

In the majority of cases, for lids with a handle, the handle was affixed after the body of the lid was shaped, and less often it was modelled together with it. Some show precision workmanship, smoothing of the base of the handle and body, while others have it roughly added and lightly smoothed. There are also handles that are modelled as an extension of the body, where the handle has no retention function.

Colour

Damyanitsa lids are characterized by three colours–beige-brown, grey-brown, and brick-red.[1]

Beige-brown colour

This is the most numerous category consisting of 111 lids, or 58%. The colour varies between beige and light brown, with many shades in this range. The majority of lids of this colour have a smoothed surface (66), with polished surfaces also occurring (24), and lids with a partially smoothed surface are the fewest (21). Three of the lids are elliptical in shape and the rest are round.

Grey-brown colour

The category is represented by 58 lids, or 31%, the colour falls in the dark range of brown and grey. Thirty-one of the lids have a smooth surface, six a polished surface, and 21 a partially smoothed surface. The lids are round, and only one is elliptical.

Fig. 5. Lid with traces of tool (© Temelko Temelkov).

1 The colour of the surface of the lids was determined using a Munsell colour chart (*Munsell 1992*).

Brick-red colour
This is the smallest category consisting of 21 lids, or 11%. The colour varies within the red range. The majority of lids are smooth (13), polished (2), or partially smoothed (6). All lids in this category are round.

Typology of the forms
The lids are composed of two parts: a body and a handle. In this study, the body is described by several elements: cross-section, inner profile, edge, and shoulders (Fig. 6). The inner profile of the lid can be straight, concave, convex, or uneven. The edge is the transition between the inner and outer (shoulders) parts of the lid. There are also several types of edges: straight, cut at an angle, and rounded. The outer part of the lid (shoulders) can be flat (flat and flat-concave lids) and convex (flat, trapezoidal, conical and curved). The transition between the shoulders and the base of the handle is smooth or pronounced.

The lids can be divided into two categories based on the lid as viewed from above: rounded and elliptical.[2]

Five groups of lids are defined based on a longitudinal cross-section (Fig. 6) of the body: I. Flat lids; II. Trapezoidal lids; III. Conical lids; IV. Curved lids; V. Flat-concave lids. The subgroups are defined by the shape of the outer part of the lid (shoulders): 1. Flat shoulders; 2. Convex shoulders; 3. Flat shoulders and holes perforating the body. The types are defined by the inner profile: 1. Straight inner profile; 2. Concave inner profile; 3. Convex inner profile; 4. Uneven inner profile; 5. A hole on the inner profile. The subtypes are defined by the form of the handles: a. Conical; b. Cylindrical; c. Banded; d. Parabolic; e. Trapezoidal; f. Without handles; g. Indefinable (conical or cylindrical).[3]

Group I. Flat lids
This is the largest group, containing 148 examples, in which the inclination of the shoulders, does not exceed 15°.

Subgroup I.1 Flat shoulders (61 lids) (Fig. 7; Fig. 8; Fig. 9.1–5)
- Type I.1.1 Straight inner profile (42 lids) (Fig. 7; Fig. 8.1–5)
  - Subtype I.1.1.a Conical handle (9)
  - I.1.1.b Cylindrical handle (5)
  - I.1.1.c Banded handle (19)
  - I.1.1.f Without handle (8)
  - I.1.1.g Indefinable handles (1)
- Type I.1.2 Concave inner profile (11 lids) (Fig. 8.6–12)
  - Subtype I.1.2.a Conical handle (3)
  - I.1.2.b Cylindrical handle (1)
  - I.1.2.c Banded handle (7)
- Type I.1.3 Convex inner profile (6 lids) (Fig. 9.1–4)
  - Subtype I.1.3.a Conical handles (1)
  - I.1.3.c Banded handle (3)
  - I.1.3.d Parabolic handle (1)
  - I.1.3.e Trapezoidal handle (1)
- Type I.1.4 Uneven inner profile (2 lids) (Fig. 9.5)
  - Subtype I.1.4.c Banded handles

Subgroup I.2 Convex shoulders (86 lids) (Fig. 9.6–16; Fig. 10; Fig. 11.1–11)
- Type I.2.1 Straight inner profile (61 lids) (Fig. 9.6–16; Fig. 10.1–13)
  - Subtype I.2.1.a Conical handles (28)
  - I.2.1.b Cylindrical handles (2)
  - I.2.1.c Banded handles (16)
  - I.2.1.f Without handles (10)
  - I.2.1.g Indefinable handles (5)
- Type I.2.2 Concave inner profile (14 lids) (Fig. 10.14; Fig. 11.1–4, 6)
  - Subtype I.2.2.a Conical handles (7)
  - I.2.2.b Cylindrical handles (2)
  - I.2.2.c Banded handles (5)
- Type I.2.3 Convex inner profile (6 lids) (Fig. 11.7, 10)
  - Subtype I.2.3.a Conical handles (5)
  - I.2.3.c Banded handles (1)
- Type. I.2.4. Uneven inner profile (4 lids) (Fig. 11.5, 8–9)
  - Subtype I.2.4.a Conical handles (1)
  - I.2.4.b Cylindrical handles (1)
  - I.2.4.c Banded handles (1)
  - I.2.4.f Without handles (1)
- Type I.2.5 A hole on the inner profile (1 lid) (Fig. 11.11)
  - Subtype I.2.5.a Conical handles

Subgroup I.3 Flat shoulders and holes perforating the body (1 lid) (Fig. 11.12)
- Type I.3.1 Straight inner profile
  - Subtype I.3.1.f Without handles

Group II. Trapezoidal lids
There are 16 lids with this shape. The inclination of the shoulders exceeds 15°. Within this group, a single subgroup is delineated based on the configuration of the

2 For the purposes of this work, lids that deviate from the geometric circle by more than 3.0cm in diameter are considered elliptical.
3 All drawings are to a scale of 1:3, except Fig. 15.6 where the lid is 1:2 scale.

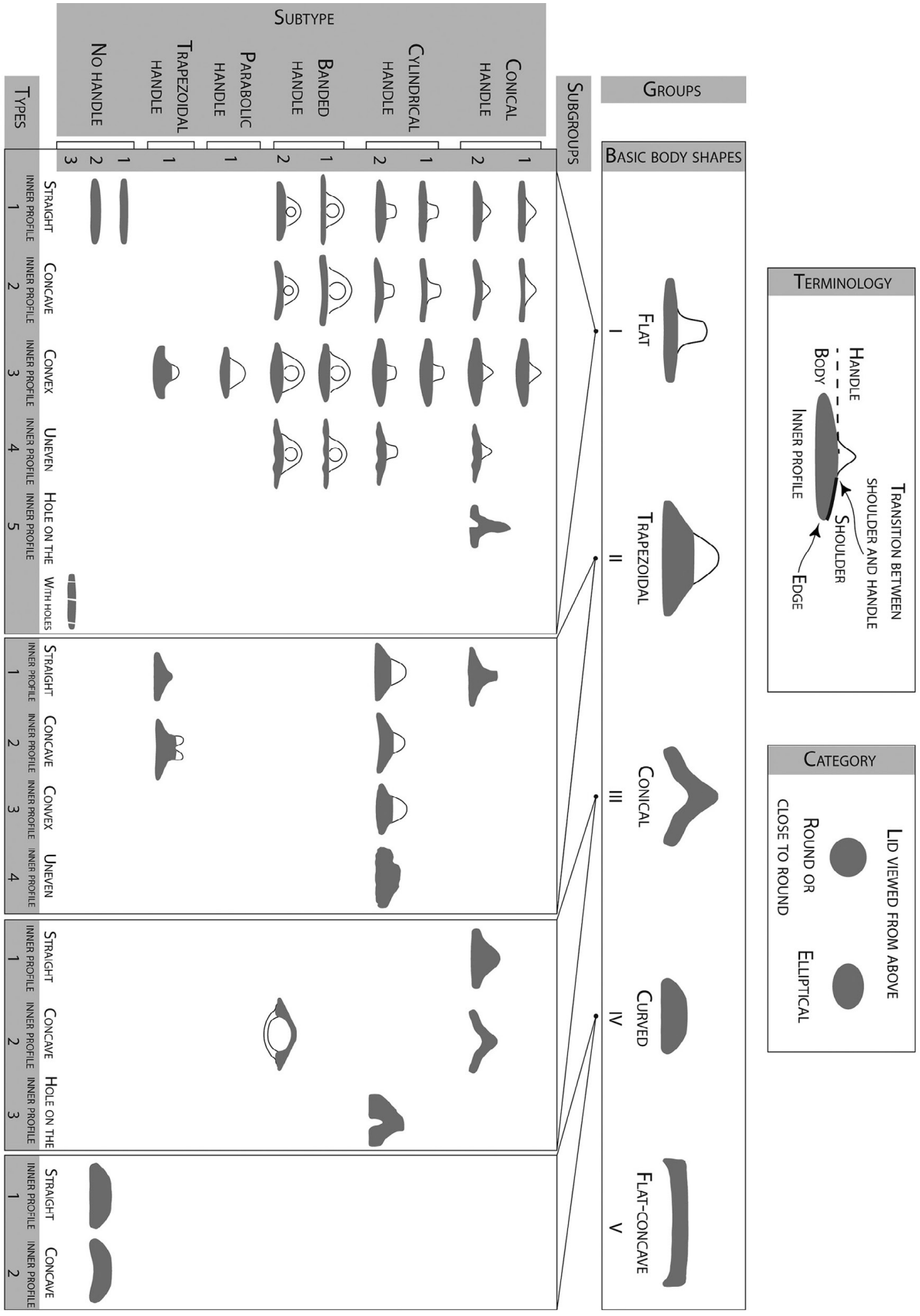

Fig. 6. Scheme of the terminology and typology of the lids.

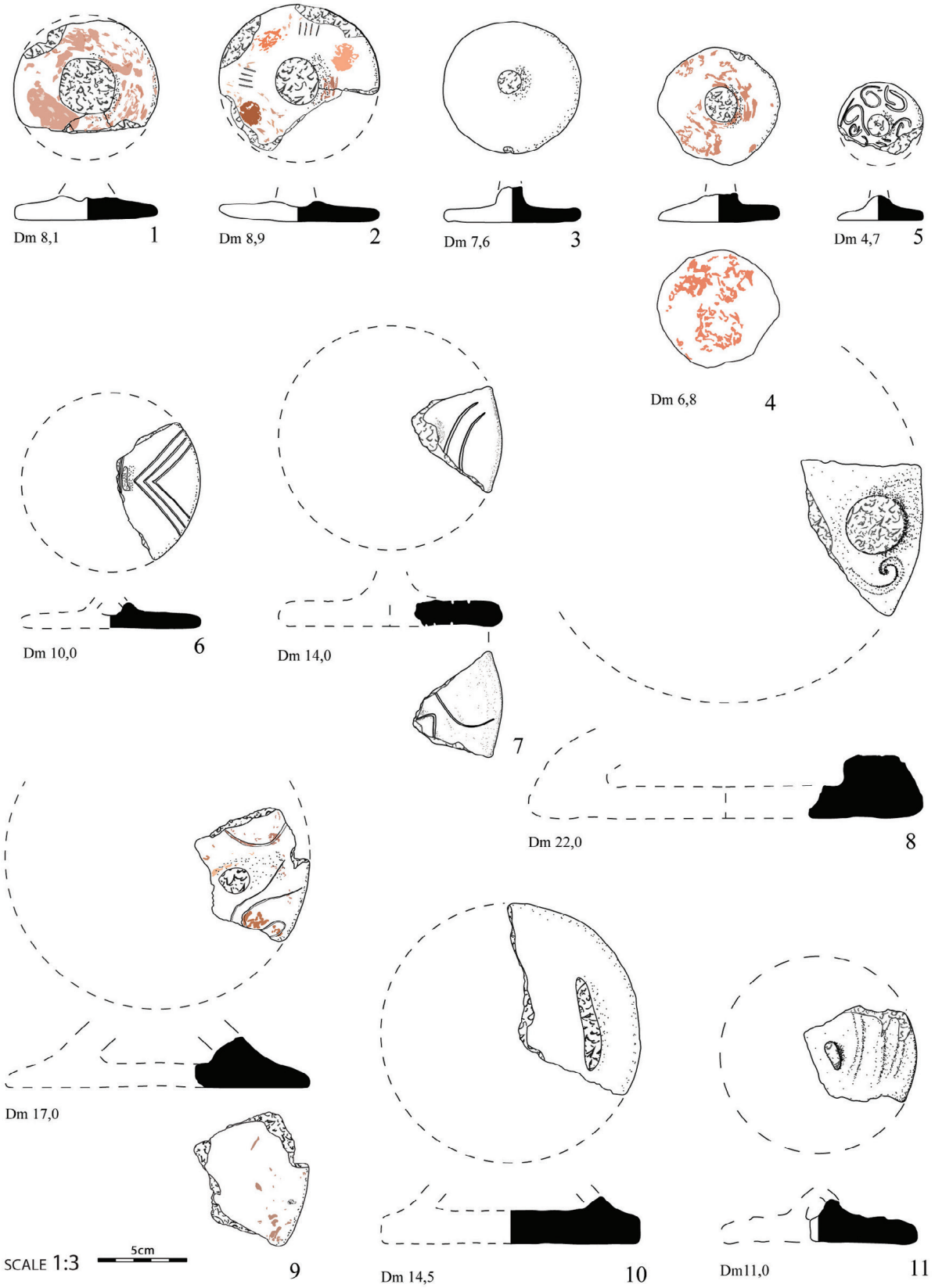

Fig. 7. Group I. Flat lids. Subgroup I.1: flat shoulders and straight (I.1.1) inner profile (scale 1:3).

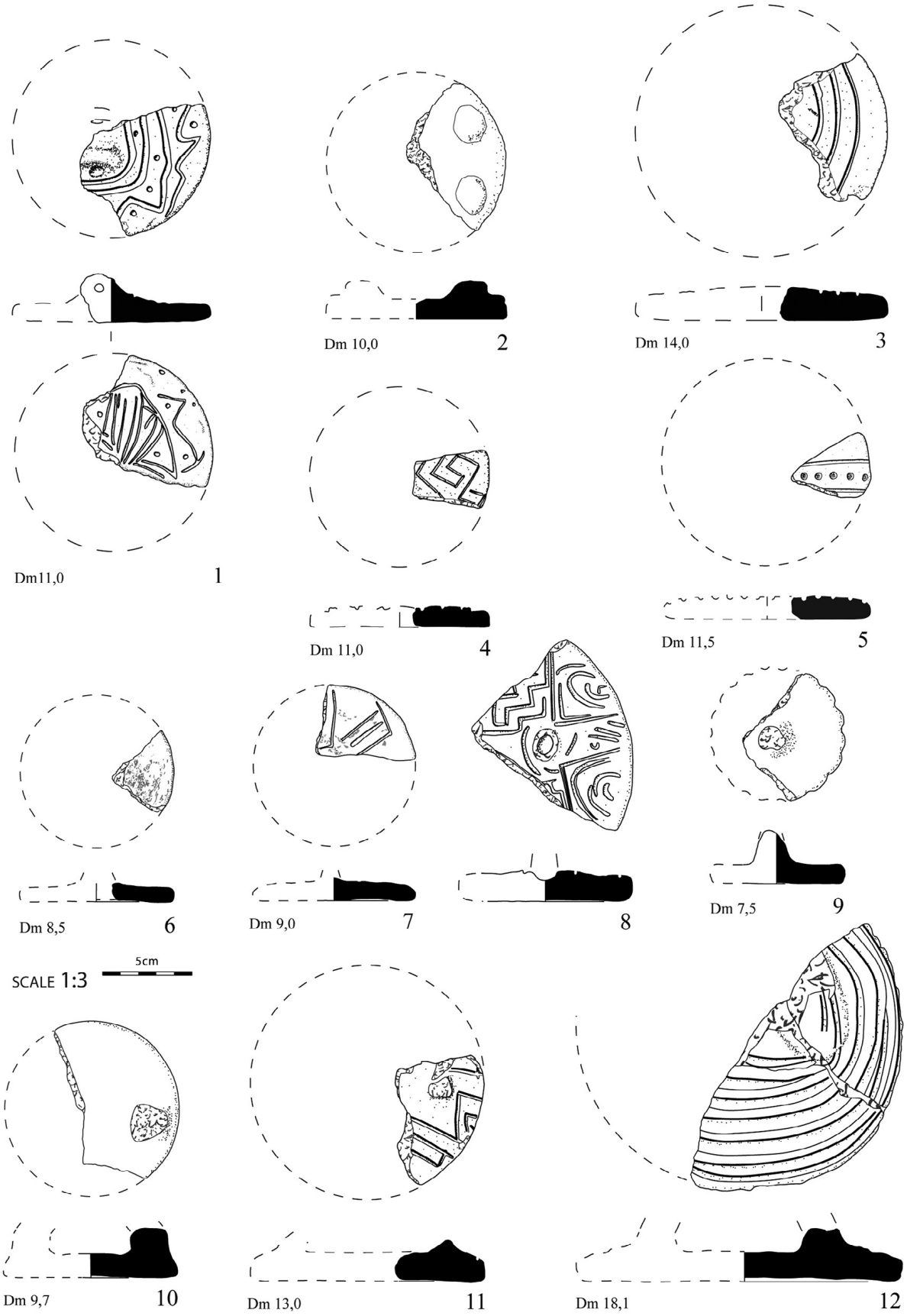

Fig. 8. Subgroup I.1: flat shouders and straight (I.1.1) and concave (I.1.2) inner profile (scale 1:3). The lids with the numbers 6 and 7 have an engobe on the surface,* i.e. *they are coloured. The illustration is shown here in black and white.

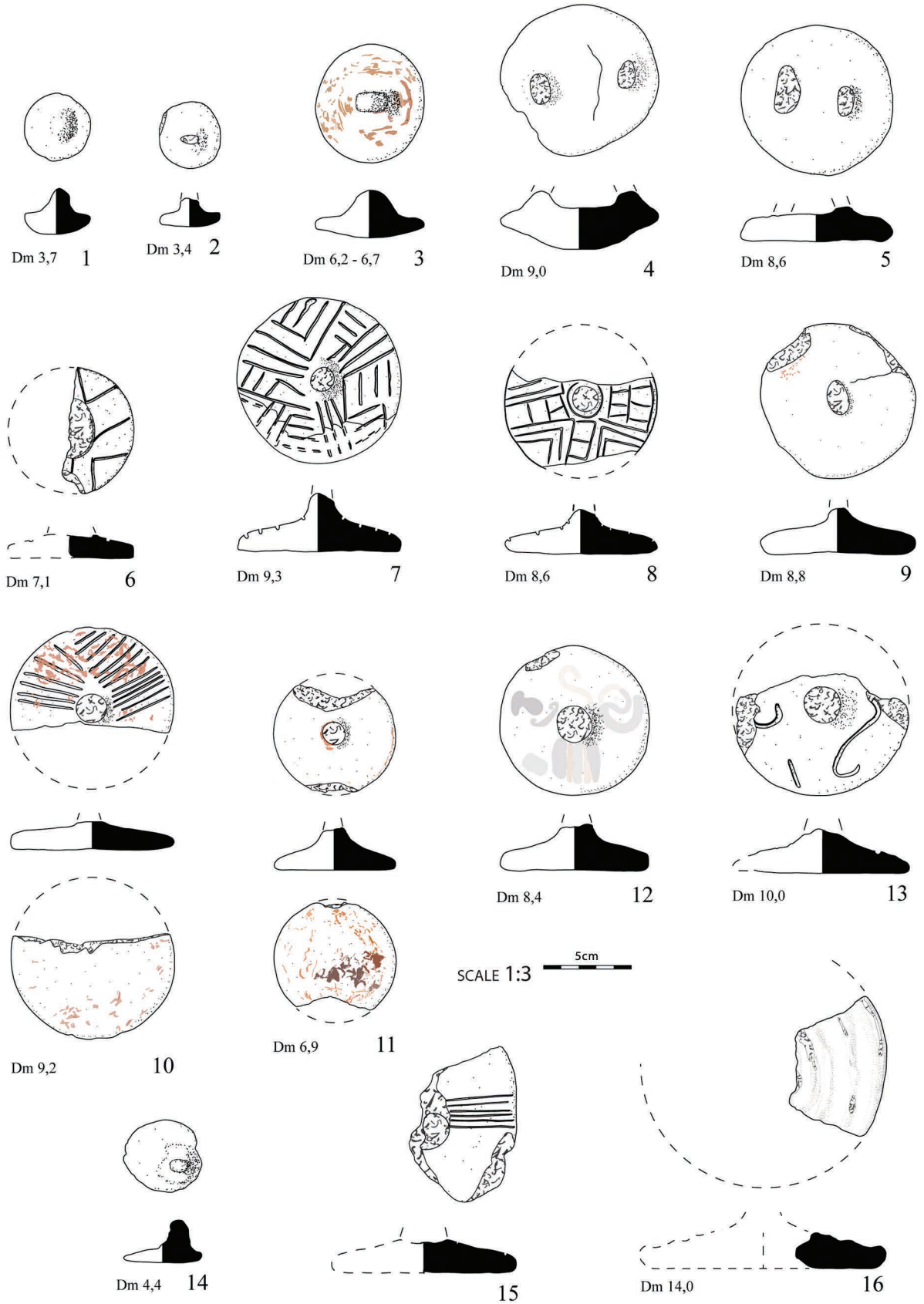

Fig. 9. Subgroup I.1: flat shoulders and convex (I.1.3) and uneven inner profile (I.1.4); Subgroup I.2: convex shoulders and straight (I.2.1) inner profile (scale 1:3).

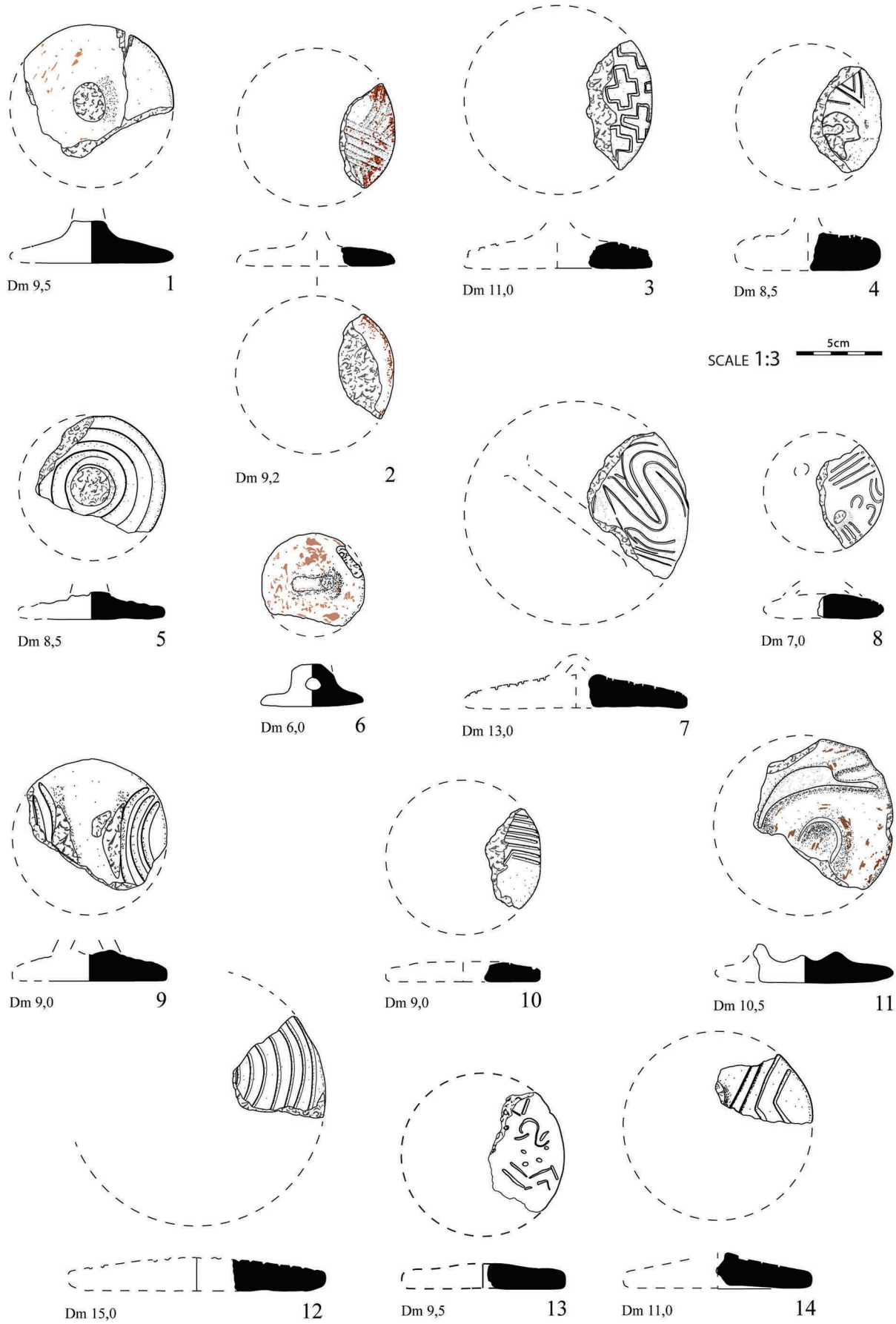

Fig. 10. Subgroup I.2: convex shoulders and straight (I.2.1) and concave (I.2.2) inner profile (scale 1:3).

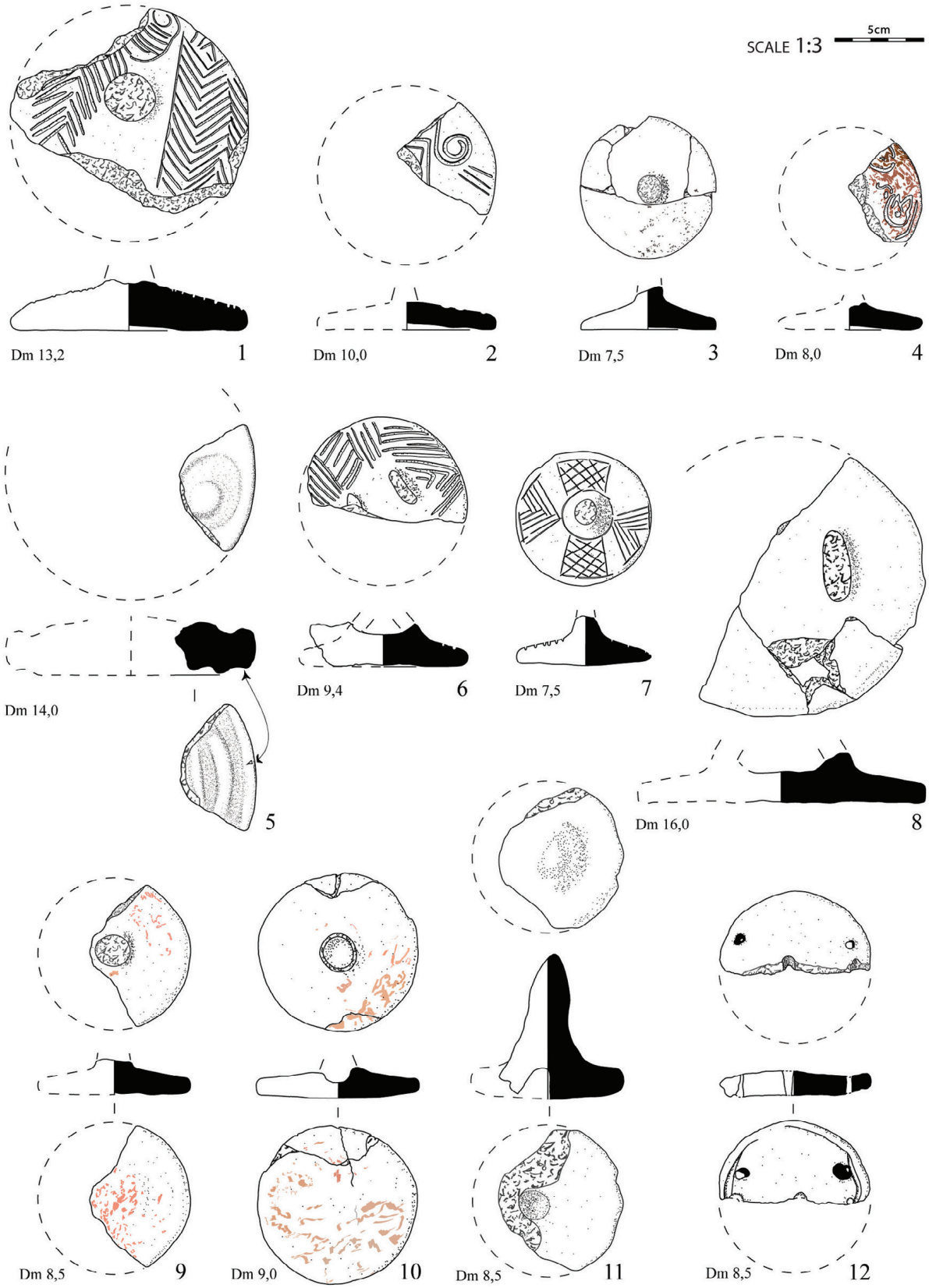

Fig. 11. Subgroup I.2: convex shoulders and concave (I.2.2), convex (I.2.3), uneven (I.2.4), and with hole (I.2.5) on the inner profile; Subgroup I.3: flat shoulders and holes perforation of the body (scale 1:3).

shoulders. The distinguishing feature of this subgroup is that the shoulders rise towards the centre of the body and transition into the handle. According to the inner profile of the lids, four types are distinguished: straight, concave, convex, and uneven.

Subgroup II.2 Convex shoulders (16 lids) (Fig. 12)
- Type II.2.1. Straight inner profile (7 lids) (Fig. 12.1–5)
  - Subtype II.2.1.a Conical handles (2)
  - II.2.1.b Cylindrical handles (4)
  - II.2.1.e Trapezoidal handles (1)
- Type II.2.2 Concave inner profile (6 lids) (Fig. 12.6–8, 10–11)
  - Subtype II.2.2.a Conical handles (5)
  - II.2.2.e Trapezoidal handles (1)
- Type II.2.3 Convex inner profile (2 lids) (Fig. 12.12)
  - Subtype II.2.3.a Conical handles (1)
  - II.2.3.b Cylindrical handles (1)
- Type II.2.4 Uneven inner profile (1 lid) (Fig. 12.9)
  - Subtype II.2.4.a Conical handles

Group III. Conical lids

This group includes 20 lids, which are characterized by a wide variety of shapes. The group is comprised of a single subgroup, defined on the basis of the shoulders.

Subgroup III.2 Convex shoulders (20 lids) (Fig. 13; Fig. 14)
- Type III.2.1 Straight inner profile (5) (Fig. 13.1–5)
  - Subtype III.2.1.a Conical handles
- Type III.2.2 Concave inner profile (14 lids) (Fig. 13.6–10; Fig. 14.1–3, 5–9)
  - Subtype III.2.2.a Conical handles (9)
  - II.2.2.b Cylindrical handles (4)
  - III.2.2.c Banded handles (1)
- Type III.2.5 A hole on the inner profile (1 lid) (Fig. 14.4)
  - Subtype III.2.5.b Cylindrical handles

Group IV. Curved lids

The group is composed of five lids, each of which is characterized by convex shoulders.

Subgroup IV.2 Convex shoulders (5 lids) (Fig. 15.1–5)
- Type IV.2.1 Straight inner profile (2 lids) (Fig. 15.1–2)
  - Subtype IV.2.1.f Without handles
- Type IV.2.2 Concave inner profile (3 lids) (Fig. 15.3–5)
  - Subtype IV.2.2.f Without handles

Group V. Flat-concave lids

This group is represented only by one lid, flat on the outside, with a concave inner profile.

Subgroup V.1 Flat shoulders (1 lid) (Fig. 15.6)
- Type V.1.2 Concave inner profile
  - Subtype V.1.2.f Without handles

The predominant number of ceramic lids have a round outline. Only four have an elliptical shape – three of them are flat lids (Figs. 8.1 and 9.15), and one is a trapezoidal lid (Fig. 12.7).

Most have a base diameter of up to 15.0cm (170 pieces). The thickness of the wall in the shoulder area varies from 0.6 to 3.1cm, with the predominant factor contributing to this variation being the shape, rather than the method of manufacture or the size of the object. The handles of the larger lids (with a diameter greater than 15.0cm) are banded, with the exception of one, which is cylindrical (Fig. 14.5).

The diameters of the lids are important in the inquiry into their functionality and its correlation with the vessels. Two distinct groups can be identified: small lids with diameters ranging from 3.4cm to 15.0cm, and large lids with diameters between 15.0cm and 33.0cm. In Damyanitsa, small lids are predominant, constituting 170 pieces, or 89% of the total of 190 lids. Of these, 64 are made of almost pure clay (without inclusions), 87 contain a small amount of mineral inclusions, and 19 are made of clay with inclusions. Decorated lids account for 58 of the total: 36 with incised decoration, 17 with relief decoration, four with painted decoration and one with impressed decoration. The large lids comprise only 20 pieces, or 11%. Six lids are made of almost pure clay, 11 of clay with a few mineral inclusions, and three of clay with inclusions. Nine pieces are decorated, and of these six have incised decoration and three relief decoration.

In comparison with prehistoric sites, where a significant number of lids were found, at the Late Neolithic settlement at Hlebozavoda, Nova Zagora (174 lids) (Fig. 1.15), large-sized lids are roughly made of poorly refined clay, poorly smoothed, and usually undecorated. The smallest lids are made with precision, and are made of well-refined clay with a smooth surface, some are polished and decorated (*Kănčeva-Ruseva 2000.117*). In Krushaka, Burgas (214) (Fig. 1.25), the lids of small sizes between 7.0cm to 16.0cm in diameter

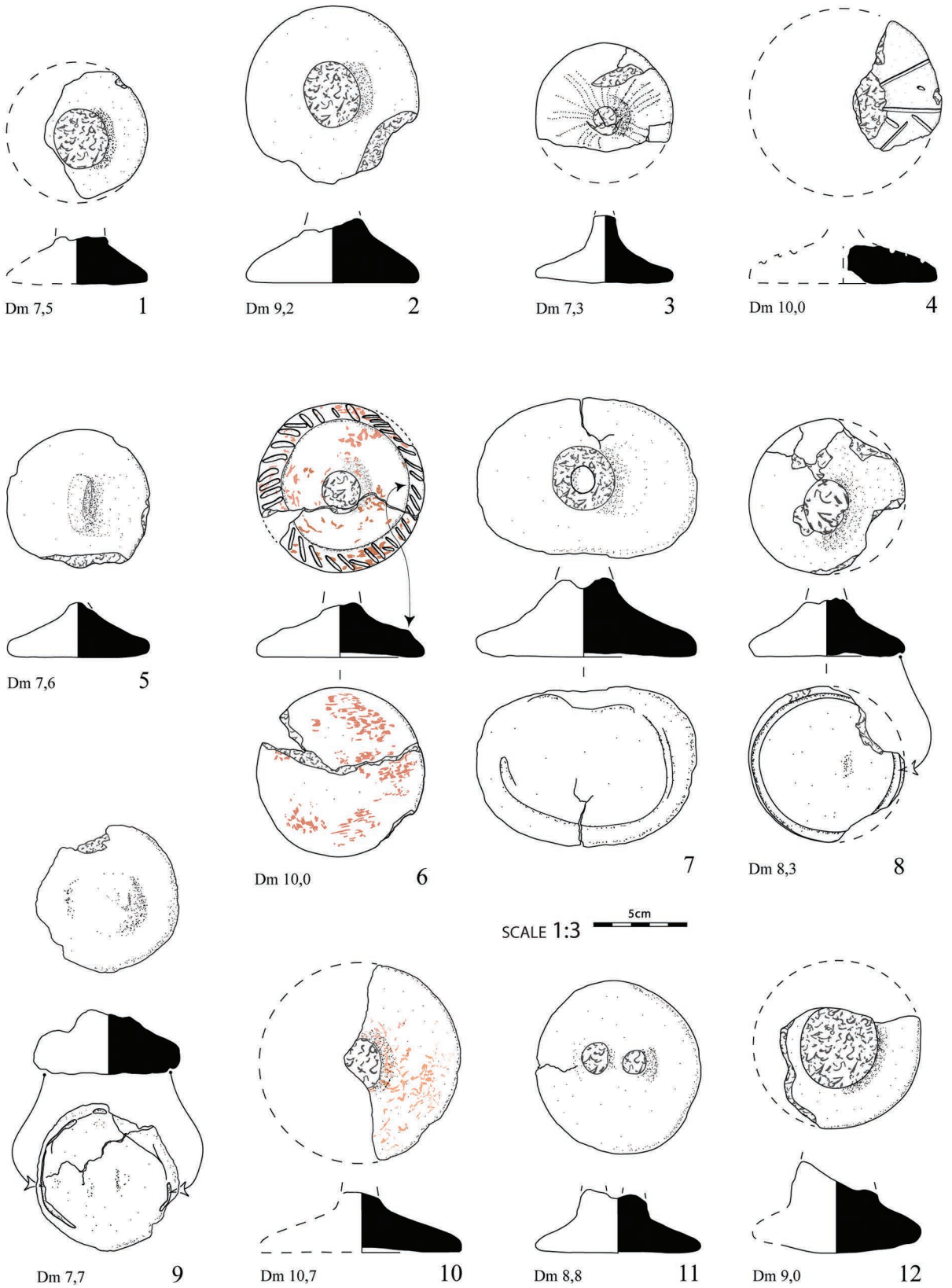

Fig. 12. Group II. Trapezoidal lids. Subgroup II.2: convex shoulders with straight (II.2.1), concave (II.2.2), convex (II.2.3) and uneven (II.2.4) inner profile (scale 1:3).

are crafted from fine clay with the surfaces are covered with fine engobe. They are often richly ornamented, dominated by flutes, incised, and pierced decoration. The surface of the lids over 15.0cm to 16.0cm in diameter is slightly smoothed. Barbotine decoration predominates, combined with oval imprints on the periphery (*Todorova 2005.46; Leshtakov 2018.22,24–25*).

Of the lids that were discovered, 164 of them had handles (Fig. 16). The majority of these were not completely preserved, and in the case of six lids it was not possible to determine the shape of the handle (conical or cylindrical) because they were broken very close to their base. There appears to be a tendency for conical handles to be associated with a smooth transition between the shoulders and the base of the handle. This transition can be most clearly observed in lids with fully preserved handles or those that are broken at the middle. Lids with a pronounced transition between the shoulders and the handle typically feature a cylindrical handle. Band handles are characterized by an oval or oblong cross-section.

In the case of conical lids (Group III), the division between body and handle is not applicable, with the handle appearing as a natural extension of the body. In

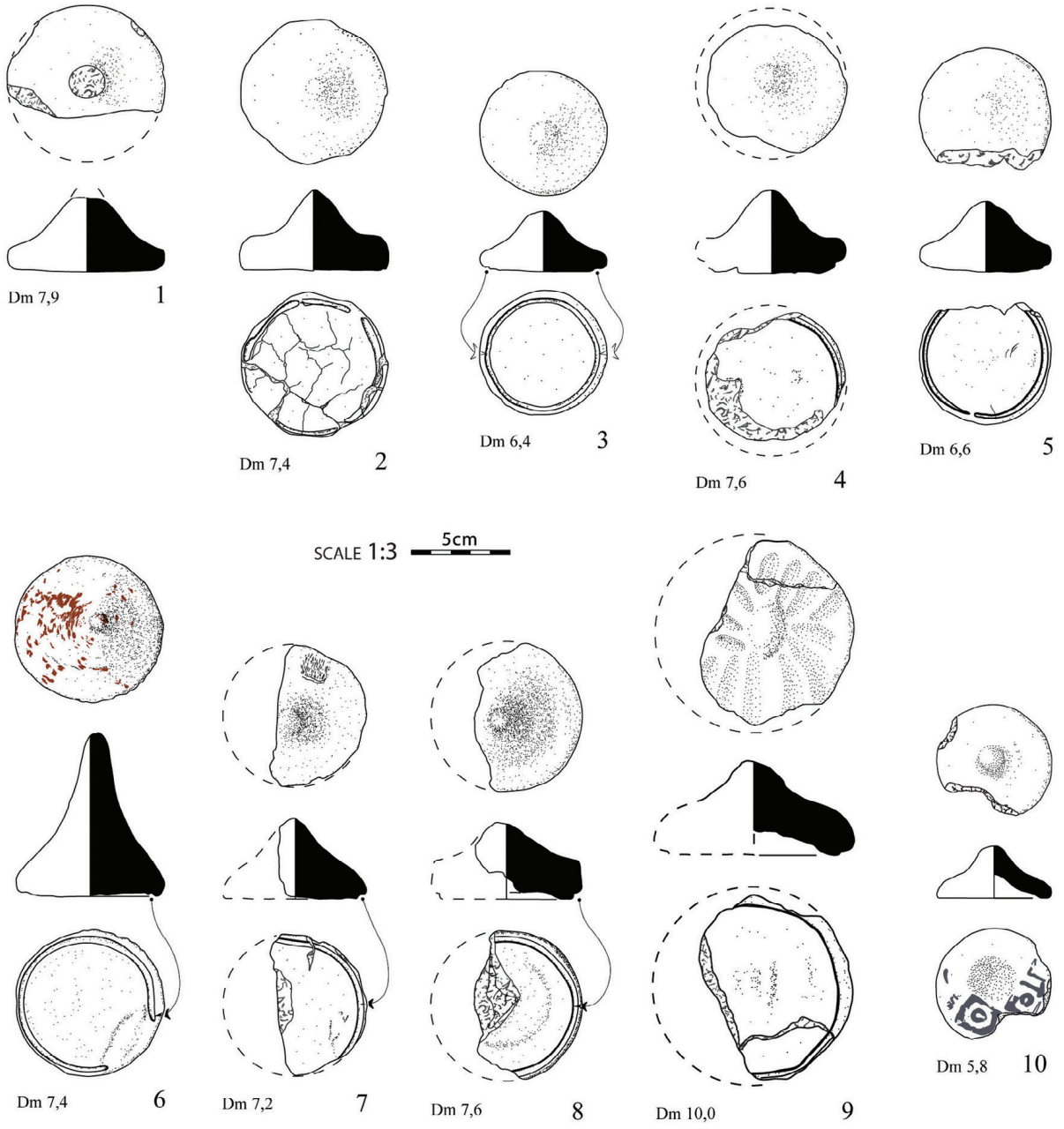

Fig. 13. Group III. Conical lids. Subgroup III.2: convex shoulders with straight (III.2.1) and concave (III.2.2) inner profile (scale 1:3).

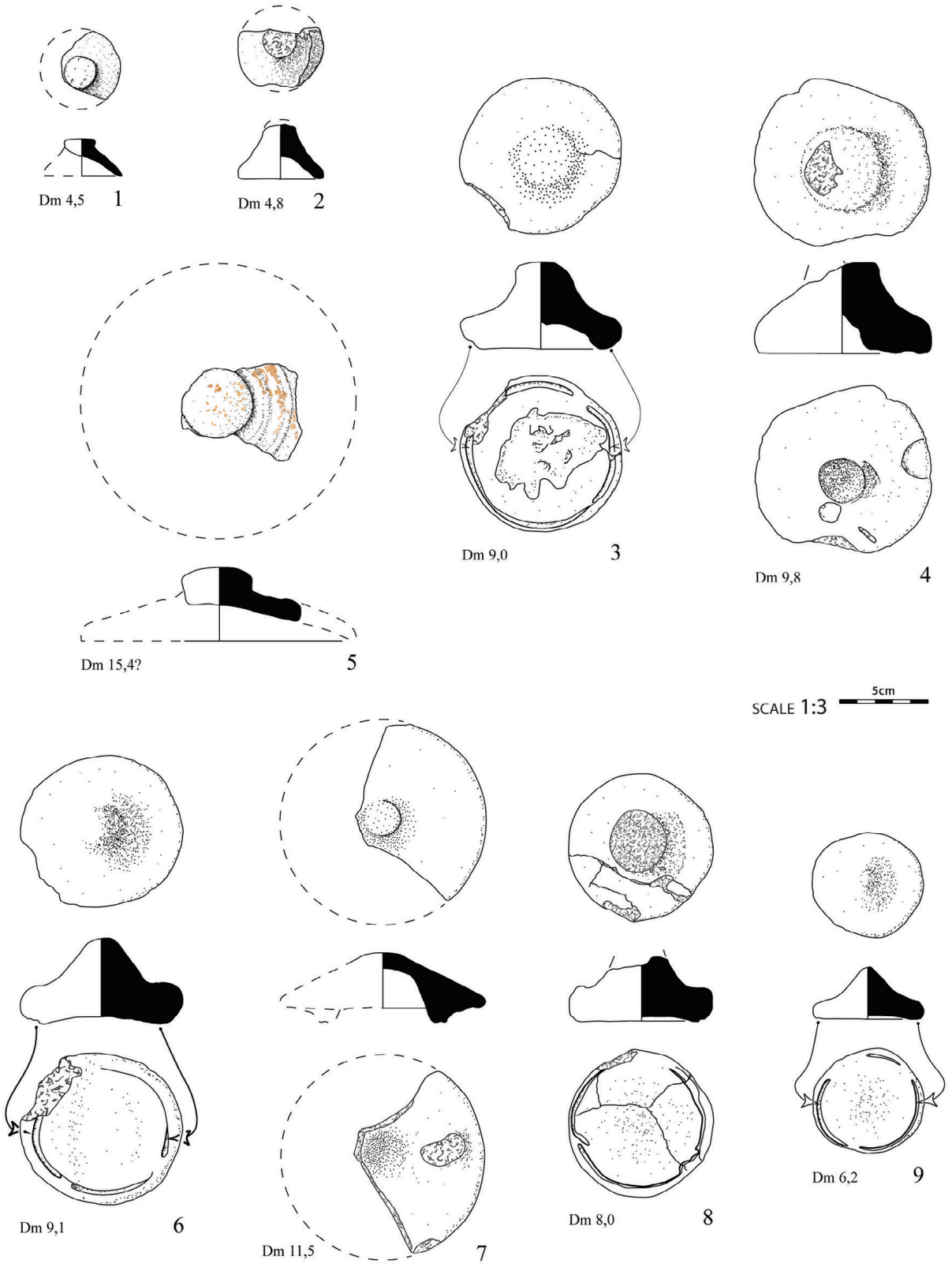

Fig. 14. Group III. Conical lids. Subgroup III.2: convex shoulders with concave inside profile (III.2.2), and with a hole on the inner profile (III.2.5) (scale 1:3).

this instance, the handle does not serve the function of gripping and lifting, but is rather intended to be decorative. In some of the lids, characterized by a concave inner profile, no handle is modelled, but the body is elongated in a conical hollow shape, in others the handle serves as a 'cap', modelled on the very top of the lid (Figs. 13.8–10 and 14.2).

Numerous Late Neolithic flat lids are known from southeastern Europe. From Bulgaria (Fig. 2.16–33), for example Hlebozavoda, west of Nova Zagora (Fig. 2.21), flat lids from the Late Neolithic layers were found (*Kănčeva-Ruseva 2000.117*). Numerous lids similar to those from Damyanitsa are known from the Late Neolithic village of Krushaka to the village of Vratitsa, in the Burgas region (Fig. 2.24), with disc-shaped flat lids predominating (*Leshtakov 2018.21–25*). Flat lids were found in the Late Neolithic layer of the Vinča settlement of Belo Brdo, Serbia (*Ignajatović 2008.266*). A flat lid similar to those found in Damyanitsa was pub-

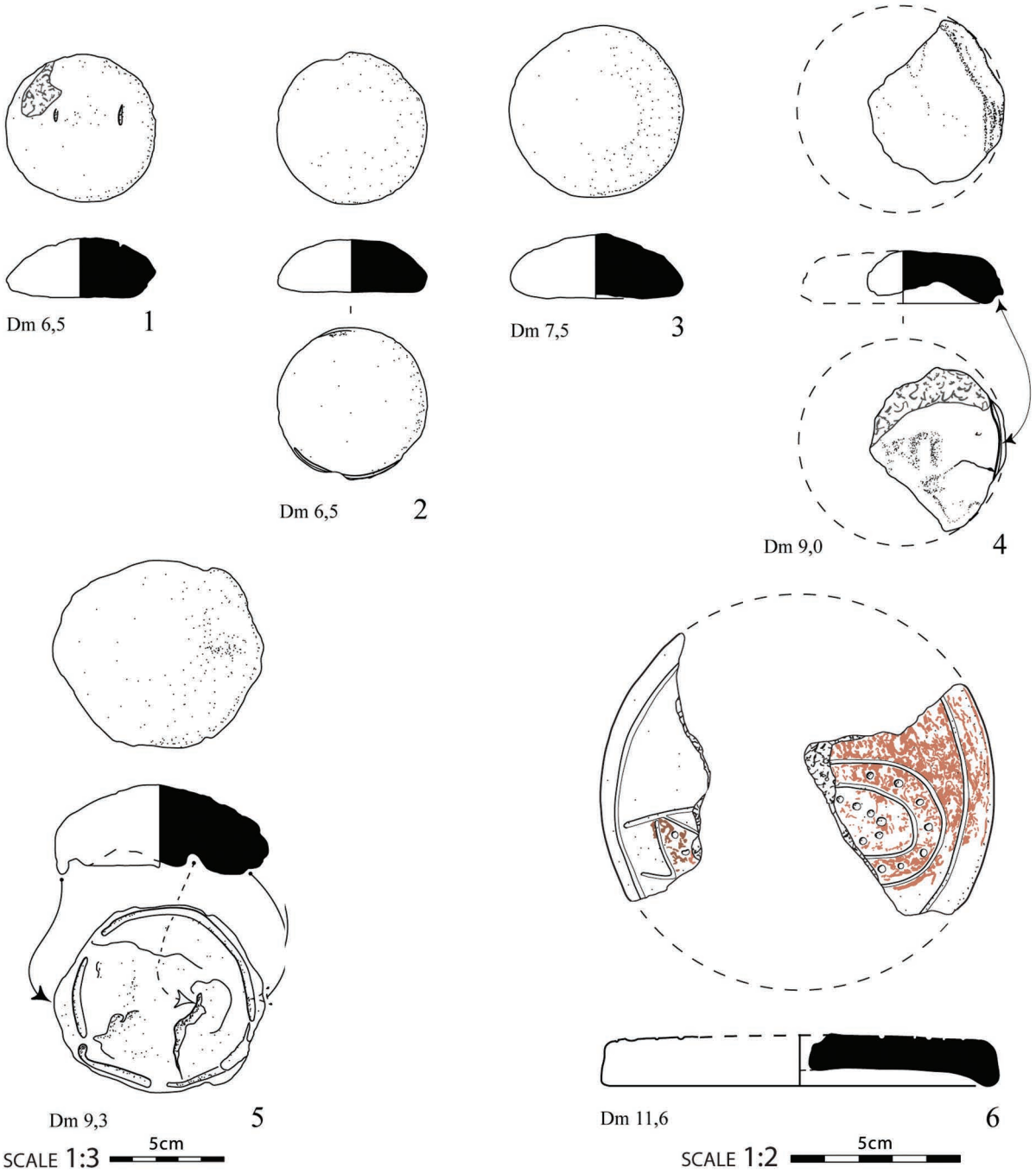

Fig. 15. Group IV. Curved lids. Subgroup IV.2: convex shoulders with straight (IV.2.1) and concave (IV.2.2) inner profile (scale 1:3); Group V. Flat-concave lids (scale 1:2).

lished in the Late Neolithic Layer 3/4 of Aşağı Pınar, Turkey (*Parzinger, Schwarzberg 2005.38,63,Taf. 77.7*).

The preponderance of small lids (up to 15.0cm in dm) in Damyanitsa can be attributed to the production of vessels characterized by a small mouth diameter. It is also interesting to note the appearance of other groups of lids, *e.g.*, conical, trapezoidal, and curved. These lids can also be associated with amphora-shaped vessels, which are characterized by two vertical handles starting from the mouth. In this case, if the vessel is to be covered, a lid that has vertical walls (Fig. 2.16,19,26,29–30) cannot be used, but instead a lid that is either flat or of a conical, trapezoidal, curved shape is necessary.

Decoration

Of the 190 lids from Damyanitsa, 67 have incised, painted, relief and impressed decoration (Figs. 17–18) and 29 lids are only covered with engobe, and these are poorly preserved and may be brown or red. Some of them have a dense engobe covering on the upper and lower surfaces (Fig. 9.11; Fig. 11.9–10; Fig. 17.1), while other lids have a dense engobe covering on only one of the surfaces (Fig. 7.1; Fig. 8.6; Fig. 9.3, 9; Fig. 10.1, 6; Fig. 12.10; Fig. 13.6; Fig. 17.3, 5). It is possible also there be taphonomic losses and that the colour slip may not survived on all surfaces. One lid has a combination of dense engobe coating only on the outside and red ochre on the inside (Figs. 7.4 and 17.2). At present, this technique is only known from Damyanitsa.

Incised decoration is predominant, applied in most cases to a well-finished surface (smoothed or polished). The decoration can be applied to the entire surface of the lid (external and/or internal), or to a specific area.

Incised decoration

Lids with incised decoration number 42 specimens.

With these items, decoration is found on the entire surface with alternating groups of horizontal and vertical straight lines, a herringbone pattern, zigzag motif, arcuate lines (spiralo-meander), developed short spirals, concentric circles, semicircles, pierced dots, wavy and S-shaped (meander?) elements, and a combination of incised lines and stabs, or a stepped line forming the crosses (Fig. 7.5; Fig. 8.1, 3–4, 8, 11; Fig. 9.6–8; Fig. 10.3, 7–8, 10, 12–14; Fig. 11.1–2, 6; Fig. 12.4; Fig. 17.7–12). Some lids have combined incised decoration with a coating of the entire surface with engobe (Fig. 7.9; Fig. 8.7; Fig. 11.4).

The zoned decoration occurs as single or a combination of various motifs: trapezoid, 'net', incised lines, S-

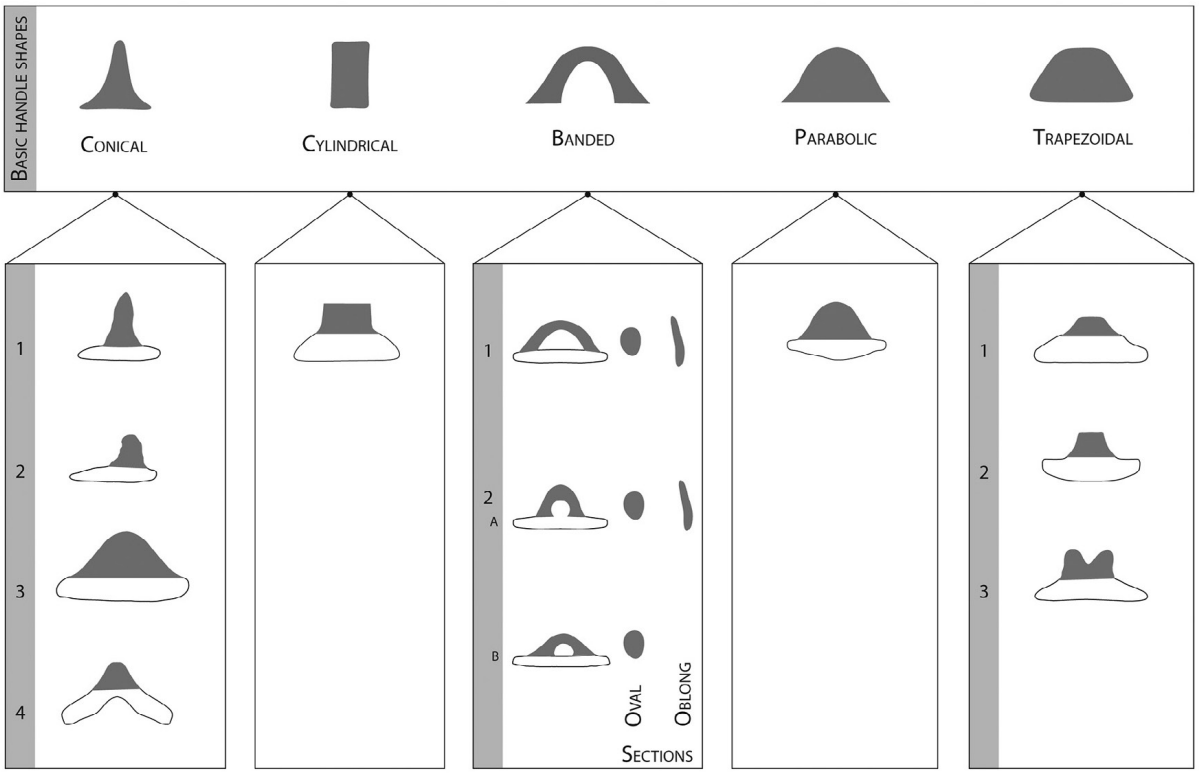

Fig. 16. Scheme showing the typology of the handles.

Fig. 17. Lids with different decorations (© Temelko Temelkov).

shaped elements inscribed in the corners, straight lines, arcuate lines and angles, and a herringbone pattern (Fig. 7.6–7; Fig. 8.5; Fig. 9.13,15; Fig. 10.4; Fig. 11.7). Several variants are found, characterized by a zoned decoration with a combination of red engobe and incised decoration (Fig. 7.2; Fig. 12.6; Fig. 18.10; Fig. 15.6; Fig. 18.12).

Painted decoration (Akropotamos, brown paint, graphite, bitumen)
One lid is identified with an Akropotamos-style drawing, created with thinned dark paint. The patterns are straight lines measuring approximately 0.3cm to 0.8cm in width and 2.4cm in length, as well as S-shaped lines (0.2cm to 0.5cm) and dots. The paint utilized to produce the drawing is notably thin and pale in colour (Figs. 9.12 and 17.4).

The second lid has brown paint on the outer surface. The painted pattern is very poorly preserved, applied on a beige-brown surface (Fig. 17.6). It cannot be attributed to the lids with Akropotamos-style decoration, because of the type and ornamentation of the painting.

Only one lid has graphite decoration. The painted decoration is applied on the inside. The motif is positive and is represented by a square, in the space of which a circle is depicted. The lid probably had four more squares with inscribed circles (Figs. 13.10 and 18.2).

There are traces of bitumen decoration on the outer surface of one lid. The decoration is very poorly preserved, with only minor traces of it remaining (Fig. 11.3).

Relief decoration
There are 20 lids with relief decoration. Here, too, two types of arrangement of decoration are observed – over the entire surface and in a specific, selected place.

Over the entire surface the variants are: flute-type decoration, modelled by pinching, pressing, and smoothing with the fingers (Figs. 7.11 and 8.12); shallow flutes (Fig. 12.3); relief circles (Figs. 9.16 and 10.5); decoration of buttons on the outside, and on the inside fluted (Fig. 11.5), fluted with meanders (Fig. 18.3), and spiral-type relief (Fig. 7.8). Some lids have combined relief decoration with an engobe coating (Fig. 9.10, Fig. 10.2; Fig. 18.4; Fig. 10.11; Fig. 18.5; Fig. 14.5). One lid has brown engobe on the inner surface, and there are traces of smoothing on the outer surface in the 'panicle' technique (Fig. 18.6).

Zoned relief decoration with a flute of two opposite groups composed of three arcuate lines is sometimes found (Figs. 10.9 and 18.7), as well as relief buds (Fig. 8.2), and impressions on the edge of the lid, giving a wavy contour (Fig. 8.9). One lid has an engobe coating, with impressions applied to the edge of the base of the lid and densely covered with brown engobe (Fig. 18.8).

Decoration in the barbotine technique only occurs on one lid, and this is made by finger strokes dragged from the handle to the edge of the lid (Figs. 13.9 and 18.9).

Impressed decoration
One lid is decorated by pressing with a round object near the edge of the base. The surface is polished (Fig. 18.1).

There is no clear relationship between the groups of shapes and the types of decorations. Of all the lids, only four with an elliptical shape have been identified, two of which have incised decoration. One has a combined incised decoration located on the entire outer surface (Fig. 8.8), and the other has a zonally located decoration, through which its elliptical shape is hypothetically established (Fig. 9.15).

It is possible that the decoration was combined with the vessels on which they were placed. On such example is known from the Late Neolithic settlement of Hlebozavoda near Nova Zagora, where a vessel with fluted decoration in spiral motifs was discovered together with its corresponding lid decorated in the same way (*Kănčeva-Ruseva 2000.119,Abb. 1*). However, in the case of Damyanitsa, the situation is a little different. Based on the processed material from the settlement, it is clear that there are a significant number of vessels with painted decoration. Only one lid has an Akropotamos painting, which suggests that much of the decoration on the lids underwent a separate development, as it did not follow that of the vessels.

The lid, the inner part of which is covered with red ochre, is interesting (Figs. 7.4 and 17.2).

Skin treatment experiments show that red ochre has disinfecting properties. The iron-rich powder reverses the decay process, as well softening animal hides for processing (*Hodgskiss 2020*). It is possible that the ochre rubbed on the base of the lid was applied to disinfect and delay the process of spoiling the contents of the vessel that the lid covered. Stone axes and adzes

Fig. 18. Lids with different decorations (© Temelko Temelkov).

with traces of ochre were also found inside ceramic vessels at the settlement (*Grębska-Kulow* et al. *2020. 231*). It is also interesting to note that many anthropomorphic figurines with ochre rubbed on the surface have been found in Damyanitsa.

The matter of the incised decoration is curious. It occurs less frequently during the Late Neolithic and appears massively during the Early Chalcolithic. Individual motifs and techniques used for decoration initially appeared on the cult tables, later passing into the decoration of vessels (*Todorova, Vajsov 1993.219–221*). This phenomenon is also observed in the Late Neolithic cult tables, including those from Damyanitsa. For instance, wavy line motifs are prevalent on Early Chalcolithic vessels, yet in the Late Neolithic at Damyanitsa III they are observed as a decoration on cult tables. The incised decoration of a stepped line forming crosses is also evident on a lid (Figs. 10.3 and 17.12), which is also attested on the Late Neolithic cult tables from Damyanitsa (*Grębska-Kulova 2000.53,Fig. 4.4*).

On some lids with incised decoration, indentations resembling 'signs' (Figs. 9.7–8 and 17.10–11) are observed. Could these lids be associated with more specific functions, for example to indicate what is stored in the vessel that the lid covers?

The incised 'spiral' type decoration can be referred to as the Akropotamos-style decoration, on the basis that the same element is found on the vessel, but in painted form (Figs. 10.7 and 17.7).

Only one lid with traces of bitumen decoration was found (Fig. 11.3). Organic bitumen decoration is one of the most characteristic attributes of the Promahon-Topolnitsa settlement, made of a thin layer of bitumen. Bitumen was more often used as an adhesive on which other types of decoration could be applied. Common motifs made with bitumen decoration include spirals and zigzag elements (*Vajsov 2007.85*). Bitumen can also be used as an adhesive. Two small stone adzes with traces of bitumen are known from Topolnitsa, which were used to clamp the tool to the handle. There are also figurines with traces of bitumen on the broken parts, probably used for gluing (*Vajsov 2007.89,Fig. 4*). Bitumen would also have been suitable for gluing the lids to the vessels. However, the absence of traces of bitumen on the inner profile of lids from Damyanitsa suggests that alternative methods may have been employed for sealing the lids to the vessels.

Spatial distribution within the settlement, dating of the lids and cultural affiliation

Lids were discovered almost everywhere in the settlement (Fig. 19). Within the northern sector, 44 lids were found: 33 flat, three trapezoidal, and eight conical. A higher concentration of lids is observed in sectors 119 (12 lids), 121 (8 lids), and 220 (7 lids). According to the researchers, it is likely that structure in sectors 119 and 220 represents a silo for storing cattle feed (Fig. 19). Fifteen lids were discovered there, all flat except for one, which is conical (Fig. 7.4, 11; Fig. 8.3; Fig. 9.5; Fig. 10.1, 3, 12; Fig. 11.2; Fig. 13.3). Two similar lids were found in a pit in sector 220 (Fig. 11.8). The lids are flat, Group I. A total of 12 lids were found in sector 119, all of which are Late Neolithic. In test trench 52, four flat lids were found in three pits (Fig. 19).

The central sector (Fig. 19) shows the highest concentration of lids. Here, 110 examples were found, and all groups are represented: 86 flat lids, 8 trapezoidal, 10 conical, 5 curved (the whole group), and the flat-concave lid.

The southern sector (Fig. 19) of the site was only occupied during the Late Neolithic. Twenty-four lids were found there, five of which fall within the same structure, number 7–a Late Neolithic house (Fig. 14.7; Fig. 9.13; Fig. 12.7). The lids found in this sector are predominantly flat (19), while three are trapezoidal and two are conical. Group IV and V lids are missing.

The spatial distribution of the lids provides a clear indication of the location and core of the Late Neolithic settlement. The lids found in the southern part of the site, where only Late Neolithic occupation has been identified, are not significantly different from those found in the rest of the site. On the basis of the typology of forms, no clear distinction can be made between the Late Neolithic and Early Chalcolithic lids.

A total of 170 lids were assigned to Late Neolithic contexts in Damyanitsa, and only 15 to the Early Chalcolithic (Fig. 8.1; Fig. 12.5, 12; Fig. 13.1, 4, 8–10; Fig. 14.1, 3, 5–6). Among the Early Chalcolithic lids, one is a flat lid, four are trapezoidal, and 10 are conical. Curved and flat-concave lids are not represented. There are five lids from the Late Neolithic to Early Chalcolithic transition, all of which are flat (Fig. 9.9,14).

Two of the lids recall elements from a slightly earlier period–the Middle Neolithic, the transition from the

Early to the Late Neolithic in the Middle Struma. In terms of form and decoration, one of the lids is reminiscent (Figs. 15.6 and 18.12) of those from the Bulgarchevo II-Dolna Ribnitsa cultural group (Fig. 2.14), which have been assigned to the Middle Neolithic (*Pernicheva-Perets* et al. *2011*). Furthermore, the discovery of a single such lid in Damyanitsa lends additional support to this assertion. It can be assumed that this is the earliest representative among the lids found there, probably made quite early in the Late Neolithic. The lid was found in the central part of the site in sector 113 (Fig. 19). Another lid also points to the earlier period, but only in terms of the combined decoration of incised and pierced features (Fig. 8.5). It was discovered during the 1985 excavations in test trench 1 (Fig. 19).

At the Middle Struma, a smooth transition from the Late Neolithic to the Early Chalcolithic has been ob-

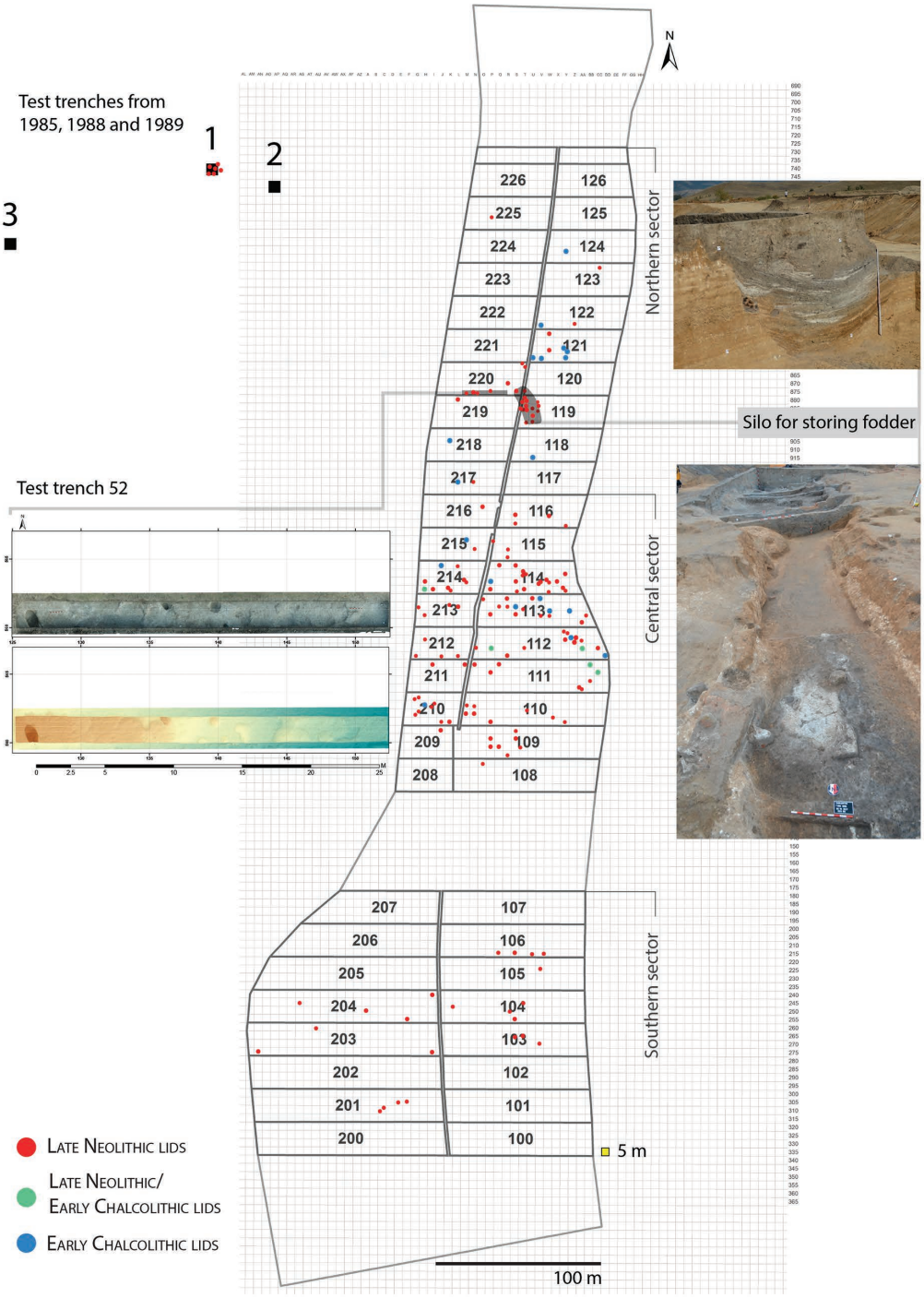

Fig. 19. Plan of the entire site with the location of the lids and some archaeological contexts in which lids were discovered (photos © Ivan Vajsov).

served. Typologically, the lids found at Damyanitsa show a strong continuity between the Late Neolithic and Early Chalcolithic. No differences were found in the technology of manufacture, mineral and organic (vegetal) inclusions, or surface colour. This trend is also noticeable at other sites along the Struma, such as at Bulgarchevo, Strumsko and Slatino (*Pernicheva 1992.222; Chohadzhiev 2006; Chohadzhiev 2007*). The only indication of the new period at Damyanitsa is the appearance of graphite decoration on pottery, while the other groups of painted ceramics continued to be made.

The first two occupation phases at Damyanitsa (I and II) are attributed to the Vinča Culture. The pottery of phase Damyanitsa III, at the end of the Late Neolithic, combines elements of the Gradac phase of the Vinča B2/C culture, painted wares of the Akropotamos type, which are typical of East and Central Greek Macedonia, the Dimitra-type bichrome painting and the Promachon-type red painting. During the Early Chalcolithic period, there are indicators of the presence of the Dikili Tash-Slatino-Gradeshnitsa cultural complex, which expanded across Western Bulgaria and Northern Greece (*Grębska-Kulow* et al*. 2018a.30*).

One of the main questions that arises is to which cultural group belong the lids from Damyanitsa–Vinča, the Akropotamos-Topolnitsa or Gradeshnitsa-Slatino-Dikili Tash? The decoration and the technology by which the ceramic objects were made often is a kind of indicator for the time and cultural affiliation.

The ornamentation, and to some extent the technical details of the making of the object, can provide information about the period to which they belong. The only reliable method of dating the flat lids is the stratigraphic layer from which they originate. Stefan Hiller (*2002.103–104*) defines flat lids with rich ornamentation as one of the elements that connect the Late Neolithic with the Early Chalcolithic.

Incised decoration is extremely rare on the vessels from the Late Neolithic, so the decoration on the lids does not follow that on the vessels, but has its own development. It shows remarkable similarities with the decoration of the cult tables, but only in terms of incised decoration and a combination of incised and stroked decoration. There are also similarities in the use of red engobe, which often covers certain surfaces between the incisions.

Based on their surface decoration, a large number of the lids can be attributed to the Vinča culture. It is characterized by incised decoration, which is also the predominant type of decoration on Damyanitsa lids, as well as the fluted decoration. The lids with incised 'signs' also belong to this culture, which some researchers associate with proto-literacy (*Merlini 2009*).

The lids with thinned dark paint and bitumen decoration can certainly be attributed to the Akropotamos-Topolnitsa culture. The lid that is rubbed with ochre on the inside and has traces of engobe on the outside also refers to this cultural group. One lid with incised decoration can also be attributed to this culture, because it repeats motifs from painted pottery (Fig. 10.7).

Of the discovered Early Chalcolithic lids, four are decorated (Fig. 8.1; Fig. 13.9–10; Fig. 14.5). Based on the decoration, one of the lids can be attributed to the Dikili Tash-Slatino-Gradeshnitsa culture (Fig. 8.1). It is noteworthy that some Early Chalcolithic lids from Damyanitsa (Fig. 13.1,4,9) have similar shapes to those found in Gradeshnitsa, and one lid in particular (*Danov 2019.213,Fig. I.13:13.7*).

The comparative analysis reveals that the lids from Damyanitsa have analogues in numerous prehistoric settlements of the Late Neolithic and Early Chalcolithic (Fig. 2).

The function of the lids

The form of the lid is indicative of its purpose. Flat lids cover the contents of the vessel, but are not conducive to transportation, *i.e.* they are typically utilized on-site. One result of the typology that has been made is that an interesting group of 19 lids, which have a circumferential groove on the inner profile, stood out. They will be conditionally called *lids with a groove* (Fig. 11.12; Fig. 12.7–9; Fig. 13.2–9; Fig. 14.3, 6, 8–9; Fig. 15.2, 4–5; Fig. 20; Fig. 21). Grooved lids may prove effective for transportation and storage.

The groove probably served to mark the mouth of the vessel. These lids may have been designed to seal the vessels, preserve their contents, and facilitate storage and/or transport of liquids and foods (Fig. 22). Exceptions are two lids (Fig. 11.12; Fig. 12.7; Fig. 20.1–2), the groove of which is only marked and probably served to settle it into the mouth of the vessel. In one group of lids the groove is not completely made, *i.e.* there is a break. It may have served only as a support to prevent the lid from falling from the mouth of the vessel, and

perhaps it did not need to be fully made to seal the vessel well. This type of lid was intended for vessels of either small and medium size (5.0cm to 30.0cm in height) or larger vessels with long necks and narrow mouths (with a diameter of the rim between 6.0cm and 10.0cm, based on the lids that were found with a groove) (Fig. 23), and in particular long-necked amphorae-like vessels with two vertical handles and/or vessels with long cylindrical necks. Such forms appeared during the Late Neolithic in Damyanitsa III (Akropotamos-Topolnitsa culture) (Fig. 23.1) (*Grębska-Kulow* et al. *2017a.18*), which continued to be produced in the Early Chalcolithic (Fig. 23.2). In Balgarchevo III and IV (Fig. 1.3), amphorae-like vessels and those with a long cylindrical neck were discovered (*Pernicheva-Perets* et al. *2011.179,181*). Later, similar amphorae vessels were associated with the transport and storage of alcoholic beverages. Some scholars link Bronze Age amphoras, narrow-necked beak-spouted jugs and others pouring, mixing, and serving vessels with the introduction of exotic alcoholic beverages and new practices associated with hospitality as a means of creating and maintaining social bonds (*Webb, Frankel 1999.39*).

It is known that some foodstuffs can be fermented into alcoholic beverages, the most widely used for this purpose being cereals (for making beer) and grape juice (for making wine) (*Barnard* et al. *2011.977*). Moreover, evidence that grapes may have been fermented dates back to the Neolithic period in the Near East from the settlement at Haji Firuz Tepe, Iran, dating from about 5400–5000 BC. Six vessels were found there, the analysis of which showed the presence of tartaric acid. Vessel shapes are suitable for wine storage – narrow, tall mouths that may have been plugged with clay or covered with some other type of material (*McGovern* et al. *2017*).

There is information about wine production in Dikili Tash, and more specifically from the so-called House 1 from the second half of the 5th millennium BC, which was destroyed by fire around 4350–4250 BC (*Valamoti* et al. *2015.131*). Large quantities of grape pips (2460) and pressed grapes consisting of empty grape skins were found in this structure, along with a number of bowls and cups. The remains of grapes are also associated with a specific vessel, and the results of analysing this show the presence of tartaric acid (*Valamoti 2015.37–41*). Finds of pressed grapes from House 1 also suggest that the grape juice was extracted there. In addition, experimental charring of fresh grapes, raisins, and waste products from wine production indicate that the archaeological remains of grapes from Dikili Tash are by-products of grape juice extraction and suggest wine production (*Valamoti* et al. *2015.131–134*).

According to Valamoti. unlike other traces of prehistoric winemaking, the presence of tartaric acid or malvidin/anthocyanin in ceramic fragments can be equally associated with grapes, must, raisins, and vinegar, and does not necessarily indicate wine. Although such grape juice could have other uses–as it can be used to make cakes, fruit syrup like *pekmez*, or vinegar – wine production at Dikili Tash is a plausible hypothesis, supported by the discovery of pressed grapes (*Valamoti 2015.134*).

Evidence of wine production was also found in the Areni-1 cave in Armenia, in a layer dating from the Late Chalcolithic to 4223–3790 cal BC. A clay platform was uncovered with raised ends at one end which sloped towards the mouth of a large vessel dug into the lower end of the platform. The discovery in the immediate vicinity of this installation of dried grapes, grape seeds and bunches, as well as grape skins attached to the stems, leads to the interpretation that it was used for pressing grapes and, by extension, producing wine (*Barnard* et al. *2011.979–983*).

There are remains of grapes in the territory of Bulgaria at Tell Yunatsite, in the Pazardjik region (Fig. 1.46), in a layer from the Chalcolithic era in Horizon BII. Along with pressed grapes, the remains of wheat, barley, rye, oats, lentils, apples, and pears were also found. The researchers do not rule out the possibility that these materials could have been used to produce some form of alcoholic drink (*Boyadzhiev* et al. *2019.65*).

The grooved lids from Damyanitsa were likely used to seal or cover containers for preserving, storing, and transporting liquids and/or foods. However, without chemical analyses it is impossible to determine the exact contents. The transport and storage hypothesis is supported by experiments involving the placement of lids on amphorae-like vessels with long and narrow necks. This type of vessel is extremely suitable for transporting liquids, precisely because of their shape. The wide bodies and long, narrow necks can prevent spillage, and the handles are ideal for gripping and carrying. And if, in addition, a lid with a groove was used which fit very well on the mouth, which was then sealed by means of an organic material (*e.g.*, wax, resin, bitumen), long-term preservation and/or transport would be more likely

Fig. 20. Lids with groove (© Temelko Temelkov).

Fig. 21. Lids with groove (© Temelko Temelkov).

to succeed. It should also be noted that most lids with a groove from Damyanitsa are conical in shape, which in turn changes the appearance of the vessel, giving it a pointed top (Fig. 23). The appearance of lids with a groove during the Late Neolithic in Middle Struma, especially those with a conical shape, can be partly explained by the emergence of amphora-like vessels, particularly in response to the need to preserve and/or transport food and liquids.

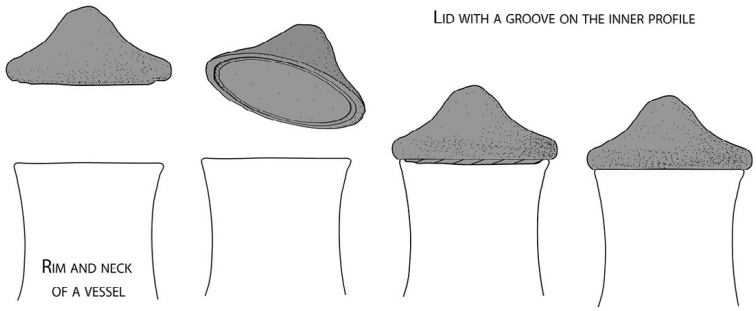

Fig. 22. A hypothetical use of grooved lids.

The question of the stoppers and sealings found in Greco-Roman Egypt is of great interest in this context. Through meticulous research, scholars have successfully identified and categorized the various stoppers and sealings utilized for the purpose of sealing amphorae. The clay sealings from the Hellenistic-Roman village of Bakchias are divided into three subgroups: the conical-trunk sealings, the mushroom-shaped sealings and the convex-with-cavity sealings. The convex-with-cavity type are closely resemble the curved lids from Damyanitsa in shape (Fig. 15.4–5) (*Denecker, Vandope 2007.115–116,Fig. 2*).

A category of rounded flat lids for small food containers and small closed-shaped vessels for cooking and other purposes was unearthed at Velika Castle in Greece dating back to the 6th century AD. The lids were found in large quantities throughout the settlement and appear to have been produced locally, as two moulds used for their manufacture were discovered on-site. The diameter of the lids is between 13.0cm and 21.5cm (*Sdrolia 2019.88,Cat. No. 251–259*).

Based on the research of ethnological studies of the pottery of Asurini do Xingu (an Amazonian indigenous population inhabiting a village in the margins of the Xingu River, Pará, Brazil), scholars have defined several types of vessels for different purposes: cooking, serving, storing and transporting foods and liquids. Liquid transportation and storage vessels are further categorized into six types. An interesting finding is that, before firing, the vessels are dried to different extents depending on their form. The vessels for water transportation–which have a rim diameter smaller than the body of the vessel – require drying with the rims upturned, allowing the body to expand (*Silva 2008.222–223,228,Fig. 1*).

It is interesting to note the 15 lids from the large structure, which is a silo for storing cattle feed. One of the

Fig. 23. Vessels from Damyanitsa:* 1 *Late Neolithic vessel with a long neck and narrow rim, Akropotamos-style decoration and grooved lid;* 2 *Early Chalcolithic amphora-like vessel with two vertical handles, graphite decoration and lid with groove (photo Temelko Temelkov). The lids do not belong to these vessels. These are combined to illustrate the suggestion that grooved lids were used for this type of vessel.

questions is what were these lids covering there? The majority of the structure is located in the northern 119 sector of the site, where the dimensions of the silo are 18.4m long and 9.6m wide, with the maximum depth of 2.8m. The silo continues in a north-westerly direction in sector 220, but with much thinner layering (Fig. 19). Fourteen of the lids belong to Group I–flat lids, and one to the typological Group III–conical lids. Twelve of the lids have handles: five conical, two cylindrical and five banded. The diameter varies from 6cm to 14.0cm. It should be noted that five of the lids have incised decoration (Fig. 8.3; Fig. 10.3, 12; Fig. 11.2; Fig. 17.12) and four are covered with engobe (Fig. 10.1). The lid with ochre from the inner side was found in the silo (Figs. 7.4 and 17.2). One of the lids without decoration is conical and has a groove on the inner profile (Figs. 13.3 and 20.6). Is it possible that in this type of structure, in addition to the storing of cattle feed, some food (grain?) could have been stored to be distributed/used/cooked later, and thus the lids would have been particularly important to store and protect (from insects and rodents) what was contained in the vessels?

From the experiments conducted on how the lids would fit on some vessels with a similar diameter of the mouth, a lid was found that probably belongs to a specific vessel, a cup. The lid (Figs. 9.11 and 24.1) was found in close proximity to where the cup was found. A comparison of the processing method, colour, mineral inclusions, and surface shows that the two ceramic objects have extremely similar characteristics. It is noteworthy that the decoration on the outer surface of the cup is fluted, and traces of engobe can be seen on the lid on both the inside and outside. The difference in decoration does not necessarily mean that the lid was not created for this particular vessel, as it is possible that the lids were used for other vessels to which they provided a good fit (Fig. 24.2–3), such as if they had similar characteristics. The option of creating vessels for specific lids (or lids for specific vessels) should not be ruled out, especially if the lids were 'masterfully' made. The author hypothesizes that one lid may have been used for several vessels with similar-sized mouths, and this assumption may in turn provide an answer to why the number of recorded lids is lower (at most sites) than the number of vessels, based on the published materials.

Fig. 24. Vessels from Damyanitsa: **1-3** ***Late Neolithic ceramic cups from Damyanitsa with lids;*** **4** ***Anthropomorphic Late Neolithic vessel with a long neck and narrow rim and lid (photo Temelko Temelkov). The lids shown in the photos are for illustration purposes only, they do not belong to the vessels on which they are placed. An interesting question is whether the lids and vessels were produced together. In cases where they were fired separately, there may be significant differences in colour, but they are ultimately used together.***

The smallest lid found in Damyanitsa is 3.4cm in diameter (Fig. 9.2), and it is possible that it also served as a stopper for some amphora-shaped vessel with a very narrow mouth, *i.e.* with the handle downwards (Fig. 24.4).

A lid was found in Damyanitsa (Fig. 14.7), which is represented in the literature in two ways: with the handle up (*Chohadzhiev 2006.Fig. 86; Danov 2019.Fig. I.13*) and with the handle down (*Chohadzhiev 2006.Fig. 86*). The lid has a very well-smoothed surface on the outside. On the inside, where the handle is, the surface varies from rough to smooth. The wide base of the handle starts very close to the edge of the lid, which leaves very little room for the lid to be attached to the mouth of the vessel. It is possible

that, due to the rough surface, the lid was placed with the handle down, *i.e.* with the handle in the vessel. It is possible that something that could be immersed in a liquid was attached to it. In the other case–with the handle on the outside – it serves for gripping and lifting, and the smoothed surface goes inside the vessel. A very similar lid, but of smaller dimensions, was found in the Late Neolithic settlement of Topolnitsa, and is currently on display at the Blagoevgrad Regional Museum of History.

Conclusion

This study presents an analysis of the development of forms and decoration of 190 Late Neolithic and Early Chalcolithic lids, along with their chronology and regional development during the same time. The lids from Damyanitsa show a smooth transition between the two periods, which is also attested in other settlements. The only indicator for the Early Chalcolithic is the appearance of graphite painting on the pottery and Gradeshnitsa-type of ornamentation. Through a detailed typology, a rare group of internally grooved lids has been distinguished, which has led to reflections on their function. This inner groove apparently had the function of holding the lid to a particular vessel type and represents an evolution in its functionality. The hypothesis that they served to preserve and transport liquids will be subject to further analysis and research in the future to clarify their exact function.

In terms of chronology, flat lids are the most common in the territory of Bulgaria during the Late Neolithic, but appear first in the Early Neolithic at Yabalkovo. In the region of Middle Struma, flat lids are first documented in the Late Neolithic and can serve as a chronological indicator for the period in the region, but only for their first appearance.

The analysis of the decoration on the lids from Damyanitsa shows that the majority of the lids indicate an independent development of decoration, different from that of the vessels.

Quantitatively, the prehistoric settlement of Damyanitsa has so far been ranked third (after Krushaka, Burgas and Hlebozavoda, Nova Zagora) in terms of the number of lids found (based on publications) on Late Neolithic sites in the territory of Bulgaria. This large number of lids allowed a detailed typology of the individual groups, subgroups, types and subtypes, and the search for relevant analogies from other sites. Regarding their distribution, it is noted that similar lids are found across the Balkan Peninsula, Turkey, and even in Hungary.

The detailed analysis of the found lids presented here is an important part of the study of the prehistoric settlement near the village of Damyanitsa, and it complements our understanding of the complete ceramic ensemble.

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Digging at the museum: unveiling the Late Neolithic/ Chalcolithic individuals of Lapa da Bugalheira (Torres Novas) through bioarchaeology

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ABSTRACT – *Lapa da Bugalheira is a natural cave with a funerary context dated to the Late Neolithic/ Chalcolithic period. This cave was excavated in the 1940s, and in 2019. The aim of this work is the osteological study of the human remains recovered from both interventions that correspond to the same funerary context. This assemblage of human bones corresponds to a minimum of 35 individuals, 24 adults and 11 non-adults. The prevalence of pathological conditions is low, and they include oral, traumatic, infectious, degenerative and congenital ones. This research confirms that the re-examination and study of old collections are an essential contribution to our knowledge of past populations.*

KEY WORDS – *collective burial; natural cave; museum collection; hypodontia; bioarchaeology*

Izkopavanja v muzeju: odkrivanje posameznikov iz poznega neolitika/bakrene dobe s pomočjo bioarheologije v jami Lapa da Bugalheira (Torres Novas)

IZVLEČEK – *V jamskem najdišču Lapa da Bugalheira je bil odkrit grobiščni kontekst iz poznega neolitika/eneolitika. Izkopavanja so potekala v 40. letih 20. stoletja in zatem še leta 2019. V prispevku predstavljamo osteološko analizo človeških ostankov, izkopanih v teh raziskavah, ki pripadajo istemu grobnemu kontekstu. Človeške kosti pripadajo najmanj 35 posameznikom, 24 odraslim in 11 neodraslim. Pojavnost patoloških stanj je nizka, odkrili smo ustne in travmatske infekcije, degenerativna ter prirojena obolenja. Raziskava je potrdila, da ponovna študija in analiza starejših zbirk pomembno prispevata k poznavanju prazgodovinskih populacij.*

KLJUČNE BESEDE – *skupinski pokop; jama; muzejska zbirka; hipodontija; bioarheologija*

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Introduction

During the later decades of the 19th century and early decades of the 20th, numerous prehistoric sites were excavated in what is today Portuguese territory.

Many of these tombs contained large assemblages of human bones, but their destinies were quite diverse, as they headed to museums and specific collections, or they were not collected or or ended up getting lost. For some of them, a brief note was published, but many ended up forgotten and never studied, despite the information they may have contained. The Museu Geológico (MG) of Lisbon houses several of these collections, which started to be studied at the end of 1990s (*Silva 2003; 2012; Boaventura* et al. *2014; Silva, Ferreira 2016/2017*).

Lapa da Bugalheira, a natural cave, is among the sites whose human remains are currently held by the MG. It was first publicly mentioned by Afonso do Paço in 1941 at the First Congress of Natural Sciences held in Lisbon, where he described the excavation phases and stratigraphy. These initial findings were promptly published (*Paço* et al. *1942*) and subsequently revisited in a posthumous publication (*Paço* et al. *1971*). In 1996, the archaeological materials were published in a review article (*Carreira 1996*).

Archaeological site and history of interventions

The natural cave of Lapa da Bugalheira is located in Almonda, Torres Novas (Portugal) (Fig. 1), with the geographical coordinates of: X=–41837.977; Y=–18648.817; Z= 165.009. Geomorphologically, this cave is located in the southwest limit of Estremenho limestone massif (*Manuppella* et al. *2000*), in the Serra de Aire mountain (*Rodrigues* et al. *2020*). The area's environmental conditions historically favoured settlement by agropastoral communities, offering excellent conditions for hunting and pastoralism on mountain slopes, and reliable water resources from the Almonda River (*Maurício 1987; Manuppella* et al. *2000; Andrade, Van Calker 2019*).

The site began to be noticed in 1940, during the excavation of the Almonda cave (*Paço* et al. *1971*). After the initial prospecting work, the archaeological importance of Lapa da Bugalheira was recognized, prompting immediate archaeological excavations beginning in 1941 under the direction of Afonso do Paço, Maxime Vaultier and Georges Zbyszewski (*Carreira 1996*). The works allowed the identification of two archaeological layers: layer 'a' which contained a lot of rubble and layer 'b', identified as the archaeological layer dated from the 'Eneolithic' based on the material typologies (*Paço* et al. *1942; 1971*). Various archaeological materials were recovered from the latter, such as polished and chipped stone utensils, hand mills, slate slabs and decorated and undecorated equid phalanx idols, with the latter becoming the iconic materials of the cave (*Paço* et al. *1942; 1971*). Human remains were also unearthed, and according Afonso to Paço *et al*. (*1971*) these correspond to ten very incomplete skeletons, in foetal position: one in the centre and the remaining next to the cave wall. These belonged to non-adults and adults of both sexes. These human bones are stored in the MG but are mixed, preventing the individual identification of burials (Fig. 2).

In 1946, Lapa da Bugalheira was classified as a Property of Public Interest (Decreto lei 35 817, DG, I Series, no. 187, 20-8-1946) (*General Directorate of Cultural Heritage 2020c; Rodrigues* et al. *2020*).

During the 1980s, the Torrejana Society of Speleology and Archaeology (STEA) conducted a speleological clearance at the site, which resulted in the identification of a narrow passage that gave access to a new gallery, named *Sala do Ricardo* (Ricardo's Room). A superficial necropolis dating to the Middle Neolithic was identified here (*STEA 1986; Maurício 1987*). During this clearance, archaeological materials and human remains were collected from the surface and chronologically dated to the Middle Neolithic (*Zilhão, Carvalho 1996*). At the end of 2021, three new dates were published on human remains

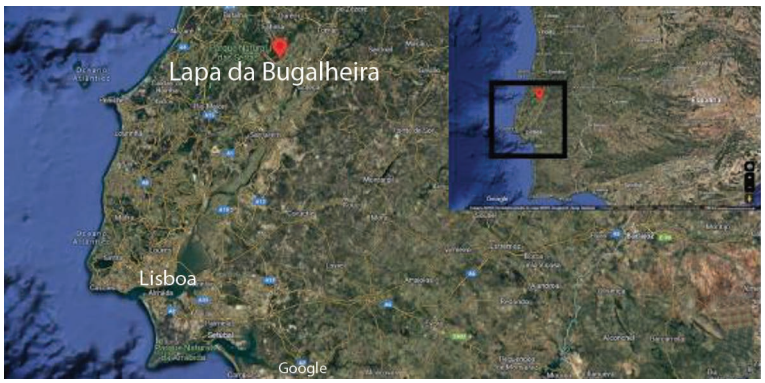

Fig. 1. Geographic location of Lapa da Bugalheira in the Portuguese territory.

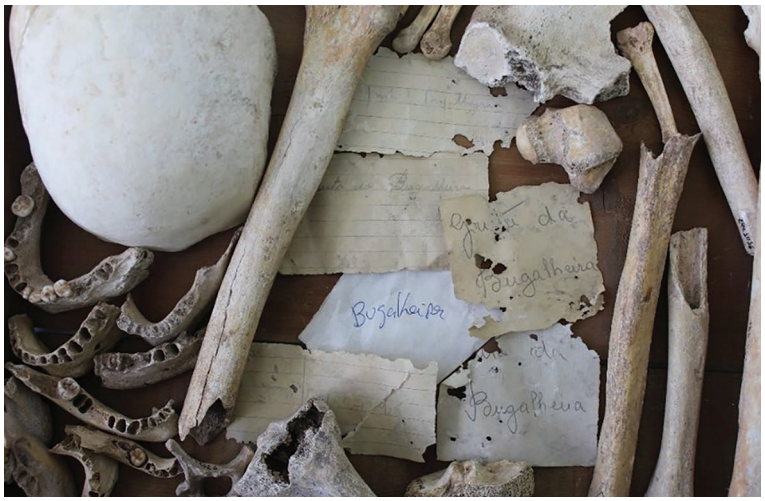

Fig. 2. Different labels and part of the osteological collection of Lapa da Bugalheira housed in the MG.

collected from the surface of Ricardo's Room, confirming the use of this part of the cavity during the first half of the 4th millennium BC, corresponding to the Middle Neolithic (Tab. 1).

In 2019, new excavations were carried out under the scope of ARQEVO (Archaeology and Evolution of Early Humans in the Western Façade of Iberia; see https://www.uniarq.net/arqevo_en.html) project under the supervision of João Zilhão and Filipa Rodrigues (*Rodrigues* et al. *2020*). In this intervention, a diagnostic survey was initially carried out around the access to Ricardo's Room, taking advantage of the trench opened by Afonso do Paço and collaborators decades before (*Rodrigues* et al. *2020*). According to published data, six stratigraphic units were defined. Layer 1 was characterized as corresponding to sediments deposited on the large stone blocks detached from the wall from the cave at the level where Paço's excavation had stopped. It contained very fragmented bone remains and scarce archaeological materials. Layer 2 corresponds to the archaeological level with materials attributable to the Early Neolithic. Absolute dating corroborates these claims (see Tab. 1). The remaining layers are sterile from an archaeological point of view (*Rodrigues* et al. *2020*). Subsequently, João L. Cardoso and Filipe Martins (*2023*) analysed the iconic decorated and/or worked on phalanges from Lapa da Bugalheira, collected by Paço *et al.* (*1942*), and confirmed the expected chronology corresponding to the transition between the 4th and 3rd millennia BC.

To synthetize these results, this cave consists of two rooms (Fig. 3): the one excavated by Paço and colla-

Laboratory Code	Sample	Context	BP Dating	Cal BC (2σ)	Reference
VERA-7047	LpBug.139 *Ovis* Metapod	M/13, C2, na 2	6084±26	5196 (2.0%) 5180 5063 (92.5%) 4932 4921 (0.8%) 4912	*Rodrigues* et al. *2020*
VERA-7048	LpBug.142 Human Femur	M/13, C2, na 2	6128±26	5209 (95.4%) 4992	*Rodrigues* et al. *2020*
ICEN-739	*Homo* Bone	Ricardo's Room Surface Collection	5090±60	4037–3711	*Zilhão, Carvalho 1996*
VERA-7231	LpBug_SR2 Human Femur	Ricardo's Room Surface Collection	4910±40	3775–3637	*Rodrigues, Zilhão 2021*
VERA-7232	LpBug_SR3 Human Femur	Ricardo's Room Surface Collection	4767±35	3638–3382	*Rodrigues, Zilhão 2021*
VERA-7233	LpBug_SR3 Human Femur	Ricardo's Room Surface Collection	4857±41	3710–3528	*Rodrigues, Zilhão 2021*

Tab. 1. Synthesis of published radiocarbon data from Lapa da Bugalheira. Calibration with the IntCal20 curve and the Calib 8.1.0 program (*Stuiver, Reimer 1993; Reimer *et al.* 2020*).

borators, in 1941, through which access is currently gained, and the more interior Ricardo's Room, accessible through a narrow passage cleared in the 1980s (*Rodrigues, Zilhão 2021*).

The aim of this research is the anthropological analysis of the human remains recovered from this cave. It thus includes the assemblage recovered in the 1940s that is today housed in the MG, and the osteological sample from layer 1 excavated in 2019.

Material and methods

The human bone assemblage unearthed from this cave is poorly preserved, and although according to the excavation notes of Paço *et al*. (*1971*) the human remains correspond to ten skeletons, nowadays the collection is disarticulated and very fragmented. The sample housed in the MG was first cleaned, labelled and marked, and an inventory of the bones was prepared. Later, the sample recovered in 2019 was added. Because the collection is entirely disarticulated and highly fragmented, the general recommendations by Ana Maria Silva (*2012*) for the analysis of commingled funerary contexts were followed. Dental remains were classified using the FDI tooth nomenclature.

Bone and tooth representations were analysed for adult individuals according to Silva (*2002; 2012*). The minimum number of individuals (MNI) was estimated following Herrmann *et al.* (*1990*), adapted by Silva (*1993*), with maturation considered for non-adults (*Silva 2012*). Age at death in non-adults was estimated using dental calcification criteria proposed by Holly B. Smith (*1991*) and Sakher J. AlQahtani, Mark P. Hector, and Helen M. Liversidge (*2010*), complemented by methods based on long bone lengths and epiphyseal fusion (*Ferembach* et al. *1980; Scheuer, Black 2000*). For adult individuals, the sternal end of the clavicle (*MacLaughlin 1990*) and changes to the auricular surface (*Lovejoy* et al. *1985*) were considered. The results were included in age groups following the suggestions of Jean-Pierre Bocquet-Appel and Clade Masset (*1977*) and Bocquet-Appel (*2002*): 0–4 years, 5–9 years, 10–14 years, 15–19 years, 20–30 years and > 30 years.

Sex was estimated in adults, based on morphological features of the iliac bone (*Ferembach* et al. *1980; Bruzek 2002*), skull (*Ferembach* et al. *1980*), long bones (*Wasterlain 2000*) and foot bones (*Silva 1995; Curate* et al. *2021*).

Metric analysis included estimation of stature based on metatarsal bones (*Santos 2002*) and flatness indices calculated for the femora and tibiae (*Martin, Saller 1957*). Non-metric analysis included dental traits according to the ASUDAS protocol (*Turner* et al. *1997; Scott, Irish 2017*) and postcranial skeletal traits (*Finnegan 1978; Saunders 1978*).

Bones and teeth were macroscopically examined for pathological lesions, performing a differential diagnosis whenever feasible. Degenerative joint conditions were recorded following Sandra Assis (*2007*), and changes in entheses, particularly at ligament insertion sites, according to Éric Crubézy (*1988*). Dental wear was scored following Smith (*1991*), as adapted by Silva (*1996*). Cariogenic lesions were classified by size according to John R. Lukacs (*1989*) and by origin following Jane E. Buikstra and Douglas H. Ubelaker (*1994*).

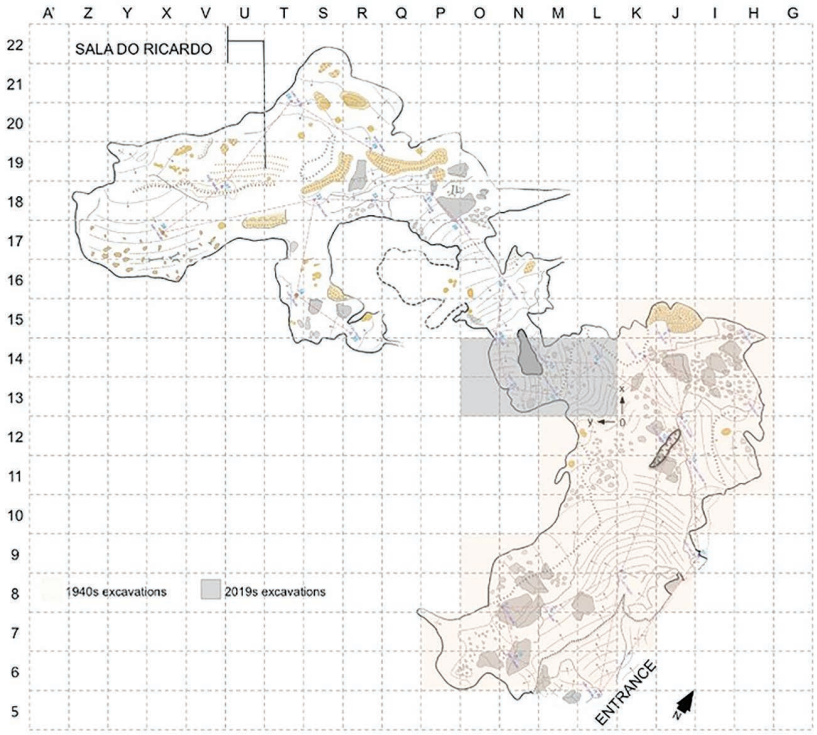

Fig. 3. Speleological topography of Lapa da Bugalheira with an indication of the area excavated in 2019 (authorship: J. A. Crispim, P. Marote/SPE/ 2019; adapted from Rodrigues* et al. *(2020.831).

Results

The sample held at the MG is comprised of 1311 fragments (including three petrosal pyramids removed for DNA analysis in 2016 by Rita Peyroteo), and two limestone concretions encasing bone fragments. Of these, 830 were anatomically identified, 747 bone fragments (692 from adults and 55 from non-adults) and 83 teeth. These remains correspond to a minimum of 30 individuals, 24 adults and six non-adults. In this sample, the long bones and skull fragments were the most representative anatomical parts.

From layer 1 (2019's excavation), 1168 fragments were recovered, but only 186 bones (160 from adults and 26 from non-adults) and 78 teeth, were able to be identified. These correspond to a minimum of 13 individuals, five adults (based on the left upper central incisors) and eight non-adults (based on the teeth sample). In this excavation, bones from the feet, hands and teeth were essentially recovered. Stratigraphic evidence indicates that both assemblages belong to a single funerary deposit, and thus herein the results will be presented together.

Taphonomy

Fragmentation is very high (83.6%; 915/1094), and taphonomic changes were recorded in 49.6% (463/933) of the assemblage. Moreover, alterations due to different agents were observed in the same bone fragment. It total, 550 modifications were registered. Identified agents include fluvial abrasion, carbonate incrustation, root etching, and dark pigmentation spots.

Demography

Crossing data from both interventions, a minimum number of 35 individuals were identified, 24 adults (68.6%, right ulna), and 11 non-adults (31.4%; dental remains) (Fig. 4). Among the non-adults, the two youngest individuals died around 10.5 months (fragment of mandible) and 2.5 years (FDI 12 and 26 in formation). Among the adult sample, iliac fragments allow to identify one individual around 35 to 39 years and one around 45 to 49 years.

Concerning sex estimation, the adult sample includes at least two females and two males.

Metric and non-metric characters

The femurs of these individuals display flatness (mean: 84.3; 5 left and 3 right), as well as the tibias (mean: 57.1; 3 right). Stature was only possible to estimate based on a left second metatarsal (LpBug-Sup-11.30): 166.67cm±47.5cm. The observation of nonmetric traits was also compromised by the nature of the sample. No

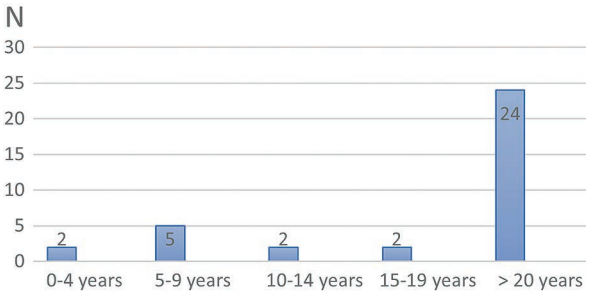

Fig. 4. Demographic profile of Lapa da Bugalheira sample.

TRAIT	LB	CM	PM I	SPII	DEA	SR	EP
Carabelli's trait FDI: 16; 26 (+=ASU 5-7)	N 7 % 0	N 15 % 2.0	N 6 % 8.0	N 3 % 25.0	N 30 % 16.7	N 14 % 0	N - % -
Cusp 6 FDI: 36;46 (+=ASU +)	N 1 % 0	N 54 % 1.9	N 179 % 1.1	N 45 % 4.4	N 36 % 8.3	N 6 % 0	N 131 % 1.5
Cusp 6 FDI: 37;47 (+=ASU +)	N 8 % 0	N 51 % 0	N 162 % 1.9	N 42 % 0	N 25 % 0	N 8 % 0	N 128 % 2.3
Groove Pattern FDI: 37;47 (+=ASU X)	N 7 % 14.3	N 41 % 46.3	N 146 % 52.1	N 36 % 55.6	N 26 % 76.9	N 8 % 75.0	N 111 % 61.3
Cusp 7 FDI: 36;46 (+=ASU +)	N 1 % 0	N 54 % 1.9	N 181 % 5.5	N 45 % 0	N 36 % 11.1	N 7 % 0	N 134 % 2.2

Tab. 2. Non-metric dental traits from Lapa da Bugalheira and coeval series. Legend:* LB *Lapa da Bugalheira;* CM *Cova da Moura;* PMI *Tholos de Paimogo I;* SPII *Hipogeu de São Pedro 2;* DEA *Dólmen de Ansião;* SR *Serra da Roupa;* EP *Eira Pedrinha (adapted from* Silva 2002*).

Carabelli cusp was recorded on any maxillary molar (Tab. 2). Frequencies of postcranial variants are also low: septal aperture (right humerus 0/4; left 1/6) and third trochanter (right femur 1/4; left 0/4).

Paleopathology

Despite the disarticulated and fragmentary condition of this assemblage, several pathologies were observed. Among the 852 adult bone fragments, five presented alterations compatible with fractures: a first left rib, a left radius and three foot phalanges. The left radius, composed of two fragments, was identified in the laboratory as belonging to the same bone (244.1149 and 244.1198). This bone revealed signs of a complete healed oblique fracture, on the middle third shaft (Fig. 5), with malunion and shortening of the bone, and lateral displacement resulting in an S-shape of the bone. No signs of complication are visible. The remaining remodelled fractures are summarized in Table 3.

Signs of osteoarthrosis were observed in 29 joints (9.1%, n=319), 12 (41.4%; 12/29) of them with lipping and porosity (grade 4). The bones affected were six phalanges (three distal phalanges of the foot, including one first distal phalanx of the right foot, two proximal phalanges of the foot and one distal phalange of the hand), one indetermined rib, four vertebrae (two cervical and two lumbar) (Fig. 6) and one proximal end of a left ulna.

Fig. 5. Remodelled shaft fracture of adult left radius (244.1149 + 244.1198) from Lapa da Bugalheira housed in the MG.

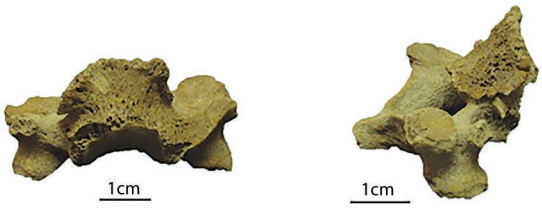

Fig. 6. Cervical vertebra (244.1328) with the presence of lipping and porosity in the body. Left: anterior view; right: lateral view.

Enthesal changes were observed in four bones: *triceps brachii* of one left and one right ulna (14.3%, n=14), bicipital tuberosity of two right and one left radius (11.5%, n=26), anterior tuberosity of one left tibia (33.3%, n=3) and *quadriceps femoris* of patella (33.3%, n=3). These lesions correspond to at least three individuals.

Periosteal new bone was observed on six long bone fragments. The only non-adult (1/81), a right fibula, display active new bone formation. The remaining cases belong to adults (5/852) and are summarized in Table 4.

Identification	Bone	Type	Notes
LpBug-Sup-10.25	Proximal phalanx of the foot	Transverse	Signs of osteoarthrosis
LpBug-Sup-10.69	Fragment of the first left rib	Oblique	---
LpBug-Sup-11.10	Proximal phalanx of the foot	Oblique	Signs of osteoarthrosis
LpBug-M.13-115.25	Distal phalanx of foot	Oblique	Signs of osteoarthrosis

Tab. 3. Description of the fractures observed in Lapa da Bugalheira (all of adults).

Identification	Fragment	Description
244.1163	Left tibia	Remodelled with new bone formation.
244.1165	Right tibia	Remodelled with new bone formation.
244.1267	Left fibula	Remodelled with new bone formation in the form of spicules.
244.1268	Left fibula	Remodelled with new bone formation in the form of spicules.
244.1164	Tibia without laterality	Woven bone and spicules

Tab. 4. Signs of infection observed in adult bones in the total sample from Lapa da Bugalheira.

The mean dental wear of permanent dentition is 1.47 (n=15), ranging between grades 1 and 8 (maximum). Cariogenic lesions were observed on 4.5% teeth (6/134), all in the posterior dentition, including upper and lower teeth. These cavities were, in general, small and the occlusal surface was the main affected area (Tab. 5).

Deposits of dental calculus were observed in 21.5% of teeth (28/130), predominantly minor deposits on upper posterior teeth (11/28= 39.29%).

Dental enamel hypoplasia is present on four teeth (2.7%, n=147), two upper central incisors (FDI 11 and 21) and two canines (FDI 23 and FDI 43 still in formation), belonging to a

minimum of two individuals, one of them a non-adult that died around 7.5/8.5 years old.

An adult mandible (244.1637), possibly of a male individual due to the morphology of the mentum area, displays the probable congenital absence of three teeth, both third molars and the left lateral incisor (Fig. 7), although this was not possible to confirm radiographically.

Discussion

Taphonomy

High levels of fragmentation and taphonomic changes characterized the human bone assemblage of Lapa da Bugalheira. These are very common in caves, since the stratigraphic layers are normally altered by anthropic and natural causes (*Zilhão 1984; Silva 2012*). Among the extrinsic taphonomic factors, 12.5% of bones were affected by roots, 15.8% by dark pigment on the surface, usually with small dark spots, 27.5% by changes caused by water and 44.2% exhibited incrustations/geological formations. The identified taphonomic alterations are commonly found in human bones unearthed from caves, an environment with high levels of humidity, and therefore prone to the development of roots, and in constant geological formation (*Baxter 2004*). The chromatic changes on the surface of the bones can occur due to sun exposure, fungi, type of soil or soil minerals (*Sauerwein 2011; Borrini* et al*. 2012*). In the present case, the presence of manganese oxide in the soil seems to be the more plausible explanation for the dark pigmentation observed in the bones (*Borrini* et al. *2012*).

Type of burial

Bone and tooth representation provides clues to funerary practices (*Ubelaker 1974; Silva 1996; 2003; 2012*). The pattern observed in Lapa da Bugalheira suggests a primary deposit followed by repeated disturbance. This was supported by the pattern of bone and teeth

Fig. 7. Mandible 244.1637 of Lapa da Bugalheira housed in the MG with possible congenital absence of lateral left incisor and both third molars. Left: occlusal view; right: left lateral view.

Identification	FDI	Size	Location
LpBug-Sup-11.8	45	2	Root
244.496	25	2	Root
244.1635	18	1	Occlusal face
Maxilla 244.1606	15	3	Smooth surfaces
Mandible 244.1602	37	4	Large cavity
Mandible 244.1623	34	1	Occlusal face

Tab. 5. Cariogenic lesions observed in the Lapa da Bugalheira sample.

representativity, the existence of small bones, such as hyoids, carpal and tarsal bones, and analysis of the proportion of single- and multi-rooted teeth. The scarce documentary sources on the first intervention also described 10 skeletons, and this seems to corroborate that this cave was used as a primary burial place. This was documented for other coeval natural caves, such as Morgado Superior cave (*Cruz* et al. *2013*), Algar do Barrão (*Carvalho* et al. *2003*), Gruta da Pedra Furada (*Silva* et al. *2014*), Porto Covo (*Silva 2008*), Poço Velho (*Gonçalves 2003*; *Antunes-Ferreira, Faria 2005*) and Lapa do Bugio (*Silva, Marques 2009*). However, secondary burials were also suggested, such as at Lapa do Fumo (*Cardoso 1990*).

Demography

The Lapa da Bugalheira sample has a minimum number of 35 individuals, with 24 adults and 11 non-adults. The proportion of non-adults is around 30% (31.4%), a value that is in line with other coeval samples documented by Silva (*2002; 2003; 2012*), where these individuals represent between 18% and 50% of the total minimum number of exhumed individuals (*Silva 2003*). The MNI in natural shelters and caves exhibits great variability, ranging from a dozen to more than hundred individuals (*Silva 2003; 2012*) (Tab. 6). In most cases, these sites have been occupied for a long time (*Silva 2003; Weiss-Krejci 2011*), and thus may represent different populations. Table 6 represents a summary of the MNI exhumed in the various caves/natural shelters with occupations framed at the end of the 4th/beginning of the 3rd millennium BC, located in the geographical area of Lapa da Bugalheira. It appears that the MNI is quite diverse, ranging from low numbers such as those in the caves of Porto Covo, Pinheirinhos I and Lapa do Fumo, to sites that revealed an MNI exceeding a hundred, such as the caves of Poço Velho and Eira Pedrinha. The proportion of non-adults ranges between 6.3% and 33.3% (Tab. 6).

The mortality profile of the non-adults of Lapa da Bugalheira was analysed in more detail, through the com-

Natural caves/shelters	NMI	Adults	Non-adults (%)	Reference
Lapa da Bugalheira	35	24 (68.6%)	11 (31.4%)	Present study
Lapa da Galinha	70	-	-	*Sá 1959*
Gruta do Morgado Superior	27	23 (85.2%)	4 (14.8%)	*Cruz* et al. *2013*
Lapa do Bugio	16	15 (93.8%)	1 (6.3%)	*Silva, Marques 2009*
Cova da Moura	90	75 (83.3%)	15 (16.7%)	*Silva 2002*
Serra da Roupa	40	28 (70%)	12 (30%)	*Silva 2002*
Gruta do Poço Velho	115	93 (80.9%)	22 (19.1%)	*Antunes-Ferreira 2003*
Gruta de Porto Covo	6	4 (66.7%)	2 (33.3%)	*Carvalho, Cardoso 2011*
Gruta da Pedra Furada	34	24 (70.6%)	10 (29.4%)	*Silva* et al. *2014*
Pinheirinhos 1	11	8 (72.7%)	3 (27.3%)	*Fernandes, Rocha 2008*
Lapa do Fumo	13	-	-	*Serrão, Marques 1971*
Algar do Barrão	20	16 (80%)	4 (20%)	*Carvalho* et al. *2003*
Gruta do Escoural	34	-	-	*Farinha dos Santos 1981*
Eira Pedrinha	144	113 (78.5%)	31 (21.5%)	*Gama, Cunha 2000*
Lapa da Furada	130	-	-	*Cardoso, Cunha 1995*

Tab. 6. Minimum number of adult and non-adult individuals recovered from caves/natural shelters from present day Portuguese territory and dated to the Late Neolithic/Chalcolithic.

parison of their mortality coefficients to those expected according to the mortality tables by Sully Ledermann (*1969*). Demographic analysis revealed a clear under-representation of infants less than five years old in comparison to the theoretical mortuary curve based on mortality frequencies of pre-industrial populations. By contrast, the two following groups display coefficients slightly above the upper limits, with those for the last age group among the expected values. Therefore, if we only consider about five years then the mortality curve is compatible to what is expected for natural populations (*Ledermann 1969; Silva 2002; 2003; Cunha* et al. *2015*) (Fig. 8). This trend is observed in most Late Neolithic/Chalcolithic coeval samples from what is today Portuguese territory, including those unearthed from other types of tombs, as artificial caves, dolmens and tholos (*Silva 2003; 2012*). This pattern has also been documented in natural caves, artificial caves, and megalithic tombs from the 4th to 3rd millennia BCE in the Spanish area of the Iberian Peninsula (*Mercadal* et al. *2005; Fernández-Crespo, de la Rúa 2016; Díaz-Navarro 2021*). Likewise, the slight over-representation of individuals aged five to ten years is a recurring pattern in other contemporaneous Iberian burial sites (*Silva 2003; Mercadal* et al. *2005; Cunha* et al. *2015; Fernández-Crespo, de la Rúa 2015; Díaz-Navarro 2021*). This elevated mortality in older children has been associated with nutritional stress following weaning, increased exposure to environmental hazards and the physical demands of early labour (*Díaz-Navarro* et al. *2021*).

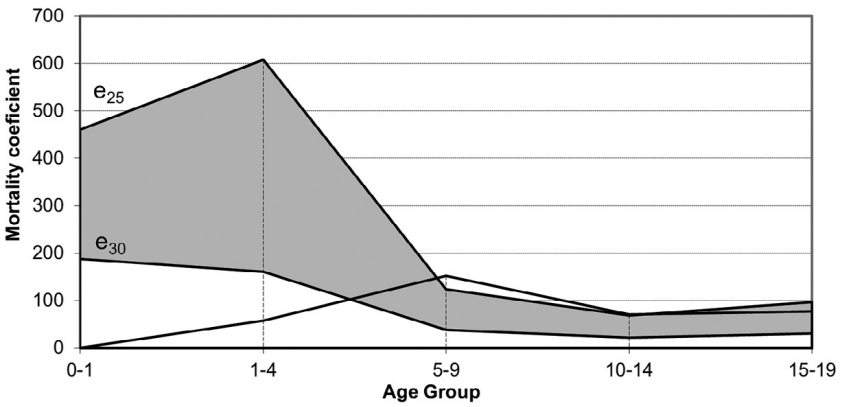

Fig. 8. Comparison of the mortality coefficients for the non-adult sample recovered from Lapa da Bugalheira according to the life tables of Ledermann (1969), with a 95% confidence interval upper limit of e^o = 25 years and lower limit of e^o = 30 years.

Among the adults, it was possible to identify two individuals over 30 years old. Adults of both sexes and children of different ages at death were identified, and so no clear selection based on sex or age at death was recognized.

Metric and non-metric characters

The lower limb bones of these individuals, femur and the proximal area of the tibia exhibit flatness (Tab. 7). Several studies reported a temporal decrease in the flatness of the femur and tibia with the transition to sedentary lifeways, like settings involving the adaptation of farming. For Portuguese assemblages, the available studies from the Mesolithic (*Cunha, Cardoso 2001*), Neolithic (*Jackes* et al. *1997*) and Late Neolithic series (*Silva 2002*) do not reveal a consistent pattern in the reduction of the flatness of the proximal femur and tibia shafts with the transition and intensification of agriculture, although a more consistent trend of decrease in flatness of the proximal area of the tibia is documented.

In the postcranial skeleton, the frequency of two non-metric traits usually present with high frequency in coeval populations (*Silva 2003; 2012*), septal opening (1/10) and the third trochanter (1/8), are less frequent in Lapa da Bugalheira (Tab. 8).

Paleopathology

Despite the poor preservation and fragmentation of this bone assemblage, it is still possible to draw a palaeopathological profile of these individuals. Signs of five factures were detected at the post-cranial level: three foot phalanges, a rib and a radius. The low frequency and observed pattern, is like other Late Neolithic/Chalcolithic samples, where the most affected bones are the metacarpals, metatarsals and foot phalanges (*Silva 2012; Boaventura* et al. *2014; Silva* et al. *2014*), a pattern that can reflect traumas related to daily activities. Here, the fracture observed on a left radius stands out due to its unusual location, middle third shaft and marked malunion, and yet it is completely remodelled and without signs of major complications. According to clinical and anthropological literature (*Silva 2017; Patel* et al. *2021; Scotcher* et al. *2023; Monge Calleja* et al. *2025,* among others), the most frequently observed fracture in the radius, both in adultsand non-adults, is the Colles-type at the distal end of the radius, which normally results from a fall onto an outstretched hand. The complete remodelling of the present fracture, without any signs of complication, suggest that this injury occurred several years before the death of the individual, still during childhood. In children, forearm fractures account for approximately 32% of all paediatric fractures, and due to the remodelling capacity of growing long bones in children these have the potential to be forgiving injuries and to heal well. Yet in this case malunion and shortening of the radius shaft occurred. According to the clinical literature, post-traumatic malunion of the radius shaft may lead to decrease of pronation and supination of the arm, and to an unstable and painful distal radioulnar joint (*Schweizer* et al. *2009; Lynch* et al. *2024*). Alberto Sarmiento *et al*. (*1992*) showed that angulated middle third radius fractures, as in the present case, resulted in greater supination loss. This facture occurred next to the *pronator teres* muscle, which influences the direction of the rotational deformity, which is a lateral displacement (*Lynch* et al. *2024*). The preserved proximal end of the radius does not show any signs of degenerative changes, and mild alterations are observed in the insertion of the *biceps brachii* muscle. The severity of this fracture likely implicates some initial disability, and this individual probably received caregiving.

Site	Platimeric Index	Platycnemic index	Reference
Lapa da Bugalheira	84.3 (n=8)	57.1 (n=3)	Present study
Cova da Moura	74.6 (n=54)	67.7 (n=20)	*Silva 2002*
Poço Velho	83.4 (n=38)	67.9 (n=38)	*Antunes-Ferreira 2003*
Serra da Roupa	83.6 (n=19)	66.6 (n=23)	*Silva 2002*

Tab. 7. Platymeric and platycnemic indices of individuals exhumed from caves/natural shelters from Portuguese sites dated to the Late Neolithic/Chalcolithic.

Site	Septal opening		Third trochanter		Reference
	Right Left	%	Right Left	%	
Lapa da Bugalheira	0/4 1/6	10	1/4 0/4	12.5	Present study
Poço Velho	3/41 3/44	7.05	8/21 5/21	30.95	*Antunes-Ferreira 2003*
Praia da Samarra	5/12 5/12	41.7	- -	-	*Silva* et al. *2006*

Tab. 8. Frequency of non-metric postcranial traits in Lapa da Bugalheira and coeval samples.

Signs of osteoarthrosis were observed in 9.1% (29/319) of the joints. In these collections the frequencies of this pathology are usually low, with the vertebrae usually being the most affected areas (*Silva 1996; 2012*), as in the present sample, although preservation bias should not be completely excluded.

Entheses changes were observed in 9.6% (7/73) of the sample, and for the upper limb these included the triceps brachii (14.3%, n=2/14) and bicipital

tuberosity (12%, n=3/25); and from the lower limb the *quadriceps femoralis* (33.3%, n=1/3) and patellar ligament (33.3%, n=1/3). These alterations belong to at least three individuals. No enthesis of the Achilles tendon was seen, because the necessary anatomical part was not found preserved in any of the recovered calcaneus.

In the spine, ossification of the yellow ligaments was observed in five thoracic vertebrae (12.5%, n=5/40). According to the clinical literature, this is the most common site of these lesions, and the main causes are related to physical effort, genetics, and obesity, among others (*Hukuda* et al*. 2000; Mann, Hunt 2013; Hirabayashi 2017*). In coeval samples, the thoracic region is the main area affected by these changes, followed by the calcaneus (*Silva 1996; 2012; Antunes-Ferreira 2005*). But again, different preservation patterns among the samples may explain, at in least part, the recorded differences.

Throughout history, infectious diseases have been a burden for human populations (*Roberts 2019*). Despite this, signs of unspecified periosteal infections in this sample are very low, found for only 0.6% of adult bones (n=5/852) and 1.2% (n=1/81) of non-adults. Only in the non-adult fibula are such alterations severe, with new bone growth. This low frequency of signs of infectious lesions is in line with coeval Late Neolithic/Chalcolithic samples unearthed from elsewhere in what is today Portuguese territory (*Silva 2003; 2019*).

In the Lapa da Bugalheira sample dental wear in generally low, with an average of 1.5 (n=15) for deciduous teeth and 3 for permanent teeth (n=136). Oral pathologies, such as antemortem tooth loss, caries and calculus, also exhibit low frequencies (Tab. 9), and are in line with those found for other Late Neolithic/Chalcolithic communities (*Silva 2002; 2012; 2017; Ferreira-Antunes 2003*).

Deposits of calculus were observed in 14.3% (1/7) of primary teeth and 21.5% (28/130) of permanent ones. For anterior teeth, the lower one was the most affected (66.7%, 8/12), while in the posterior teeth, it was the upper ones (68.8%; 11/16). Small deposits predominate.

Linear enamel hypoplasia (LEH) was detected in four anterior permanent teeth (2.7%, 4/147), two upper central incisors (one right and one left), one left upper canine and one right lower canine in formation (7.5/8.5 years), and thus correspond to a minimum of two individuals, one of them a non-adult. These defects in permanent teeth are associated with periods of nutritional and/or physiological stress during an individual's childhood (*Hillson, Bond 1997; Hillson 2000; 2005; Armelagos* et al. *2009; Hillson 2014)* while hypoplasias in deciduous teeth represent some stress during foetal formation (*Johnsen* et al*. 1984 in Waterman 2012; Forshaw 2014; López Onaindia, Subirà 2020*). In the coeval series, LEH in deciduous teeth seems to be rare, since only one case was published, from Paimogo I (n=1/523) (*Silva 2002*). In permanent teeth, the frequencies are also predominantly low (*Silva 2002; 2012*), although it is difficult to compare the results of different studies due to the varied methodological approaches, as they estimate by total sample or tooth type.

One mandible (244.1637) showed evidence of hypodontia (the absence of one to six teeth, excluding the third molars). In the present case, it is the left lateral lower incisor, besides the two third molars, that is missing. Agenesis is the most common dental abnormality (*Garib* et al. *2010*). Although the distribution of tooth agenesis differs between populations, the upper lateral incisors or the lower second premolar are usually the most frequently absent teeth, while lower incisors are among the rarest (*González-Allo* et al. *2012*). According to Christian Schulze (*1987*), the lower incisors are so similar that it is difficult to be sure which one is missing, although it is generally the central one. In the

Site	Occlusal wear Mean	Caries	Antemortem loss	Reference
Lapa da Bugalheira	3 (n=136)	4.5% (6/134)	11.3% (14/124)	Present study
Cova da Moura	3.65 (n=339)	8.2% (27/331)	8.8% (101/1145)	*Silva 2002*
Serra da Roupa	3.10 (n=60)	4.5% (3/67)	22.1% (62/281)	*Silva 2002*
Poço Velho	Moderate	2.6% (27/1034)	-	*Ferreira-Antunes 2003*
Algar do Barrão	Moderate to High	6.3% (5/79)	-	*Carvalho* et al. *2003*

Tab. 9. Dental wear, caries and antemortem loss of individuals dated to the Late Neolithic/Chalcolithic period exhumed from natural caves of what is today Portuguese territory.

present case the location of the tooth, and the comparison of the medio-distal length between antimeres, point into the lateral incisor.

Ana González-Allo *et al*. (*2012*), found a frequency of 6.7% individuals (175/2888) with tooth agenesis, excluding third molars, in a Portuguese sample. This was found more in females than males, but without statistical significance. This study also found a significantly higher prevalence of missing third molars in the agenesis group than in the non-agenesis group. All these findings are in alignment with the present case.

Conclusion

The study of human bone collections that have been housed for many years in a museum is a challenge, due to several constraints in addition the nature of the assemblage, such as limited or missing fieldnotes and lost or misplaced material, but at the same time, it represents a unique opportunity to get insights about the individuals the bones belonged to, and thus knowledge about ancient populations (*Silva, Ferreira 2016/2017*).

The study of the Lapa da Bugalheira sample was not an exception to this, since it shed light about the biology and lifestyles of these individuals, besides in addition to the discovery of undescribed pathologies for prehistoric populations.

Like other coeval prehistoric communities, this assemblage showed evidence for the low prevalence of oral, infectious, traumatic, degenerative and congenital pathologies. Among them, two stand out: the shaft fracture of the radius, due to its unusual location and substantial malunion, but completely remodelled, and the possible case of hypodontia of a left lower lateral incisor, a tooth type that is rarely congenitally missing. In the former case the lesion remodelled completely, although the facture was severe and there were some initial complications, suggesting not only the resilience of the individual, but also that he received some support from other members of the community. Meanwhile, the latter is the first documentation of a possible congenital absence of lower incisor in prehistoric Portuguese samples.

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New insights into the Mesolithic and Neolithic layers of the Darkveti rock shelter in the Imereti Region, Western Georgia

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ABSTRACT – *The Darkveti multi-layered site in the Imereti region of Georgia offers valuable insights into prehistoric human activity. Despite extensive research conducted in the 1960s and 1970s by Lamara Nebieridze, certain aspects of the site's chronology and inhabitants' mobility remained unclear. This study aims to address these gaps through collaborative, interdisciplinary research involving Georgian and foreign scientists. The primary objective is to precisely date the cultural layers belonging to the Mesolithic and Neolithic epochs using absolute dating methods. By combining archaeological evidence with palaeontological, geoarchaeological, and palaeobotanical data, this study aims to reconstruct the palaeoenvironment and subsistence strategies of the Darkveti inhabitants. Additionally, the analysis of stone tools and lithic raw materials will shed light on technological developments and possible connections with neighbouring regions. The findings will contribute to a better understanding of the cultural dynamics, mobility patterns, and adaptations of prehistoric communities in the Imereti region and the wider Caucasus.*

KEY WORDS – *Georgia; Darkveti; Mesolithic; Neolithic*

Nov vpogled v mezolitske in neolitske plasti spodmola Darkveti v regiji Imereti, zahodna Gruzija

IZVLEČEK – *Večslojno najdišče Darkveti v regiji Imereti v Gruziji ponuja dragocen vpogled v človekove dejavnosti v prazgodovini. Kljub obsežnim raziskavam, ki jih je v šestdesetih in sedemdesetih letih 20. stoletja opravila Lamara Nebieridze, sta kronologija naselbine in poselitvena mobilnost ostali nejasni. Namen naše študije je odpraviti te vrzeli z interdisciplinarnimi raziskavami, v katere so vključeni znanstveniki iz Gruzije in tujine. Osnovni cilj je natančno datiranje mezolitskih in neolitskih kulturnih plasti s pomočjo absolutnih metod. S povezanimi arheološkimi, paleontološkimi, geoarheološkimi in paleobotaničnimi podatki želimo rekonstruirati paleookolje in strategije preživetja prebivalcev Darkvetija. Poleg tega analiza kamnitih orodij in litičnih surovin osvetljuje tehnološki razvoj in povezave s sosednjimi regijami. Ugotovitve prispevajo k boljšemu razumevanju kulturne dinamike, vzorcev mobilnosti in prilagoditev prazgodovinskih skupnosti v regiji Imereti in na širšem Kavkazu.*

KLJUČNE BESEDE – *Gruzija; Darkveti; mezolitik; neolitik*

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Introduction

Western Georgia, located in the South Caucasus region of Eurasia, is notably distinguished by the Kvirila River valley, situated in the Colchian lowland and bordered to the west by the Black Sea. This area boasts a remarkable concentration of archaeological sites, with representations from every period ranging from the Palaeolithic to the Neolithic. It is characterized by a rich array of natural caves, grottos, and open-air sites, all of which provide evidence of extensive and prolonged human habitation.

Archaeological investigations have established that the Kvirila River valley was first inhabited by early humans during the Palaeolithic, and specifically since the Acheulean period. Successive discoveries of significant archaeological sites in this region have been well-documented by numerous researchers (*Bernatsky 1884; Krukovsky 1916; Nioradze 1933; 1953; Kiladze 1944; 1948; Tushabramishvili 1960; 1969; Javakhishvili 1971; Dochanashvili 1973; Nebieridze 1973; Nioradze 1975; Tushabramishvili, Tsereteli 1975*). A major advance in the study of these sites occurred in the 1990s, with the launch of joint international archaeological expeditions that included both Georgian and foreign scientists (*Meshveliani* et al. *1999; 2004; 2007; Tushabramishvili* et al. *1999; Adler* et al. *2006; Baz-Oz* et al. *2008; Bar-Yosef* et al. *2011*).

One of the most prominent sites within the valley is the multi-layered Darkveti rock shelter, notable for its extensive stone tool collection and a diverse array of archaeozoological findings. This site was extensively documented in a seminal work by the archaeologist Lamara Nebieridze (*1978*). However, in 2023 and 2024 the recent interdisciplinary research on the stone inventory and bone material yielded valuable new information regarding the mobility of early humans at the Darkveti site and the chronological framework of its habitation.

This paper presents the latest data obtained from these laboratory analyses, along with the corresponding archaeological context and overarching conclusions.

Archaeological background

The Darkveti rock shelter was extensively studied from 1968 to 1972 by the Kvirila Valley Archaeological Expedition of the Institute of History, Archaeology, and Ethnography, led by Nebieridze (*1978*). The site is situated in the northwestern part of Upper Imereti (Figs. 1 and 2), within the Chiatura municipality, on the left bank of the Kvirila River, embedded in the limestone massif of the canyon-like valley. The Darkveti rock shelter was located approximately 5m above the current river level, with its entrance facing northeast.

Unfortunately, the archaeological site has since been completely destroyed. During the Soviet era, the construction of a narrow-gauge railway along the river's scarp led to the cutting and toppling of the main and side sections of the rock shelter. This destruction exposed material in the collapsed layers and on the surface. Fortunately, timely intervention by the archaeological expedition allowed for the study of untouched areas (*Nebieridze 1978.10*).

An area of approximately 75m^2 was excavated, revealing the following stratigraphy (Figs. 3–5):

- Layer I: Ash mixed with fine gravel, lying on an 8cm thick compacted clay floor. This layer contained materials from the Chalcolithic-Early Bronze Age.

- Layer II: Brown loose loam with ash admixture, approximately 30–35cm thick, resting on a 5cm thick compacted clay floor. A coal layer (5cm) was found

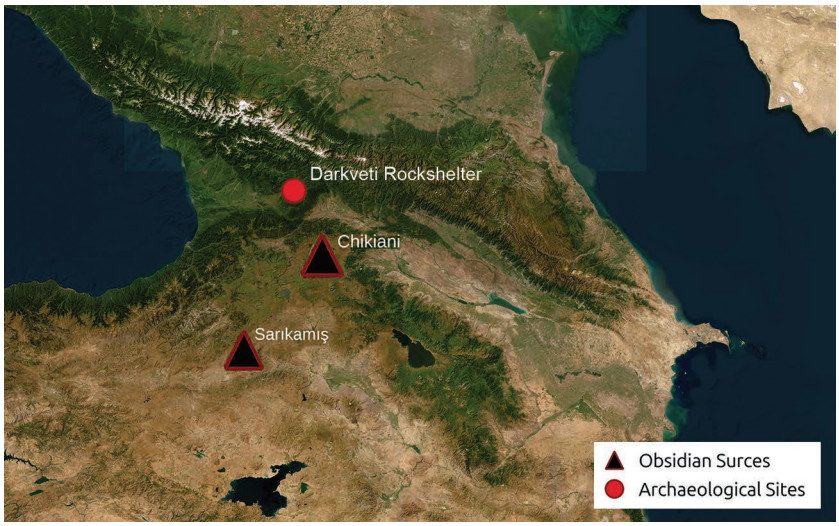


Fig. 1. Map showing the location of the Darkveti rock shelter and the sources of obsidian.

directly on the floor, topped by fine gravel (3cm). This layer contained numerous ceramics, stone, and bone tools.

- Layer III: Ash, approximately 30–32cm thick, was the richest in archaeological remains.

- Layer IV: Peaty ash, with hearth remains (burnt earth, ash) in the lower part. Only stone and bone materials were found in this layer.

- Layer V: Gravel and large boulders, approximately 1m thick, contained no material (*Nebieridze 1978.11–12*).

Beneath the coarse layer on the main excavation area, an 8–30cm thick ash layer was found, representing the sixth cultural layer. The archaeologist Nebieridze observed that, despite differences in structure and colour, all cultural layers of the rock shelter shared a common feature: an abundance of ash and charcoal, indicating intensive use of fire by the ancient inhabitants. The large boulders deposited on top of the Mesolithic and Neolithic layers indicate a natural disaster that likely led to significant changes in the area and a temporary abandonment of the site. During the excavations, the large fallen boulders were still visible atop the Neolithic layer, supporting the assumption that habitation ceased before the Chalcolithic era (*Nebieridze 1978.17*).

Natural disasters likely forced the inhabitants to leave the rock shelter temporarily. However, the ceiling collapse might have continued during human occupation, as manifested by fine cracks on the walls of the shelter. The study of the layers in Darkveti rock shelter revealed that the site was selected as a place of residence starting from the Mesolithic, and continued to be used until the Early Bronze Age. Favourable ecological conditions, such as dryness, clear walls, proximity to water, and possibly rich flora and fauna, contributed to its intensive use.

Chipped stone assemblage of the Darkveti rock shelter

As previously mentioned, our study presents significant results from the interdisciplinary analysis of the stone and bone collection from the Mesolithic and Neolithic layers of the Darkveti rock shelter. We thus provide a brief description of the layers and the recovered inventory.

Fig. 2. Darkveti rock shelter. General view from the northwest.

The work on the stone collection used the methods of Jacques Tixier and Khizri Amirkhanovich Amirkhanov. In particular, specimens with a width of less than 12mm are categorized as bladelets, and those with a width of more than 12mm as blades (*Tixier 1974.10–11*). As for microblades, their size is 7mm and less (*Amirkhanov 1987.10*).

Layer V was found at a depth of 2.10m from the surface, beneath a sterile gravel layer approximately 1m thick. This layer contained a significant number of flint and obsidian tools, production debris, and animal bones (Tabs. 1–2; Fig. 6). The tools were primarily manufactured using pressure flaking techniques, as evidenced by the presence of pencil-like cores (4 items), three of which are obsidian and one flint. These cores show traces of regular microblade detachments on their sides (Fig. 6.1).

Among the tools there are an interesting group of burins (Fig. 6.2–4), with a total of 17 pieces. Most are made on blades. Burins are selected in various forms: simple, unifacial, bifacial, oblique, and others. Within the collection, the second position after the scrapers is occupied by points (Fig. 6.7,28). Most are made on blades and flakes, they are chiefly represented by side-scrapers. Among the tools, numerous blades and microblades show signs of retouching, and several of these have undergone indirect retouching (Fig. 6.24–27).

The collection includes a few combined burins (scraper-burins) (Fig. 6.6,15), and there are also a few perforators, denticulated tools, and a chisel (Fig. 6.5,8–9).

Of particular interest are the microliths (rectangular), which are made on blades and microblades (Fig. 6.10–14,16–23), some with two retouched edges (*Nebieridze 1978.20–21*). These artefacts likely served as inserts for hunting tools. Among the pebble tools, a single stone net sinker was found (Fig. 6.34), featuring slight notches on both sides.

It is noteworthy that bone material is also present in the assemblage (Fig. 6.29–33). The bones belong to various species of animals and birds, with some being used as tools (*e.g.,* perforators). Additionally, a pendant made from bird bone was discovered (*Nebieridze 1978.21*).

The lithic assemblage includes a large quantity of production debris, primarily consisting of blades, indicating that the inhabitants were proficient in blade production techniques, allowing them to produce blades and microblades of various sizes for toolmaking on the spot.

Layer IV is characterized by a diverse array of materials (Tabs. 1–2; Figs. 7–8). There are a total of 25 cores, including prismatic, conical, and pencil-like examples (Fig. 7.8–14). Both pressure flaking and direct percussion techniques appear to have been used in core processing. Some cores have two platforms, showing clear detachments from blade production. The pencil-like cores exhibit negatives from the removal of microblades.

Scrapers are less numerous in this layer (Fig. 8.1–4), but several forms can be identified: end-scrapers, round scrapers, and high-edged scrapers. There are also fewer burins, though they come in various shapes (Fig. 8.8–16).

Compared to the Mesolithic layer, there are more perforators in this one, made on blades and flakes with retouched working tips on both sides (Fig. 8.5–7).

The trapezoids are made from the medial sections of the blades, which have been retouched on the edges (Fig. 7.16–19) (*Nebieridze 1978. 22*).

In addition to the aforementioned tools, the collection includes a few unique items such as points, adzes, chisels, and others (Fig. 8.17–22). The pebble tool collection features a polished axe and a fragment of an oval-shaped hand grinder (Fig. 7.1).

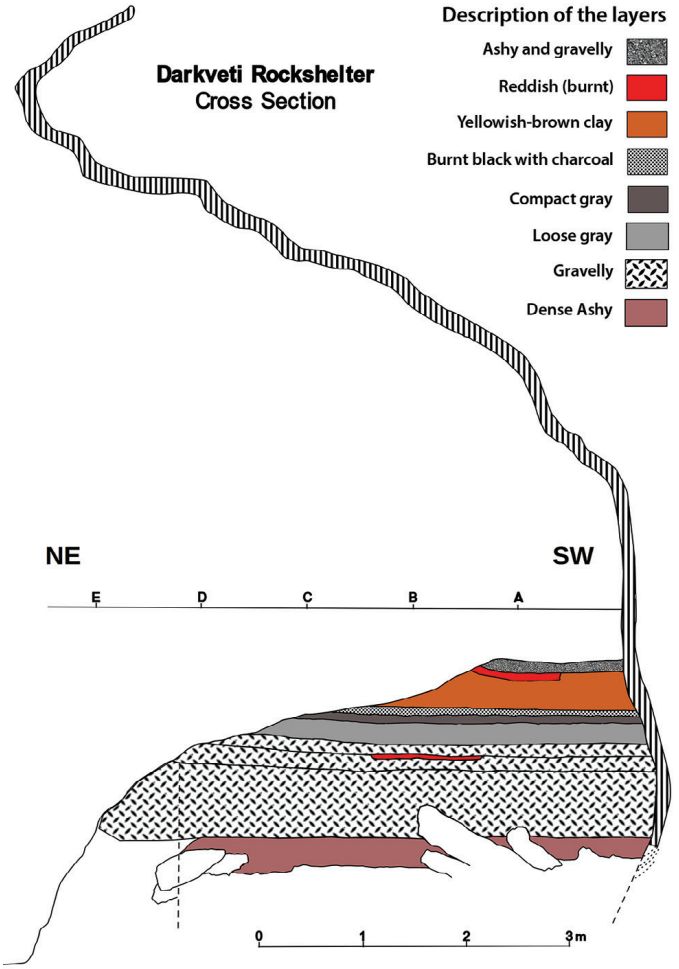


Fig. 3

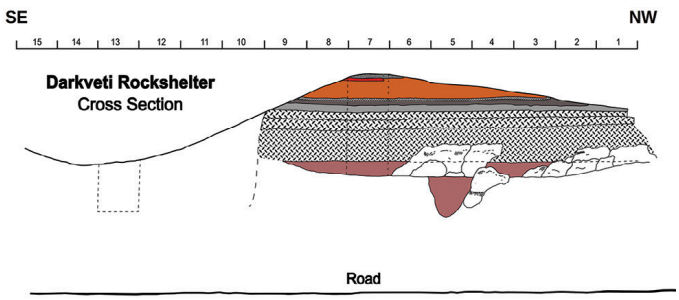
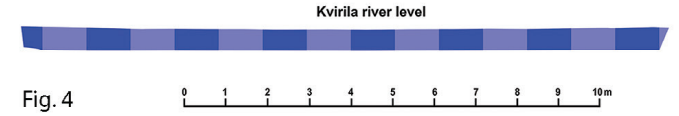


Fig. 4



Figs. 3 and 4. Darkveti rock shelter. Cross sections.

In Layer IV, isolated items include a bird bone awl and a perforator (Fig. 7.2–7), as well as a large, polished fragment of a deer antler (Fig. 7.15). Smaller antler fragments, likely used as tools, were also found (*Nebieridze 1978.24*).

Archaeozoological remains

As previously noted, a substantial quantity of faunal remains was discovered in the Mesolithic and Neolithic layers (Tab. 2). The palaeontologists Nikolai Iosifovich Burchak-Abramovich and Oleg Bendukidze identified the following species: red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), bear (*Ursus spelaeus*), wild boar (*Sus scrofa*), wild goat (*Capra sp.*), and beaver (*Castor fiber*), among others (*Nebieridze 1978. 35*).

In the Early Neolithic (IV) layer, osteological remains of domesticated animals appear, including cattle (*Bos taurus*), pig (*Sus domesticus*), small ruminants (*Ovis aut Capra*), and dog (*Canis familiaris*) (*Nebieridze 1978.91*).

It is noteworthy that the faunal material is typical of the Early Holocene (Preboreal and Boreal) faunal assemblages in western Georgia. The abundance of red deer, roe deer, wild boar, and wild goat bones suggests that these species were particularly significant to the ancient hunters. The Mesolithic layer at the nearby Kotias-Klde site provides valuable information for reconstructing the hunting practices and broader faunal landscape (*Meshveliani* et al. *2007*).

Materials and methods

Obsidian is present in smaller quantities compared to flint in the lithic assemblage from the Darkveti rock shelter. However, it is noteworthy for its high quality. The collection is dominated by artefacts made of black and translucent obsidian, which likely originate from various sources. To investigate this, obsidian artefacts from layers III-V of the Darkveti rock shelter were selected for analysis.

The goal of the geochemical analysis was to determine the chemical composition of the obsidian to ascertain its provenance. This research was conducted at the Archaeometry Laboratory of the University of Missouri Research Reactor Center.

The study was conducted by submitting 47 artefacts from the Darkveti rock shelter samples to the Archaeometry Laboratory at the University of Missouri Reactor Research (MURR). Analysis was performed using a Thermo Quantx ARL lab-based XRF spectrometer. The instrument has a rhodium-based X-ray tube which was operated at 35kV with a current to measure the emitted X-rays with a silicon diode detector. The instrument was specifically calibrated for obsidian by measuring a set of 40 very well-characterized obsidian source samples using data acquired by neutron activation analysis (NAA), inductively coupled plasma-mass spectrometry (ICP-MS), and XRF. For more information about this calibration see a publication by Michael D. Glascock (*2020*).

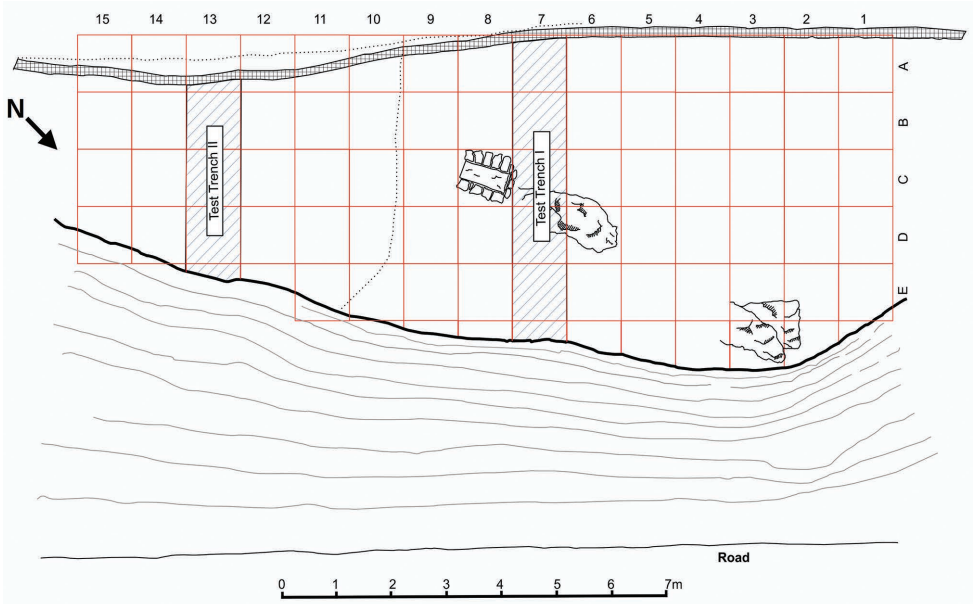


Fig. 5. Darkveti rock shelter. Plan of the excavations.

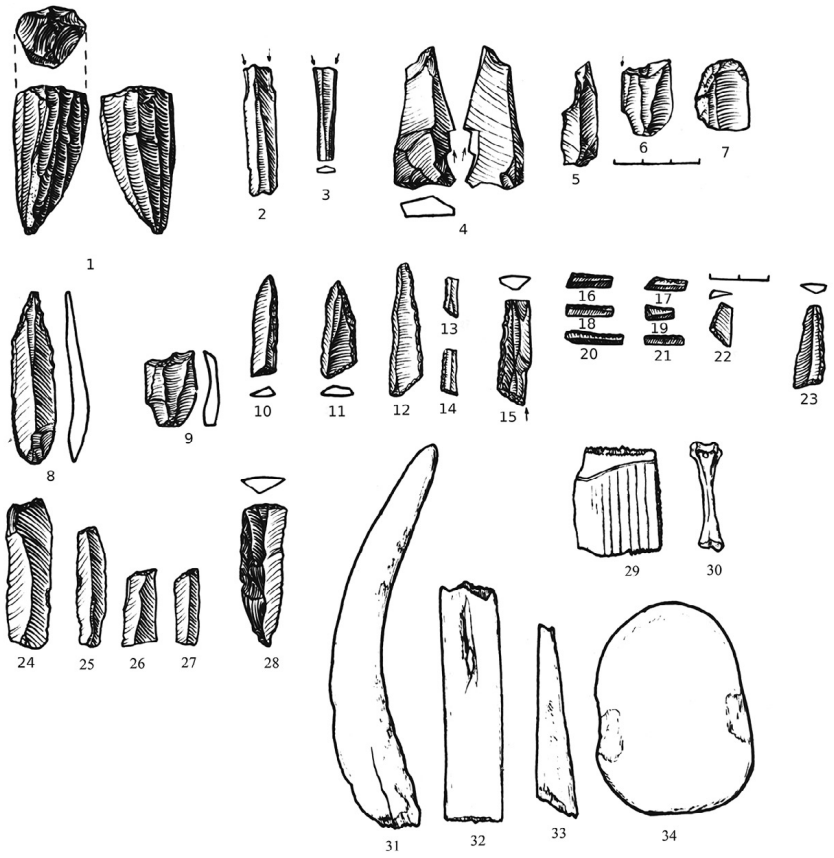


Fig. 6. Darkveti rock shelter. Lithic and bone artefacts.* 1 *core;* 2–4 *burins;* 5, 8, 9 *perforator, denticulate tool, chisel;* 6, 15 *scraper-burin;* 7, 28 *scrapers;* 10–14, 16–23 *blades and microblades (microliths) with abrupt retouch;* 24–27 *retouched blades and microblades;* 29–33 *bone tools;* 34 *net sinker.

The artefacts were non-destructively analysed by XRF. Samples were counted for one minute each. The elements measured include K, Ca, Ti, Mn, Fe, Zn, As, Rb, Sr, Y, Zr, Nb and Th. However, due to the variation in sizes, shapes and thicknesses of the artefacts, the most reliable data is usually only possible for Rb, Sr, Y, Zr, and Nb. Sample size and thickness can be problematic for small artefacts, an issue that was solved by examining element ratios (Sr/Rb, Rb/Zr, *etc.*) as recommended by Richard E. Hughes (*2010*). Multiple elements were used to determine differences between sources where ratio values would otherwise overlap.

To determine the absolute dates of the Mesolithic and Neolithic layers at the Darkveti rock shelter, bone material was selected for radiocarbon analysis. This research was conducted using the AMS (Accelerator Mass Spectrometry) method at the Vilnius Radiocarbon Laboratory.

Radiocarbon dates were calibrated using the online calibration program OxCal 4.4.4 (*Bronk Ramsey, Lee 2013*) using atmospheric data from Paula J. Reimer *et al.* (*2020*). Samples comprise two fragments of bone *Cervus elaphus*. The selected samples come from the layers V and IV of the Darkveti rock shelter.

Results

The results of the XRF analysis were compared to a database of obsidian source samples which were also analysed at MURR using the same Thermo Quantx ARL lab-based XRF spectrometer. An overview of the data reveals two sources for the obsidian in this study. These are Chikiani in Georgia and Sarıkamış 2 (Hamamli) in Türkiye. All samples from layers III and V originated from Chikiani. For the samples from layer IV, two were from Türkiye (Figs. 9–11), and 20 samples from Chikiani. The data can be found in supplemental Table 3 (https://doi.org/10.4312/dp.52.2).

The Chikiani source has several subsources (*Biagi, Gratuze 2016*), which are primarily distinguished by variable percentages of barium and zirconium. Barium was not detected in this analysis, and as a result subsource assignments within the Chikiani source could not be reliably determined.

Radiocarbon analysis yielded a very interesting series of absolute dates, which significantly determined the age of the Mesolithic and Neolithic layers of the Darkveti site (see Tab. 4). It is noteworthy that Nebieridze, using the data and methods available in the 1970s, accurately determined the ages of layers IV and V at this site (6216–5929 cal BC and 7308–6826 cal BC, respectively).

Discussion

At the end of the Pleistocene, the southern Caucasus went through considerable floral turnovers, between 14 and 11 ka BP eastern and southern Georgia was dominated by glacial desert-steppe and the moist refugium of western Georgia by mixed forests (*Connor,*

Types of artefacts	Total Number		
Cores and products of knapping	**V layer**	**IV layer**	**Total**
Pencil-like core	4	7	11
Prismatic core	-	2	2
Conic-like core	-	10	10
Flakes (primary, seconday)	616	749	1365
Blade, Bladelet	219	214	433
Microblade	14	-	14
Tools	**70**	**41**	**111**
Scrapers	29	6	35
Burins	17	5	22
Asimetrical triangles	8	-	8
Trapeze	2	16	18
Segments	-	2	2
Microblades with abrupt retouched	4	-	4
Borers	3	6	9
Denticulate tools	4	2	6
Combined tools	1	-	1
Axe	-	1	1
Millstone	-	1	1
Net sinker	1	-	1
Points	-	2	2
Slingstone	1	-	1
Total	**923**	**1023**	**1946**

Tab. 1. Darkveti rock shelter. Stone tool complexes.

Kvavadze 2009). The Pleistocene–Holocene transition was characterized by a shift from desert-steppes to oak-xerophyte communities and mixed forests (*O.c.*). This situation remained relatively stable until the early Holocene and became apparent by 9 ka BP, which changed during the mid-late Holocene when coniferous forests and mountain grasslands advanced (*O.c.*). After the Last Glacial Maximum (LGM), the early Holocene witnessed repeated sea-level fluctuations in response to different climatic-environmental influences, altering coastal geomorphology (*Bruckner* et al. *2010*), later, around the beginning of the mid-Holocene, the Black Sea reached its present level with insignificant alterations since (*Tskvitinidze* et al. *2020*). These events were accompanied by increased aridity at the end of the Pleistocene, followed by a gradual increase in precipitation, culminating around the mid-Holocene and retreating since then (*Connor, Kvavadze 2009*). All these events appear to have been more oscillatory in character, but may have had significant impacts on humans (*Bruckner* et al. *2010*). Increasing temperatures led to the formation of modern vegetation belts, creating fertile ground for new migrations (*Gavashelishvili* et al. *2021*).

Recent research demonstrates that the physical environment has strongly shaped the cultural and genetic landscapes of the Caucasus since the Upper Palaeolithic, implying genetic continuity in the region and that Y-DNA haplogroups of the past populations were associated with particular biomes (*Tarkhnishvili* et al. *2012*). According to this research, Caucasian hunter-gatherers (CHG) are the descendants of early anatomically modern humans, dispersed from Africa into Eurasia. They separated from western hunter-gatherers around 45ka BP, shortly after their expansion into Europe, and from the ancestors of Neolithic populations at 25kya, around the LGM (*Jones* et al. *2015*). It seems that CHG associated with the forested environment

№	Species	Layer IV	Layer V
1	*Bos taurus*	5/2	-
2	*Sus domesticus*	47/5	-
3	*Ovis aut capra*	17/3	-
4	*Canis familiaris*	1/1	-
5	*Capreolu capreolus*	179/8	4/1
6	*Cervus elaphus*	66/2	7/1
7	*Sus scrofa*	53/1	1/1
8	*Rupicarpa rupicapra*	3/1	-
9	*Capre sp.*	1/1	1/1
10	*Ursus arctos*	8/2	1/1
11	*Felis silvestris*	2/1	-
12	*Males meles*	2/1	-
13	*Microtus sp.*	1/1	-
14	*Lutra lutra*	4/1	-
15	*Martes sp.*	14/3	-
16	*Erinaceus Europaeus*	3/2	1/1
17	*Castor fiber*	1/1	1/1
18	*Glis glis*	3/1	-
19	*Duromus nitedula*	2/1	-
20	*Querquedula querquldula*	1/1	-
21	*Authia ferina*	1/1	-
22	*Alectorisg raeca*	1/1	-
23	*Grus grus*	1/1	-
24	*Pica pica*	2/1	-
25	*Corvus corone*	1/1	-

Tab. 2. Osteological remains of the Darkveti rock shelter. The numerator of the fraction represents the number of bones, and the denominator represents the number of individuals.

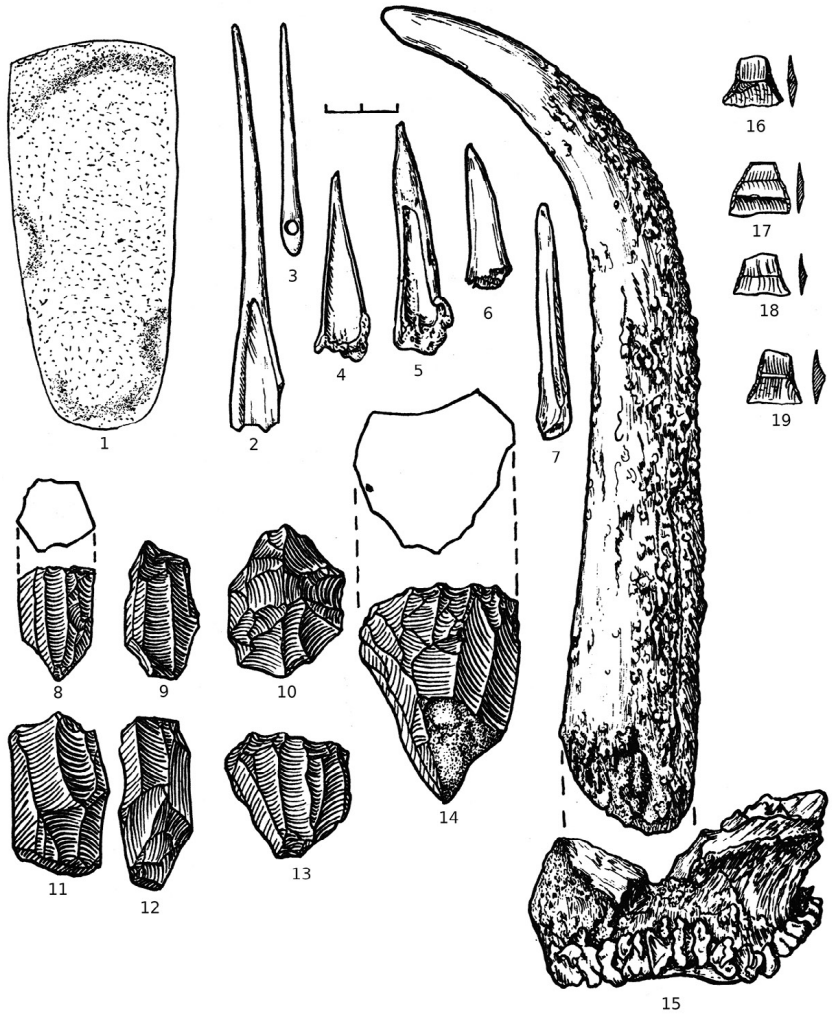


Fig. 7. Darkveti rock shelter. Lithic and bone artefacts.* 1 *polished axe;* 2–7 *bone tools;* 8–14 *cores;* 15 *polished fragment of a deer antler;* 16–19 *geometric microliths (trapezoids).

survived in the Colchic refugium of western Georgia during the LGM (*Tarkhnishvili* et al. *2012*), but in the early post-glacial period the migration of hunter-gatherers from elsewhere into the Caucasus intensified (*Gavashelishvili* et al. *2021*). Around 9 ka BP Neolithic societies initiated expansion at a greater rate, and gradually displaced hunter-gatherer communities in regions with lower forest density, and drove hunter-gatherers towards more densely forested areas (*Tarkhnishvili* et al. *2014; Gavashelishvili* et al. *2023*). Research confirms that during this period hunter-gatherers dominated in western Georgia, while farming societies developed in eastern Georgia, taking more time to colonize the dense forests of the west (*O.c.*). The archaeological sites of western Georgia echo these climatic/environmental events and cultural turnovers, especially the cavernous sites of the Upper Imereti, which are on the frontline of some important changes (*Tskvitinidze* et al. *2020*).

The inhabitants of the Darkveti rock shelter mostly preferred flint for making stone tools. Geological surveys indicate numerous sources of flint in the Imereti region, which is especially rich in Turonian-Cenomanian type flint, distinguished by its high quality. It appears that the ancient inhabitants of the rock shelter were well acquainted with different types of flint and preferred using it. The geochemical analysis has also given us a very interesting picture in this context (Tab. 5). It is quite reasonable that people preferred using flint, a readily available raw material in the region, over obsidian, the sources of which were far away.

Chikiani Mountain, located in the Javakheti region of southern Georgia near Paravani Lake, is the only source of high-quality obsidian in Georgia, and it is found in the stone collections of archaeological sites from many eras (*Badalyan* et al. *2004; Biagi* et al. *2017; Biagi, Nisbet 2018; Gratuze, Rova 2022*). The Darkveti rock shelter is 102km away from Chikiani in a direct line. For ancient humans, covering such a distance to obtain obsidian was not a significant challenge, and numerous examples of this practice are well-documented (*Doronicheva 2015.221,227; Blegen 2017; Chkhatarashvili, Glascock 2022; Chkhatarashvili* et al. *2024a; 2024b*).

The Sarıkamış source of obsidian is located in eastern Türkiye, in the modern province of Kars. This region is characterized by a highly mountainous terrain, includ-

№	Layer	Dates (BP)	Dates 95.4% (BC)	Dates 68.3% (BC)	Lab. Index	Sample	Reference
1	V	8085±47	7308-6826	7174-6863	FTMC-JU83-8	Bone	First published
2	IV	7190±42	6216-5929	6076-6012	FTMC-JU83-9	Bone	First published

Tab. 4. Radiocarbon dates of layers of the Darkveti rock shelter.

ing volcanic mountains. The obsidian from this area is of high quality, predominantly black and brownish in colour. The Sarıkamış obsidian deposit is approximately 227km away from the Darkveti rock shelter in a straight line.

It is noteworthy that geochemists distinguish between the so-called 'northern' and 'southern' groups in Sarıkamış obsidian (*Bigazzi* et al. *1998; Chataigner* et al. *2014*). Within the northern group there are three subgroups – Kızıl Kilisa, Handere, and Hamamlı – and obsidian from the Hamamlı subgroup has been identified in the Darkveti obsidian collection.

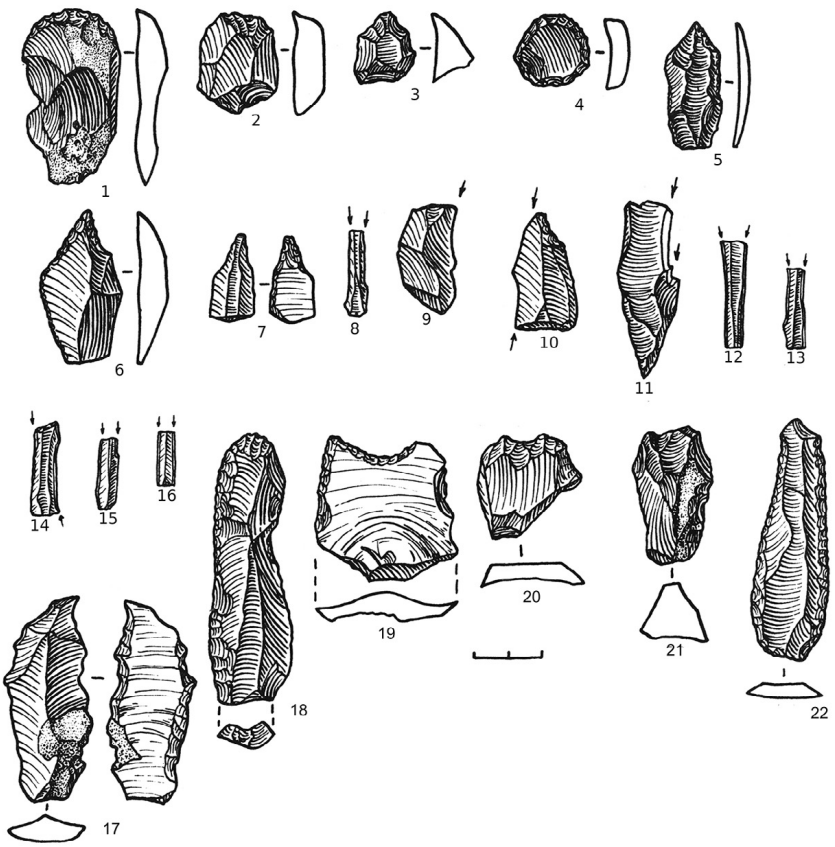


Fig. 8. Darkveti rock shelter. Lithic artefacts.* 1–4 *scrapers;* 5–7 *perforators;* 8–16 *burins;* 17–22 *retouched blades, flakes and chisels.

It is notable that Sarıkamış obsidian has been repeatedly discovered in Stone Age archaeological sites in western Georgia (*Le Bourdonnec* et al. *2012; Chkhatarashvili, Glascock 2022; Chkhatarashvili* et al. *2024a*). This indicates that ancient humans were well acquainted with these sources of obsidian and exhibited a discernible preference for them. This serves as further evidence of the mobility and extensive contacts among ancient human populations.

A significant amount of information has been provided in connection with the chronology of the Mesolithic and Neolithic layers of the Darkveti rock shelter discussed in Nebieridze's work. Thus, with the use of new dates, we further refine the ages of the cultural layers.

The distinguishing feature of the Mesolithic layer at the Darkveti rock shelter is the use of the pressure technique to produce straight, knife-like blades and microblades from pencil-shaped and conical cores. Additionally, this layer contains a significant quantity of lateral microblades, asymmetric triangles, burins of various shapes, end-scrapers, and other tools. As a direct parallel to this layer, notable

Layer	Chikiani	Sarıkamış 2 (Hamamlı)
Layer III	18	—
Layer IV	20	2
Layer V	7	—

Tab. 5. Summary of the sources of obsidian for the samples found in the Darkveti rock shelter.

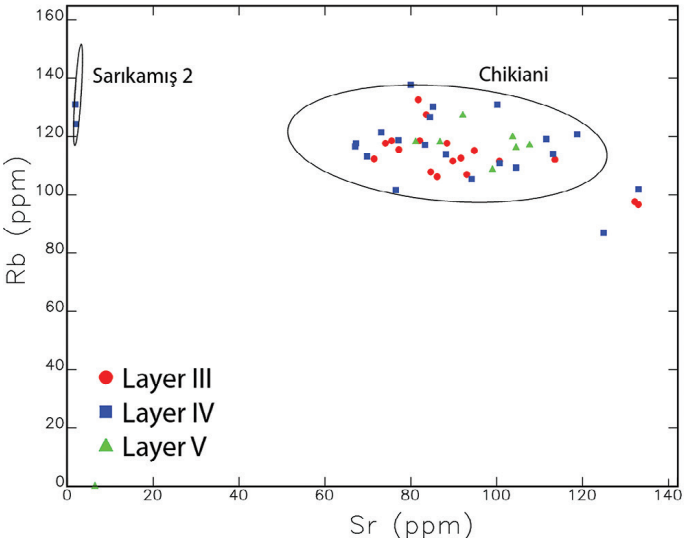


Fig. 9. Scatterplot of strontium (Sr) versus rubidium (Rb) showing obsidian samples from layers III, IV, and V of the Darkveti rock shelter, with ellipses drawn at 90% confidence intervals representing probable sources.

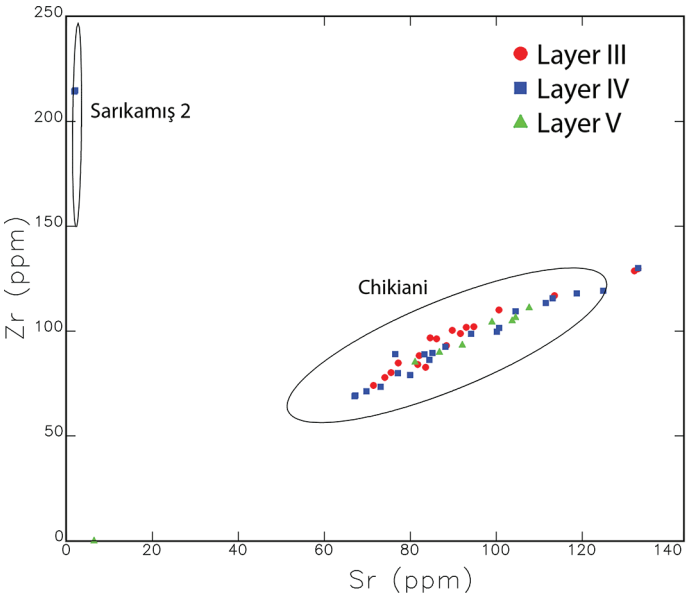


Fig. 10. Scatterplot of strontium (Sr) versus zirconium (Zr) showing obsidian samples from layers III, IV, and V of the Darkveti rock shelter, with ellipses drawn at 90% confidence intervals representing probable sources.

examples include Kobuleti (*Gogitidze 1978; 2008; Chkhatarashvili, Manko 2020; Chkhatarashvili* et al. *2020*), Khutsubani (*Gogitidze 1978; Chkhatarashvili* et al. *2024b*), Bavra, Bavra I, Bavra II (*Gabunia 2001; Gabunia, Tsereteli 2003*), Bavra-Ablari (*Varoutsikos* et al. *2017*), Kvirike (*Gogitidze 1978; Manko, Chkhatarashvili 2022*), and Sosruko (M1-M2) (*Zamiyatnin, Akritas 1957; Leonova 2021; Manko, Chkhatarashvili 2021*), among others.

To determine the age of the Mesolithic layer, the stratigraphic data from the Darkveti rock shelter are crucial. Layer V (7308–6826 BC) was deposited directly on sterile, alluvial yellowish loam, and is separated from the Neolithic layer above it by another sterile layer.

The Neolithic layer of the Darkveti rock shelter represents the non-ceramic Neolithic period. The primary characteristic of this layer is the use of the hand pressure technique, along with the direct percussion method, demonstrated by the presence of prismatic, conical, and pencil-shaped cores. Numerous microliths, including trapezoidal chips from two phases, are abundant in this stratum. Unlike the Mesolithic period, asymmetric triangles are absent in this layer, as anticipated.

Comparable to Layer IV of the Darkveti rock shelter, we should highlight the complexes of the 'Cold Cave' ('Tsivi Mgvime'), Apiancha, and Melouri (*Kalandadze 1986*), as well as Anaseuli I (*Nebieridze 1972*) and Jvartskvma (*Manko, Chkhatarashvili 2020*). These complexes are characterized by a notable presence of polished stone axes, with ceramics absent in these contexts.

One of the key defining factors of Layer IV is its stratigraphic context with a newly acquired absolute date (6216–5929 BC). This layer directly overlays the Mesolithic layer, with a sterile gravel layer measuring 1m thick separating the two.

Conclusion

Recent collaborative laboratory work by Georgian and international scientists has provided crucial insights into the mobility and interactions of the inhabitants of the Darkveti rock shelter. The Darkveti rock shelter had a very good strategic location, which attracted the attention of the ancient humans of the region. Of course, the intensive use of the site is indicated not only by its good location, but also, apparently, by the favourable palaeo-climatic environment and the corresponding abundance of flora/fauna. The study of the cultural layers of the rock

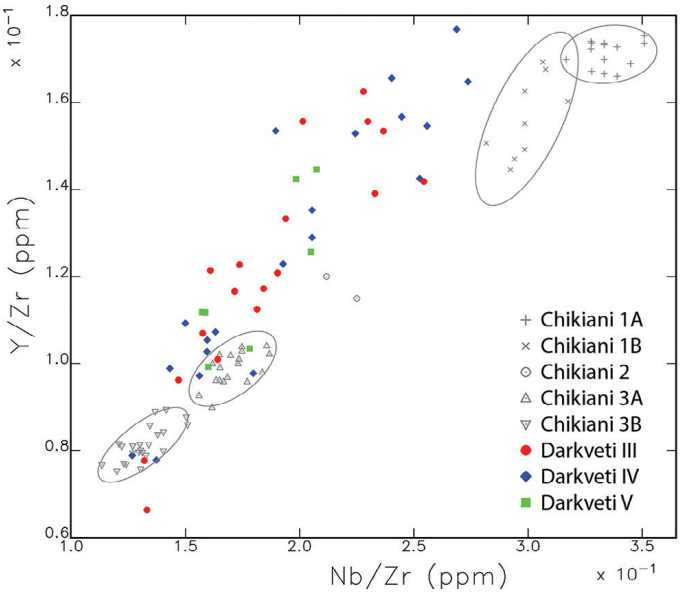


Fig. 11. Scatterplot of the ratios of niobium and zirconium (Nb/Zr) versus yttrium and zirconium (Y/Zr) showing obsidian samples from layers III, IV, and V of the Darkveti rock shelter determined via XRF, with data and ellipses drawn at 90% confidence intervals from Chikiani subsources determined via LA-ICP-MS, as calculated by Paolo Biagi and Bernard Gratuze (2016).

shelter showed that the site was intensively although intermittently used for a number of reasons, from the Mesolithic to the Early Bronze Age.

It appears that the selection of raw materials for tool manufacture was of paramount importance to the dwellers of Darkveti, who employed specific strategies for this purpose. They were likely well versed in the available resources and made informed decisions on which materials to prioritize. The fact that these prehistoric societies did not rely solely on the abundant flint deposits in the Imereti region but travelled several hundred kilometres to obtain obsidian is particularly noteworthy. This highlights the need for further study of flint deposits, which could offer a unique perspective on the movement and behaviour of prehistoric societies.

As part of the interdisciplinary research, determining the precise age of the Mesolithic and Neolithic layers at the Darkveti rock shelter using the radiocarbon method was of utmost importance. We must, however, acknowledge the contributions of the site's first researcher, the archaeologist Nebieridze, who approximately 50 years ago, based on the available information at the time, provided us with an estimated age of the layers. Recent research has validated her earlier hypothesis, indicating that life in the Darkveti rock shelter began around the 8th millennium BC and resumed again towards the end of the 7th millennium cal BC.

Acknowledgements
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New ^{14}C data from the tumuli necropolis of Dubac in Jančići near Čačak and their role in establishing the chronological sequence of the Late Bronze Age for western Serbia

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ABSTRACT – *This paper presents 17 new ^{14}C dates from the tumulus cemetery of Dubac in Jančići, in western Serbia. Burials were accompanied by bronze personal ornaments and occasionally pottery vessels. ^{14}C dates are considered together with the stratigraphy, mortuary practices and material culture from the graves in two tumuli in order to explore local mortuary conventions and to set these in their regional context. It is shown that after being founded in the third millennium BC, the tumuli were reconfigured and re-used for burials at multi-decade intervals during the 15th to 12^{h} centuries BC.*

KEY WORDS – *Dubac in Jančići; Late Bronze Age; necropolis; ^{14}C dates*

Novi ^{14}C datumi iz gomilnega grobišča Dubac v Jančićih pri Čačku in njihova vloga pri oblikovanju kronološkega zaporedja pozne bronaste dobe v zahodni Srbiji

IZVLEČEK – *V članku predstavljamo 17 novih ^{14}C datumov iz gomilnega grobišča Dubac v Jančićih v zahodni Srbiji. V grobove je bilo pridano bronasto osebno okrasje, včasih tudi lončene posode. ^{14}C datume obravnavamo v povezavi s stratigrafijo, pogrebnimi praksami in materialno kulturo iz grobov v dveh gomilah, z namenom prepoznave lokalnih pogrebnih praks in njihove umestitve v regionalni kontekst. Raziskava je pokazala, da so bile gomile, prvotno postavljene v tretjem tisočletju pr. n. št., kasneje preoblikovane in znova uporabljene za pokope v več desetletnih presledkih med 15. in 12. stoletjem pr. n. št.*

KLJUČNE BESEDE – *Dubac v Jančićih; pozna bronasta doba; nekropola; ^{14}C datumi*

Introduction

Tumuli are a recurrent feature of the prehistoric landscape of Southeastern Europe. Their construction occurs from the fourth millennium through to the first millennium BC and occasionally after that older monuments came to form palimpsest landscapes in which these 'made places' continued to have resonance across generations. As prominent landscape markers, they thereby featured in conceptions of landscape and society for multiple millennia. Their roles as places for burying the recently deceased, for marking lineages or histories within a community and as deeper, ancestral markers are all relevant for understanding the diachronic conceptualization of landscapes. To address the evolution of these monuments in their social landscapes, we conducted absolute dating of burials from monuments that were known to have earlier and

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later phases of use. Our aim was to better understand the punctuation of use of tumuli in a specific landscape. We selected a tumulus cemetery from Dubac in Jančići near Čačak (hereafter Dubac) in western Serbia because multiple tumuli appear to have been built and used in different phases, and many of the burials were accompanied by highly diagnostic metalwork. This links to our second aim, which was to use absolute dates to build upon recent work and better ground the relative chronology of metalwork to provide insights into the use of other monuments in this area. Given the dearth of known settlements, the insights we get from mortuary monuments are a critical resource for developing a sense of how societies in this area were organized and how they related to surrounding societies. These new dates also enable a much-needed consolidation of relative chronologies, following recent developments in this area.

For the Middle and Late Bronze Age (MBA and LBA, respectively) recent work requires substantial rethinking of the sequences and terminology used for western Serbia. It is now evident that there are considerable differences between what Milutin Garašanin (*1983*) termed the West Serbian variant of Vatin culture and the material culture typically considered to fit within the Vatin typo-chronological scheme in the south Pannonian Plain and its environs. Indeed, these differences are clearly chronological, with Vatin dating to the earlier second millennium BC and the West Serbian group dating to the later second millennium BC, equating with the MBA and LBA, respectively, for this region (*Ljuština 2022.105–109,131–134,146–147 with references*). Consequently, building on Vojislav Filipović's work, we now term this the LBA West Serbian group (*Filipović 2013.70; Ljuština 2022.147*). Following Aleksandar Bulatović and Jovica Stankovski's (*2012.241,260,343*) recategorization of Vatin variants in Central Serbia to a Bubanj-Hum IV-Ljuljaci group that is contemporary to Vatin, there is now greater clarity on spatial and chronological frameworks for the material from Dubac. The LBA West Serbian group thus reflects a distinct phenomenon that is clearly distinguished from both the Vatin and Bubanj-Hum IV – Ljuljaci traditions (*Bulatović 2021.129,141; Ljuština 2022.117,126–129*).

With this in mind, general models for social practices linked to Vatin culture in the previous literature have little relevance to Dubac, and so this paper explores chronological and cultural developments characteristic of western Serbia during the Bronze Age, with a particular focus on mortuary contexts of the mid- to late-second millennium BC. We present new absolute dates to shed light on the development of two tumuli from the cemetery at Dubac and explore the regional relationships the monuments, burial practices and material culture reflect. It is argued that claiming or appropriating ancestral monuments (dated to the EBA) was important to local communities during the LBA and that a convention emerged whereby tumuli were opened for burial once in every one or two generations over the course of one to three centuries. The communities buried there were well-networked with surrounding areas, and integrated some regional conventions of mortuary practice and material culture, but ultimately followed a defined local tradition of use of burial monuments. Furthermore, the new dates from Dubac are used to better calibrate and qualify relative chronological sequences for material typical to the second half of second millennium BC. In this way, we place the material and practices from this site in their wider context. By tracing the history of use of the tumuli, we consider their role as meaningful spaces within past communities. Specifically, their punctuated use indicates that despite some interments being separated by decades, the recurrent use of these specific monuments demonstrates they remained focal points for landscape and personal identities across centuries, from their initial foundation activities through to their recurrent use in a later period. In order to explore the temporality of their use, we begin with a brief presentation of the chronological and cultural context of these tumuli in their southeast European, and more specifically their western Balkan, context.

Dubac in Jančići: results

Dubac is a prehistoric tumulus cemetery with both cremation and inhumation burials. There are two main periods of use – the first is the Early Bronze Age (EBA) and the second in the LBA. The site is situated in the range of the Kablar Mountain in western Serbia (Fig. 1). It is one of the best preserved cemeteries in the region with respect to the survival of human remains and the variety of objects interred with burials (*Nikitović 1999; Dmitrović 2016.60–84; Dmitrović, Molloy 2022b*). The necropolis was excavated during several fieldwork campaigns[1] and five out of eight mounds

1 The excavations took place in 1984 and 1985 under the directorship of Milena Ikodinović (*Nikitović 1999*), while those in 2013 and 2014 were conducted by Katarina Dmitrović (*2016*), both curators of National Museum in Čačak.

were archaeologically investigat-ed. All mounds used a combination of soil and stone, with stone used also to define spaces within the mound, including individual grave structures. There was little complex stratigraphy, and the LBA activity evidently reworked earlier EBA monuments by adding further material to the tumuli. The EBA tumuli consisted of single, central inhumations encircled with stones, as defined for Mounds 1 and 2 through excavation (Figs. 3 and 4). LBA re-use included inhumation within roughly modelled stone settings and cremation burials within urns. These were commonly placed concentrically relative to the mound centre. Each grave apparently respected earlier ones, with no visible signs of disturbance, which may suggest graves had been marked on the mound. The creation of cremation pyres on the surface of the tumulus caused some minor disturbance (*Molloy, Dmitrović, forthcoming*). Mound 3 (Figs. 5 and 6) was established during the LBA and some stratigraphic relations could be defined. The foundational, *i.e.* central Graves 3 and 5 were covered by tumulus material and the individuals from Graves 2, 4 and 6, were then buried into graves cut into the tumulus. Though biritual, inhumation graves were more frequent and cremation graves tended to be stratigraphically higher, a little later than the earliest burials, which were all inhumation in the case of Mounds 1, 2 and 3. The results of excavation of the necropolis in Dubac have been published in detail (*Nikitović 1999; Dmitrović 2016*). A first bioarchaeological report on the human remains and more detailed work on some of the material culture – torcs, bracelets and spectacle-shaped pendants – have also been published (*Vasić 2010; Radović 2016; Dmitrović 2019; 2021*).

Our key focus in this paper is to evaluate the chronology of these burials and how they relate to the development of the burial monuments that contained them. For this reason, we began by correlating the stratigraphy of excavated features with the typo-chronology of material culture accompanying burials. Metalwork (exclusively copper alloy) was the most common find type, with relatively few ceramic vessels being recovered. In previous research, Mound 1 Grave 6 and Mound 2 Grave 4 were believed to be earlier (EBA or MBA) in date than other burials in these mounds, on the basis of the flexed placement of the body and their central location in the first phase of mounds, though the absence of accompanying material culture precluded accurate relative dating of these two interments. Due to the extension of Mound 2, now known to be an LBA action, the original central grave was decentred. Other

Fig. 1. Map of the Balkans showing the location of Dubac, Jančići.

graves were originally dated to the final phases of the MBA (Br B2-C and Br C) on the basis of bronze artefacts and their relative positions in the tumuli (*Nikitović 1999; Vasić 2010; Dmitrović 2016*).

To test these relative sequences and explore the life history of these monuments, the authors obtained AMS ^{14}C dates for 17 inhumation burials (Fig. 2). One sample from a cremation burial failed to yield results. Absolute dates confirmed distinct earlier and later phases, now known to be EBA and LBA in chronology. Considering absolute dates and stratigraphic analysis and mortuary practice together, it is likely that activity at the tumuli took place intermittently. Due to the relatively wide, and overlapping, ranges of the ^{14}C dates, it has not been possible to define distinct phasing or sequences. Nonetheless, a case is made that burials were punctuated, taking place every one to three generations, with as little as 16 years and as much as three centuries separating the earliest and latest LBA burials, as discussed below. There are two clear phases, one EBA the other LBA, and we tentatively split the LBA into earlier and later phases, accommodating some overlap in absolute date ranges. These are:

I. EBA period – 26th to 21th century cal BC
II. LBA period – 15th to 13th century cal BC
  (a) Beginning of the 15th to early 14th century BC.
  (b) Beginning of the 14th to the end of the 13th century BC.

Two cremation and one inhumation burial from Mound 2 were not dated as part of this project, but they can be relatively stratigraphically dated to late in the burial sequence of this mound but within the LBA. The distinct EBA and LBA phases demonstrate that the Dubac cemetery was used for centuries, and that within each phase it played an important diachronic role

Our ref.	Lab ID	Mound No.	Grave No.	Uncal. date	(±)	δ^{13}C	Sigma 2	Sigma 2	Sigma 1	Sigma 1	Element
TF074	OxA-41189	1	6	4018	20	-20.84	2576–2472 BC (95.4%)		2572–2556 BC (16.4%)	2543–2513 BC (32.2%)	Lower canine
TF074_2	BRAMS-4342	1	6	4012	28		2618–2610 BC (1.2%)	2581–2466 BC (94.3%)	2570–2518 BC (47.0%)	2499–2476 BC (21.3%)	Lower canine
TF062	OxA-41230	1	9	3161	23	-16.53	1500–1400 BC (95.4%)		1492–1481 BC (11.9%)	1451–1414 BC (56.4%)	Right petrous
TF067	OxA-41293	1	3	3127	20	-16.07	1446–1377 BC (72.9%)	1346–1306 BC (22.5%)	1431–1392 BC (57.6%)	1334–1324 BC (10.7%)	Lower 2nd R molar
TF073	OxA-41296	1	1	3113	20	-17.22	1436–1372 BC (58.5%)	1352–1301 BC (36.9%)	1421–1387 BC (45.4%)	1338–1319 BC (22.9%)	Right petrous
TF066	OxA-41111	1	8	3105	19	-17.15	1430–1370 BC (51.5%)	1355–1298 BC (44.0%)	1416–1385 BC (39.3%)	1340–1316 BC (29.0%)	Right petrous
TF063	OxA-41557	1	4	3085	18	-16.39	1415–1287 BC (95.4%)		1404–1378 BC (25.0%)	1346–1304 BC (43.2%)	Right petrous
TF072	OxA-41295	1	5	3083	20	-16.67	1416–1282 BC (95.4%)		1405–1376 BC (25.0%)	1350–1302 BC (43.3%)	Right petrous
TF070	OxA-41112	1	7	3017	20	-17.07	1384–1341 BC (16.5%)	1310–1199 BC (78.7%)	1288–1220 BC (68.3%)		Left petrous
TF061	OxA-41292	2	4	3679	20	-20.73	2140–2016 BC (87.4%)	1999–1977 BC (8.0%)	2133–2084 BC (46.3%)	2054–2027 BC (21.9%)	Right Petrous
TF068	OxA-41294	3	3	3178	19	-19.06	1498–1418 BC (95.4%)		1494–1478 BC (24.0%)	1456–1426 BC (44.3%)	Deciduous lower molar
TF053	BRAMS-4333	3	5	3173	27		1502–1408 BC (95.4%)		1495–1477 BC (21.6%)	1456–1420 BC (46.7%)	Petrous portion
TF071	OxA-41113	3	1	3155	19	-17.05	1497–1470 BC (15.0%)	1464–1396 BC (80.5%)	1448–1412 BC (68.3%)		Right petrous
TF065	OxA-41109	3	2	3091	19	-16.20	1419–1291 BC (95.4%)		1408–1380 BC (28.7%)	1344–1307 BC (39.5%)	Left petrous
TF065_2	OxA-41110	3	2	3078	19	-16.16	1412–1281 BC (95.4%)		1398–1375 BC (21.0%)	1351–1301 BC (47.3%)	Left petrous
TF064	OxA-41108	3	4	3052	20	-16.43	1399–1258 BC (92.6%)	1244–1230 BC (2.9%)	1382–1342 BC (34.4%)	1310–1270 BC (33.9%)	Right petrous
TF075	OxA-41297	3	6	3024	21	-17.73	1386–1338 BC (22.6%)	1316–1210 BC (72.9%)	1370–1356 BC (10.3%)	1296–1225 BC (57.9%)	Left Petrous

Fig. 2. Table of uncalibrated and calibrated ^{14}C dates from samples taken from human remains from Dubac at the Oxford Radiocarbon Accelerator Unit.

as a meaningful place for the inhabitants of the area.

As we are dealing with probability ranges for ^{14}C data, we can speak about minimum and maximum durations of use for each of the monuments. It is improbable that a date would occur at the limit of the probability range because the probability of accuracy falls off towards the margins. However, working with minimums and maximums, we can propose the following general timelines for the use of the mounds at Dubac. It is statistically possible that all bar one burial in Mound 1 occurred simultaneously, with the outlier offset by a minimum of 16 years. For Mound 3, Burial 6 must be later than Burials 1, 5 and 3, with 32 years being the minimum gap between Burials 3 and 6, and all bar two burials could be contemporary to each other. For Mound 1, the maximum difference between the earliest and latest LBA burial is 301 years (Burials 9 and 7) and for Mound 3 the maximum is 292 years (Burials 5 and 6). As there are few stratigraphic relationships, Bayesian modelling of the data is not helpful to define sequences.

Working with approximations (not formal models) based on the higher probability ranges of dates in the Sigma 1 range, a period of use for both mounds of 150 to 250 years appears likely. This would involve nine burials taking place during the LBA phase of Mound 1 and six burials being interred in Mound 3 along a very similar timeline. The dates are distributed with no evident clustering throughout the range, suggesting punctuated burial events with a few burials being interred in close succession. It is likely that one to several decades separated specific burial events in each tumulus. The possibility that some of those interred shared close biological relationships is currently being explored through genetic analyses, and this will potentially enable closer refinement of the ^{14}C datasets (*Iraeta-Orbegozo* et al*., in preparation*).

Early Bronze Age

Absolute dates confirmed the hypothesis that both Mounds 1 and 2 were constructed during the EBA, with Grave 6 (Fig. 3) and Grave 4 (Fig. 4), respectively, being interred prior to the creation of the mound that would cover them. The

cemetery was subsequently re-used and enlarged in the LBA after a multi-century hiatus. The many centuries separating the EBA burials in two tumuli at Dubac further underscores the diachronic relevance of this place, such that these two mortuary monuments were created at least three and as many as six centuries apart. The EBA burials have been discussed recently in a broader study of the absolute chronology of EBA graves from western Serbia (*Dmitrović, Molloy 2022a*). Mound 1 Grave 6 is dated 2576–2472 cal BC (95.4%) and belongs to our second EBA phase dated to the third quarter of the third millennium BC, contemporary to tumuli at the sites of Ivkovo Brdo, Ruja and Suva Česma (*ibid.*). Mound 2 Grave 4 is dated to 2140–2016 cal BC (87.4%) which places it in our EBA Phase 3 (Fig. 10) (*ibid.*). Only one contemporary grave is known in the area, occurring at the site of Prijevor. Though based on few finds, these EBA phases are useful for cross-referencing activities in this region given the sparsity of well-dated archaeological contexts.

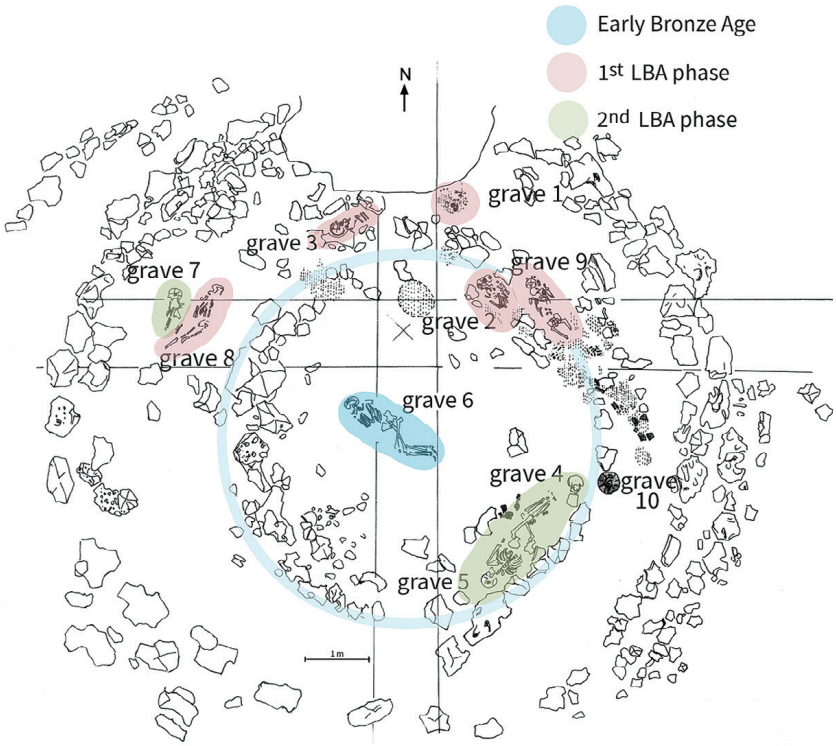

Fig. 3. Drawing of Mound 1 at Dubac with Late Bronze Age graves highlighted according to two proposed general phases (modified after* Nikitović 1999*).

Late Bronze Age

The 15th to mid-14th century BC

Seven graves fall within this date range at 95.4% probability (see Fig. 2). Some of these were accompanied by metalwork commonly dated to this time span (Final Br B to Br C), which suggests these can be attributed to a Phase IIa. This is further supported by the location of these seven burials within the mound, as well as specific features of their placements, which suggests these can be separated from those we attribute to Phase IIb below. To be clear, there was likely to have been more than two phases but these cannot be determined using archaeological stratigraphy or ^{14}C data. Burials attributed to Phase IIa are:

- Mound 1– Graves 1, 3, 8 and 9;
- Mound 3 – Graves 1, 3 and 5.

Two types of activity occurred in the Late Bronze Age – the re-use of existing tumuli and the creation, or part creation, of new tumuli, beginning in the early 15th century. During the 15th to early 14th century BC, the majority of graves were oriented NW – SE and had some form of enclosing, defining stone structure under, around or above the interred individuals. Bioarchaeological analyses indicate individuals from Mound 1 – Graves 3 and 9 (Fig. 3) and Mound 3, Graves 1 and 5 (Figs. 5 and 6) were adult women furnished with personal ornaments (Figs. 7 and 8). Excavation records indicate that the individuals buried in Mound 1 Grave 9 and Mound 3 Grave 5 were interred in a prone (face-down) position. Mound 1 Grave 6 was interred under a small tumulus during the EBA, visible as a stone setting in Figure 3, which was substantially extended to the northeast during the LBA. Mound 3 appears to have been entirely constructed during this period as there is no evidence of reuse of an older structure, and Grave 5, and probably Grave 3, served as central graves. The absolute date ranges of these two burials suggest they were closely contemporary. The monument was evidently completed after these burials were interred. It was reopened later in the 15th century BC, but the new cut did not disturb the earliest burials, so that Grave 1 was interred almost directly above Grave 3. This provides us with two stratigraphic phases for Mound 3. Graves 3 and 5 have closely overlapping date ranges suggesting general contemporaneity, which also accords with them both being covered by the cairn.

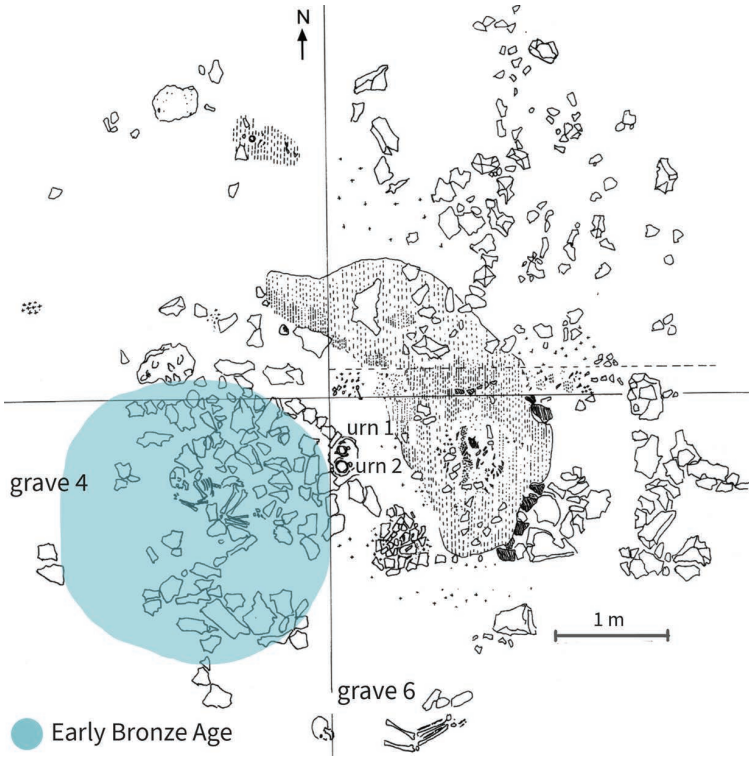

Fig. 4. Mound 2 at Dubac with the Early Bronze Age grave highlighted (modified after* Nikitović 1999*).

However, these date ranges also overlap with the burial lying stratigraphically above this. Given the very substantial overlap between the ^{14}C date ranges, Bayesian modelling was not helpful for determining the time that passed between these two stratigraphic phases, and it is likely therefore we are speaking about a few years or decades at most. It is most probable that a short space of time – a few decades at the very most – separated the initial burials associated with the construction of the mound and several of the subsequent burials that were set into this mound when it had become a standing monument (Fig. 11). However, in general it is not feasible to use the absolute dates to create sub-phases due to the dearth of stratigraphic relationships, and a general trend appears to be that burial activity at both Mounds 1 and 3 was initiated early in the 15th century BC with one and two burials, respectively. Looking to the metalwork, particularly the very rare type of torcs from Graves 1 and 9 in Mound 1 with coiled and elevated ends, the relative chronology supports a date early in the ^{14}C probability range.

The 14th to the end of the 13th century BC

- Mound 1 – Graves 4, 5 and 7
- Mound 3 – Graves 2, 4 and 6

The absolute dates of the graves discussed here partly overlap with those described above, but the duration of their probability range means they may have been interred decades apart, but no more than that. For the activity in Mound 3 it is possible that Grave 4 was interred slightly later than Grave 2, both probably in the 14th century BC. For Mound 1, two burials (Graves 4 and 5) from the end of 15th and 14th centuries were likely closely contemporary to each other and to Mound 3 Grave 2. Some graves from Mound 1 to a certain extent 'bridge' Phases IIa and IIb, as shown by their ^{14}C dates as well as with reference to the material culture in these graves, which is closer to the Phase IIa repertoire. This suggests punctuated, perhaps cyclical, use of these monuments. While it remains possible that decades se-

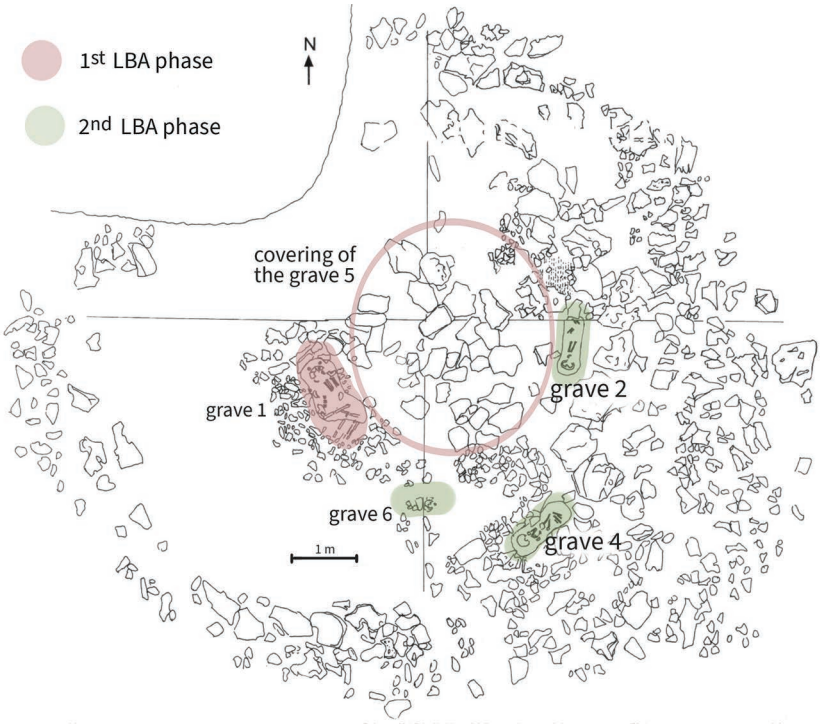

Fig. 5. Mound 3 at Dubac. Upper layer in the cairn with later stratigraphic phase of Late Bronze Age graves highlighted according to the two proposed general phases (modified after* Nikitović 1999*).

parate each of these burials, in the centuries-long duration of their use these represent occasional and widely punctuated and restricted interventions into the monuments. Notably, such interventions occur in both of these tumuli along very similar timelines.

The location of three graves from the 14th century BC can be documented, with two graves from Mound 3 (Fig. 5) and one grave from Mound 1 (Fig. 3). The three documented graves were defined by stone structures set around and above the burial and their orientation was NE-SW. Considering the changing meaning of these monuments over time, this 90-degree rotation from the NW-SE oriented burials of the 15th century BC may be significant. The orientations are not universally the same for each phase, though this is a general trend. A small quantity of bronze items – the discs from a spectacle-shaped pendant and hair rings – along with a ceramic vessel, were deposited alongside Mound 1 Grave 5 and Mound 3 Grave 4 (Fig. 9). A bracelet deposited in Mound 3 Grave 4 is of a form that would typologically be dated earlier, and so it may represent an heirloom or the reuse of an older object. Activity continued in both mounds into the 13th century BC, with one single burial (probably) interred into each mound in the 13th century BC. These are both fragmentary secondary burials, lacking associated finds, and so it is difficult to say much about the associated mortuary practices except that the activity appears to have been more superficial, with less modification of the monument and therefore reduced protection of the burials over time.

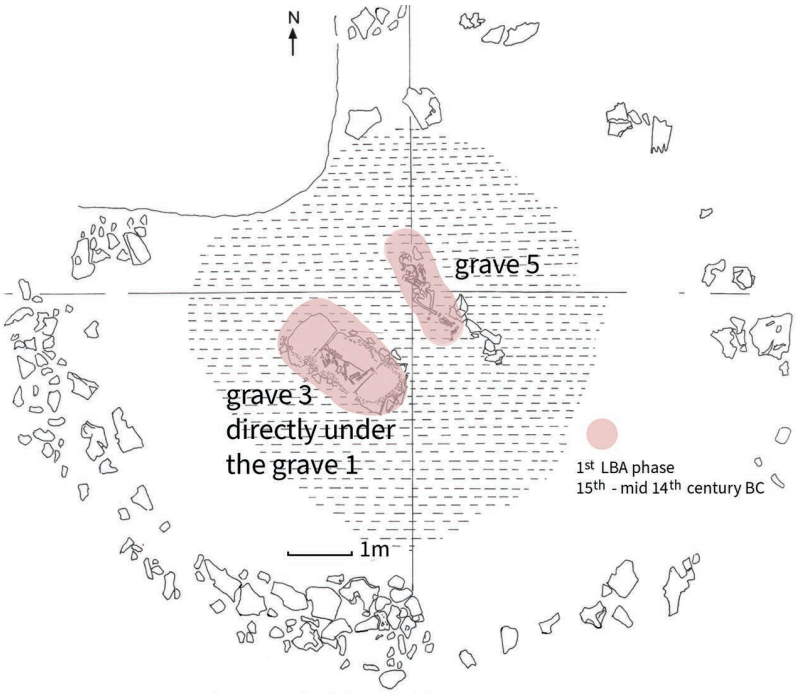

Fig. 6. Mound 3 at Dubac. Initial pre-mound Late Bronze Age burial phase with graves highlighted belonging to the first of the two proposed general phases of activity (modified after* Nikitović 1999*).

In the original published results (*Nikitović 1999; Dmitrović 2016*) based on the numbering of physical collections of material in the Museum of Čačak, five graves were recorded as coming from Mound 3. However, in the original documentation from the excavation a sixth grave was recorded, which was preserved as a small number of skull fragments belonging to a juvenile that were interred into the southern area of tumulus mound. Follow up bioarchaeological analyses and ^{14}C dating of these fragments, along with other burials, has helped clarify this situation, and so now we attribute these cranial fragments to a poorly preserved burial recorded here as Grave 6. In the museum records and storage, the partial remains of two individuals are documented as belonging to Grave 5. Individual 1 was an adult female skeleton and Individual 2 was a poorly preserved juvenile, represented by cranial fragments (*Radović 2016.280*). The excavation records and photographs clearly document the presence of a single adult skeleton in Grave 5, which indicates the cranial fragments do not belong to this burial. As Grave 6 was documented as lying in the southern part of the tumulus and consisted only of skull fragments, we consider it most probable that what was stored as Grave 5 Individual 2 is in fact the missing Grave 6 remains. We therefore use this latter number to refer to these human remains. This conclusion is also supported by the ^{14}C dating which point to the 15th century for the Grave 5 Individual 1 (adult female) and a likely end of the 14th to 13th century date for the remains stored as Grave 5 Individual 2 (a juvenile).

Absolute dates are also available for the central cremation grave from Mound 7 at the Dubac necropolis, which is dated to 1370–1200 (68.2%) or 1390–1120 (95.4%) cal BC (*Bulatović* et al*. 2018.Tab. 1*). There were no associated finds, but green stains on the cremated bones indicate that bronze objects had been present but corroded away. Though falling within the probability range of the above dates, it is possible that this burial was slightly later. As with the stratigraphic

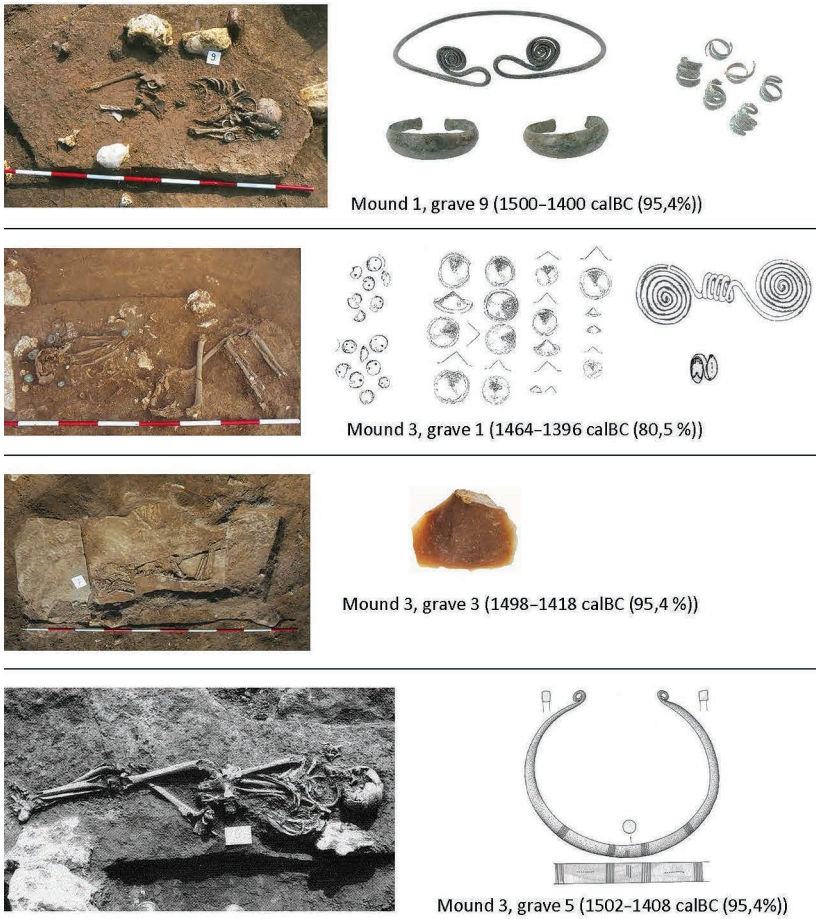

Fig. 7. Photographs of Late Bronze Age burials and material culture from the Mound 1 – Grave 9, Mound 3 – Graves 1, 3 and 5, dated to the 15th/ early 14th century BC (after* Nikitović 1999; Dmitrović 2016*).

position of cremation burials in other mounds, the trend is for cremation burials to be late in the sequence. However, they do chronologically overlap with inhumations, as seen for example in the central cremation grave – from the nearby necropolis of Ivkovo Brdo in Krstac (Mound 4 Grave 1). This was dated to 1390–1230 (68.2%) or 1400–1210 (95.4%) or cal BC (Fig. 10) (*Bulatović* et al. *2018.123,125, Tab. 1*). That burial was only accompanied by a whetstone.

Dates from the surrounding area

In the Pannonian Plain to the north, the intensity and density of activity increased from 1600–1550 BC and declined again *c.* 1200 BC (*Sava, Gogâltan 2022; Molloy* et al. *2023*). This was a period when metalwork and some ceramics associated with the Tumulus culture in the northern half of the plain were introduced into the south, including today's Serbia, and the influence of these styles is seen in the Dubac assemblage.

The cemetery of Brezjak (Paulje) lies to the northwest of Dubac close to the River Drina. The central grave from Mound 18 was a cremation burial. This was associated with a small ceramic beaker, two massive bronze bracelets, a bronze button and hair rings and the grave was dated 1402–1302 (68.2%) or 1415–1278 (95.4%) cal BC (*Gligorić* et al. *2016*). From the same cemetery come several more recent ^{14}C dates. Two samples from mound 28 come from an organic surface on which a finely engraved bronze bracelets were deposited, provide dates of 1408–1204 (95.4 %) and 1424–1292 (95.4%). Within the mound the bronze items found include a pin, torc, bracelets, and lunular pendants. These are from disturbed contexts and cannot be associated with specific graves (*Filipović* et al. *2022.82, Fig. 8, Pl. I, II*). Three ^{14}C dates from the central cremation grave in Tumulus 11 at Brezjak were obtained from samples from a single oak plank (1497–1440 (68.2%) or 1517–1414 (95.4%); 1456–1414 (52.8%) or 1503–1394 (94.8%); 1356–1302 (39.0%) or 1432–1267 (95.4%) cal BC (*Cwaliński* et al. *2023.84–86, Tab.1, Fig. 4*). The authors state that the difference between dates is likely a consequence of how the oak plank had been cut in antiquity, such that they sampled heartwood and sapwood of the same tree, thereby dating older and newer growth. As a result, they argue their modelling of the data indicate a date of 1517–1267 cal BC at 95.4% probability, though in light of their scenario the likelihood is that the later date range of 1432–1267 cal BC is perhaps more probable as a date for the tree being felled, although that is further complicated by this having a slightly lower overall weight of carbon preserved. In any scenario, the ^{14}C accords in general with the relative chronology of the metalwork finds, which would favour a 15th to 14th century date, with the ^{14}C likely pushing that to the later 15th to 14th century. This places its use as contemporary to Dubac, but it was likely constructed some decades after the resurgence of burials within the Dubac monuments. This grave contained bronze bracelets, lunular pendants, long pins, bracelets of coiled wire, ceramic vessel and amber beads. Based on these results, the authors argued that the mound was probably

established between the end of the 15th century BC and the end of 14th century BC, which corresponds to the Br C2 phase in Reinecke's central European metalwork chronology, which is widely employed as a regional reference framework (*Cwaliński* et al. *2023.85–86, Pl.1*).

Mound 1, grave 1 (1436–1372 calBC (58,5%))

Mound 1, grave 3 (1446–1377 calBC (72,9%))

Fig. 8. Photographs of Late Bronze Age burials and material culture from Mound 1 – Graves 1 and 3, dated to the 15th/early 14th century BC (after* Nikitović 1999; Dmitrović 2016*).

To the NW of the Drina-Sava confluence, a large tumulus cemetery at Purić–Ljubanj is possibly entirely Late Bronze Age in date. This includes disturbed cremation burials in Tumulus 2 associated with Belegiš II pottery (common to the Pannonian Plain *c.* 1400–1100 BC), dated no later than 1390–1010 cal BC (*Budden-Hoskins* et al. *2014*). The cemetery at Velebit in north Vojvodina was biritual and the metalwork and pottery there are characteristic of the Tumulus culture in this area. Cremation Grave 107 included a ceramic urn and lid and has been ^{14}C dated to 1408–1260 cal BC (95.4%), and the earliest dated inhumation burials there are closely contemporary with the first at Dubac, dating to the earlier 15th century cal BC (Fig. 10) (*Kapuran 2018.39–40; 2019.93*). On the opposite bank of the Tisza to Velebit, a dense network of new settlements was established and used along timelines that are very similar to those of the tumuli at Dubac (*Molloy* et al. *2020; 2023*). Those cemeteries were biritual in principle, but inhumation was rare and cremation was dominant.

In general, metalwork was frequently deposited in both cremation and inhumation burials dated 1600–1200 BC in the area around western Serbia and eastern Bosnia. Ceramic vessels are not commonly included alongside inhumation burials, while they commonly served to contain bones in cremation burials (*Dmitrović 2016*). Belegiš pottery was commonly consumed at sites to the north in the hinterlands of the Sava River, while to the south, including around Dubac, pottery followed local conventions but with influences from Belegiš forms. Most settlements and cemeteries from the north and cemeteries from the south of the Sava River in Serbia were abandoned by 1200 BC. The consumption of pottery inspired by Belegiš forms at Dubac indicates interactions between these broad areas, but the comparative rarity of cremation demonstrates either the multi-generational preservation of local burial conventions or differences in beliefs. A very important common feature, however, is the appropriation of older mortuary landscapes by communities. Tumuli dated to the third millennium BC in particular are widespread in the Pannonian Plain.

Mound 1, graves 4 and 5

Inventory of grave 5 (1416–1282 calBC (95,4%)

Mound 3, grave 4 (1399–1258 calBC (92,6%)

Fig. 9. Photographs of Late Bronze Age burials and material culture from Mound 1 – Graves 4 and 5, and Mound 3 – Grave 4, dated to the 14th/early 13th century BC (after* Nikitović 1999; Dmitrović 2016*).

Bronze Age period	Absolute dates (cal BC)	Culture	Phase in Western Morava upstream area	Graves at Dubac	Other graves from the area
Early Bronze Age	2900/2800 2600/2500	Proto Belotić – Bela Crkva	Phase 1	-	Veliko Polje in Jančići
	2200	Belotić- Bela Crkva	Phase 2	Mound 1, G. 6	Ivkovo brdo in Krstac, Suva Česma in Lučani
	2000/1900		Phase 3	Mound 2, G. 4	Ade in Prijevor
Middle Bronze Age	-	-	-	-	-
Late Bronze Age	1500 1200	LBA West Serbian Culture	15th – beg. of 14th cal BC 14th - end of 13th cal BC	Mound 1, G. 1, 3, 8, 9 Mound 3, G. 1, 3, 5 Mound 1, G. 4, 5, 7 Mound 3, G. 2, 4, 6	Brezjak, Mound XI, centr. grave Brezjak, Mound XVIII, G. 1 Ivkovo brdo, Mound 4, G. 1 Velebit, G. 107 Dubac, Mound 7, G. 1

Fig. 10. Chronological table.

After the widespread abandonment of tells in the southern plain *c.* 1600–1450 BC, new settlements were often co-located with older tumuli and the possible construction of new ones (*Molloy* et al*. 2023*). This idea of an adopted, appropriated or invented lineages accords with the contemporary activity at Dubac.

Conclusion

Re-use of EBA tumuli, and the construction of new ones at Dubac, began after 1500 BC and this second phase of use ended by 1199 BC (at 95.4% confidence). There is a striking correspondence in this chronology to occurrences in the south Pannonian Plain. Old cemeteries were abandoned and new ones established *en masse c.* 1600–1500 BC. In turn, these were abandoned in most cases or more rarely reverted to occasional use by *c.* 1200 BC. This temporality goes beyond coincidence, and is reinforced by the deposition of pottery and metalwork inspired by the Belegiš and Tumulus culture traditions at Dubac.

In their local setting, we can approximate the phasing of the use of the tumuli at Dubac. We argued this was likely to have occurred once in every one to three generations. Given the probable duration of use of the tumuli extended from less than one to up to three centuries and the distribution of ^{14}C dates throughout the span of 1502 to 1199 cal BC, burial was evidently intermittent but occasionally clusters of activity are suggested by closely similar dates. In our broad approximation using the ^{14}C dates and stratigraphy as guidelines, we suggested there were around four or five occasions when interventions took place, which would equate to episodes of intensive use on average once every 30 to 50 years. While distinct phases cannot be subdivided, we can broadly speak of burials falling into, and between, an earlier and a later phase of the LBA. In light of the probability ranges of dates, should some burials in practice have taken place closer together then this would mean that there were even longer periods of hiatus between use phases. That nonetheless supports the model of deliberately punctuated use of the monuments with decades or more between interventions. This means it was less likely that the monuments were reopened any more frequently than once or twice per generation. This intergenerational reopening was evidently part of the expected and routine lifecycle of the monuments. That is reinforced by the general contemporaneity of the changes made to Mounds 1 and 3, suggesting they had parallel 'lives' within the community. While cremation burials are not yet dated, the associated finds indicate that LBA burials into Mound 2, established in the EBA, also followed a similar timeline.

The inclusion of adults and juveniles indicates that being buried into these monuments was unrelated to specific identities (*e.g.,* a religious leader or a chief) or accrued social status (*e.g.,* a warrior or a smith). This suggests to us that inclusion was related to corporate identity, such as being part of a specific family lineage or being from the nuclear or extended family of a high status individual, and so selection for interment may have been somewhat opportunistic or arising from particular social circumstances. That is, there was an expectation that a member of a group would be buried at certain junctures, and the choice was impacted by the timing and perhaps causes of deaths. This need not exclude the relevance of the identity or specific lineage of the person, but as ancestral spaces for the community, the family or social unit identity may have

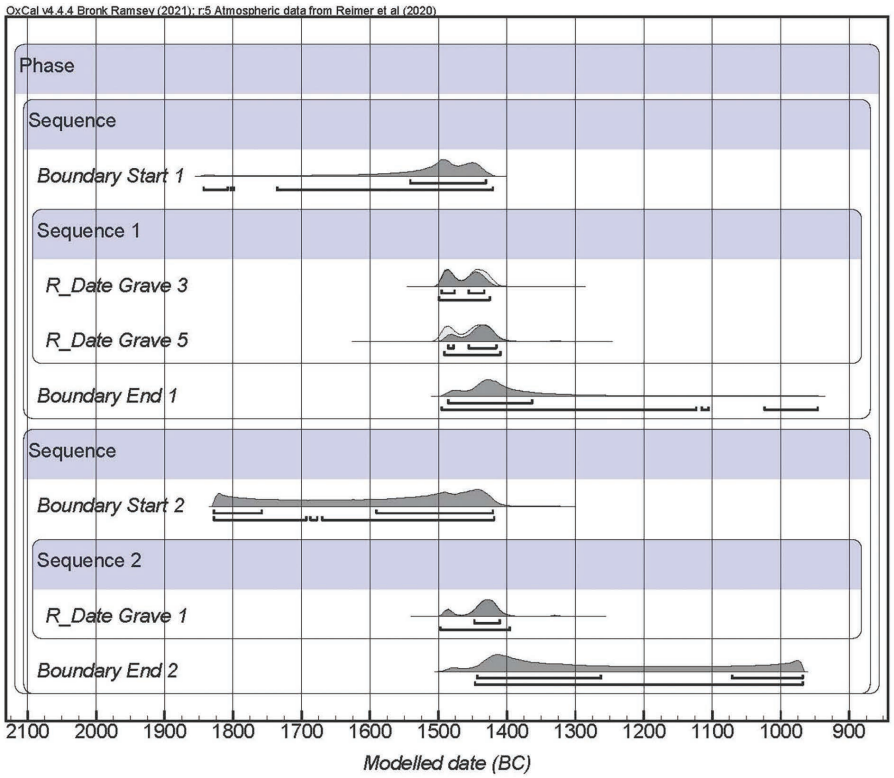

Fig. 11. Bayesian model of dates for Mound 3, Graves 3 and 5 (pre-mound construction) and Grave 1 (set into the mound immediately above Graves 3 and 5 stratigraphically), suggestion a short duration of time between the interment of primary and secondary burials in this tumulus.

been paramount over and above the identity of the individual themselves. In light of this, the parallel use of Mounds 1, 2 and 3 following broadly similar, punctuated, patterns of use may hint at different subgroups within society using this same cemetery and being represented by different monuments. As there need not be a one-to-one relationship between this cemetery and a specific settlement, this may for example be a consequence of residents of distinct settlements co-constituting a multi-local community for which the mortuary landscape was a common link. Biomolecular research as part of 'The Fall of 1200 BC' project will address issues of genetic (dis-)continuity and relatedness between the EBA and phases of the LBA and how 'local' people interred were to their place of burial (*Iraeta-Orbegozo, in prep*).

The tumulus cemetery at Dubac in Jančići is one of the few monuments in the wider area from which inhumation burials have been documented and retained in collections. The 17 new ^{14}C dates from human skeletal remains represents the largest set of published radiocarbon dates from a tumulus cemetery in Serbia. They support an important link between the established relative chronology of metalwork and burial monument phases that substantially improve our understanding of the chronological framework of the LBA in western Serbia. This has supported the development of new insights into the chronology and temporality of activity within an important tumulus cemetery in western Serbia, and demonstrates its regional relevance. The builders were evidently well-networked with communities in the Pannonian Plain, as reflected through material culture and the intensified activity between 1500 and 1200 BC. The local Bronze Age societies have been discussed in the past using a range of different typo-chronological terms, but these have recently been brought together under a common umbrella as the West Serbian group (*Ljuština 2022.146–147*). This provides an important step for linking the traditions of this area into wider discussions of the Bronze Age Balkans (*Dmitrović 2016. 215*). At the same time, the character of the use of these monuments in their mountainous setting reveals insights into the role of tumuli within local communities across time.

Acknowledgements
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