‘ORGANIC TEMPER’ AND THE EARLY NEOLITHIC POTTERY PRODUCTION: INTERPRETATIONAL CHALLENGES

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ABSTRACT

Well-preserved plant remains found in clay bodies of Early Neolithic pottery of Southeastern Europe have been largely understudied. The characteristics and provenance of this ‘organic temper’ remain mostly unknown, making interpretations obscure. Based on a range of research methods, this article explores the macro and micro plant remains within the pottery clays, considering such aspects as the use of domesticated versus wild plants and actual functional temper versus organic inclusions as background noise. This innovative approach is applied to explore three different Early Neolithic Balkan sites, demonstrating the importance in distinguishing between (a) deliberate addition of selected temper as a technological prerequisite; (b) sporadic occurrence of plant parts in (domestic) areas where pottery was made, (c) natural characteristics of the local clays containing organics and used as raw materials, and (d) plant use pointing towards more specific pottery-making techniques. Possible misinterpretations and pitfalls are discussed in using the applied integrated methodology, thus revealing crucial details on the variability of the technological approaches applied during the Early Neolithic of Southeastern Europe.

INTRODUCTION

Plant use in pottery production has been recognised in various prehistoric- and historic sites worldwide (e.g. Rice 1987; Fuller et al. 2007; Mariotti Lippi et al. 2011; Vrydaghs et al. 2014) and yet, the specific features of such vegetal inclusions often remain underexplored, especially in Southeastern Europe. Referred to as ‘organic matter’ or ‘organic temper’ (Spataro 2009, 2011; Kreiter et al. 2014) and usually as ‘chaff’ (cf. Starnini et al. 2007; Spataro 2010), the plant inclusions found in ceramics are among the hallmarks of the Early Neolithic pottery production at many sites along the Eurasian Neolithisation trajectories (e.g. Todorova & Vaysov 1993; Elenski 2006; Özdoğan 2011; Çilingiroğlu 2012; Vuković 2016).

The hidden potential of this archaeobotanical inclusion (see Kreiter et al. 2013; 2014; Pető & Vrydaghs 2016; Mariotti Lippi & Pallecchi 2016) lies in revealing the interplay between two fundamental aspects, which define the Southeast European Early Neolithic – the agricultural (farming/crop husbandry) and the technological cycle (pottery production) – integrated locally, within a settlement-specific environment. To explore this, however, it is essential to establish whether the vegetal remains are those of cultivated crops (cereal plant parts), as well as whether their presence in the fabrics plausibly reflects the intentional addition of organic materials to the clay paste as temper, rather than incidental inclusion. Thus, the article is focused on these two main questions, rather than examining all possible research avenues in detail (see Fig. 1). Based on the contrasting preliminary results obtained from three Early Neolithic Eastern Balkan key study sites, located in present-day Romania and Bulgaria (Fig. 2), this study explores a series of challenges and potential biases when interpreting such vegetal remains in the Early Neolithic context.

Temper, as a pottery-making component that reflects shared values incorporated in technological activity (e.g. Stark et al. 2000), is traditionally studied from the perspective of fabric variation, to help outline cultural group membership and classify ware types (Rice 1987, 406). Here, a range of plant inclusion variables is considered with an aim to differentiate between the intentional ad-

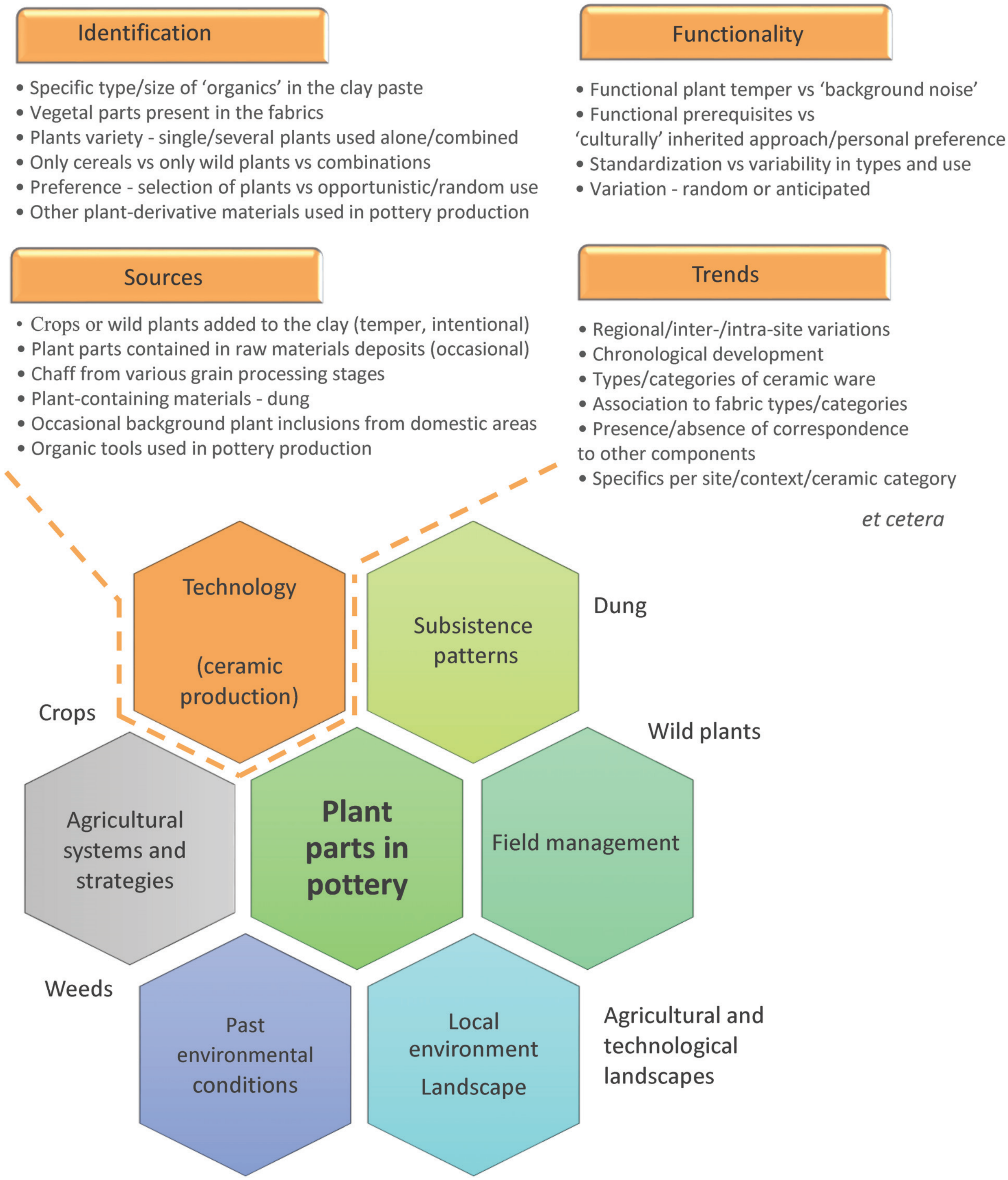

Fig. 1. Plant materials in the clay used for pottery production: some study aspects.

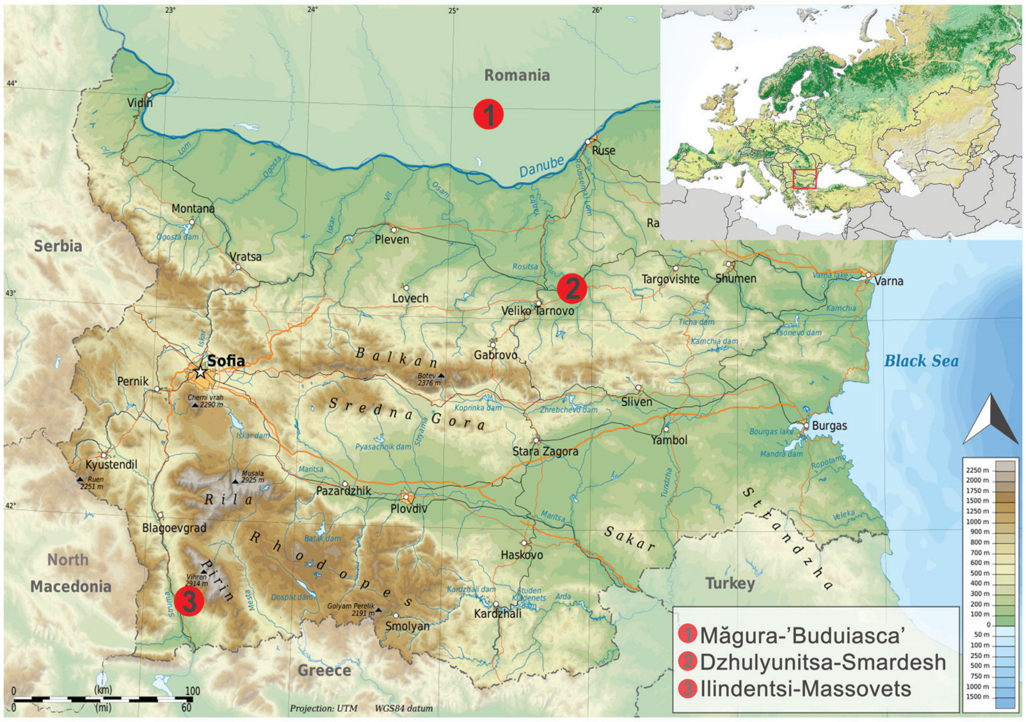

Fig. 2. Map of the study area with the location of the three archaeological sites. Map of Europe (Source: P. Rekacewicz, E. Bournay & UNEP/GRID-Arendal (https://www.grida.no/resources/5351)) and map of Bulgaria (modified, after Ikonact; File: Bulgaria-geographic map-bg.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=24850742).

dition of plant temper (cf. Doherty et al. 2000; Mariotti Lippi & Pallecchi 2016) versus the accidental occurrence of the organics from site-specific context. It is necessary to study the provenience of plant material and determine the functionality of the temper components within the clay fabrics with variances such as (a) domesticated plants versus wild plants and (b) intentional temper versus background noise. Such a systematic approach allows an inference to be made as to whether the addition of organic temper was a functional prerequisite due to technological limitations of the local clays, intentional but based on other decision-making factors, or whether it merely reflects accidental occurrences (Fig. 3).

Whereas intentionally added organics reveal the complex interaction between technological choices and subsistence patterns within contemporary local environments, the background noise plants usually point towards procurement strategies and social locations where clay was collected and pottery made. There are various caveats to the possible interpretation of the true complexity of this agricultural component, embedded within material culture, especially when interpreted in the context of socially transferred ceramic traditions, technological and agricultural landscapes, and regional subsistence patterns.

ORIGIN OF PLANT MATERIALS: POSSIBLE ORGANIC INCLUSIONS

Chaff alone has been suggested as a deliberately added 'functional temper', but close examination of the vegetal inclusions is imperative to verify this claim. If chaff was used as temper, a series of individual vegetal components should be present in the clay paste, potentially reflecting specific crop husbandry strategies and grain processing stages (see Hillman 1984a, 1, 39; Bogaard et al. 2017; Kreuz et al. 2005). These should be identifiable by their unique features (organics type, state, amount, fragmentation, shape and composition, et cetera).

Chaff – the non-grain parts of the cereal plant – can include the bracts, the protective part of the seeds (light chaff), or straw fractions (heavy chaff) (Hillman 1984b),

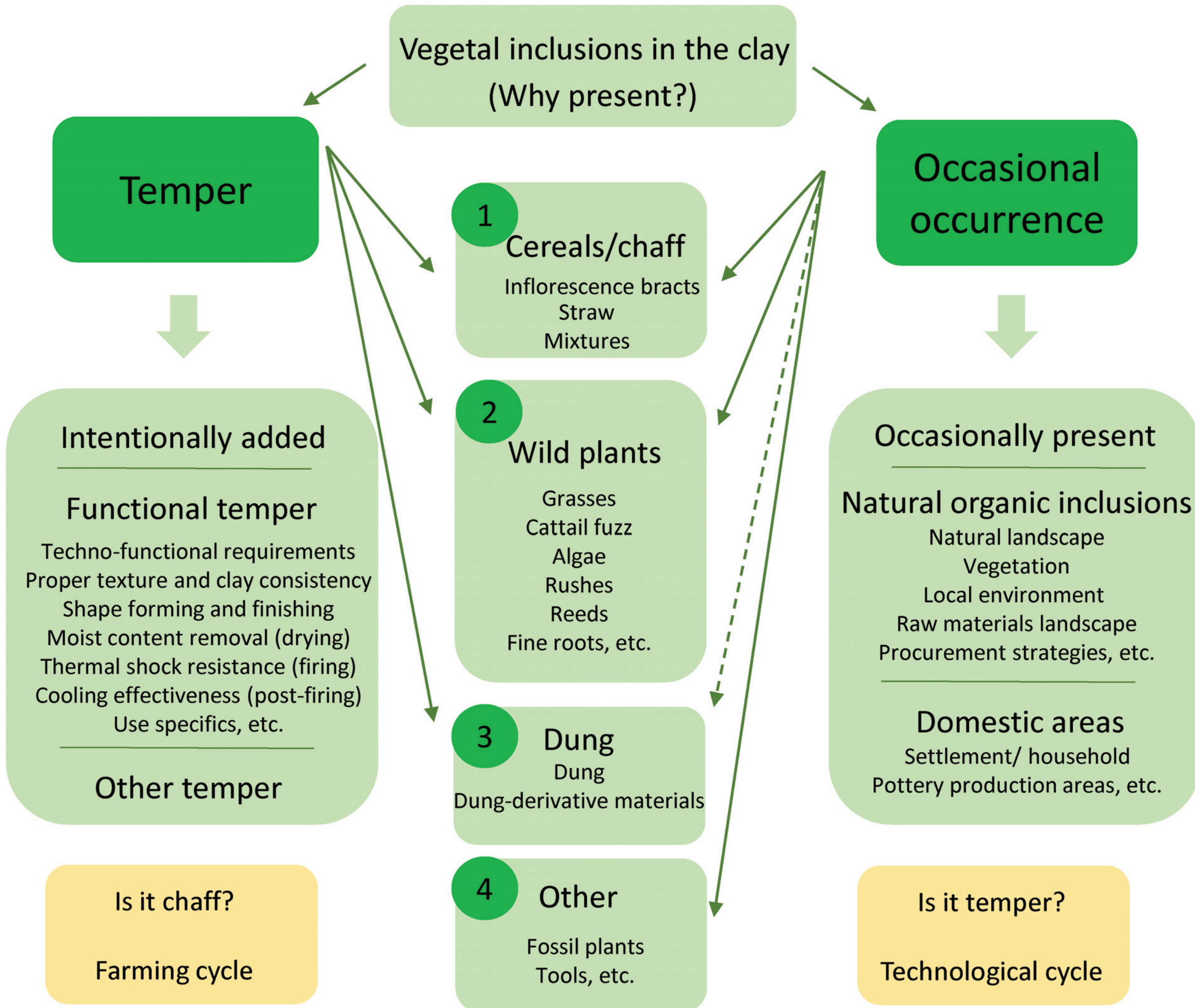

Fig. 3. Origin of plant materials in the clay fabrics used for pottery production. Summary of the effects of tempering on properties of the clay. After Rice 1987.

sometimes also finely chopped when used as temper. The thin bracts surrounding the crop seeds form a dry, inedible husk which must be removed before consumption (Hillman 1984a; 1984b; van der Veen 1999). Whereas *glume wheat* needs multiple dehusking procedures because the grains are tightly invested in the hull, the ears of the *free-threshing wheat* can immediately break up and release the grain in fewer processing steps (Hillman 1984a; 1984b; Jones 1984). Whereas threshing directly separates the grains from the chaff for free-threshing cereals, it breaks the hulled cereals into spikelets, which requires a second threshing procedure, usually pounding or grinding (Hillman 1984b, 128, 146) (Fig. 4). Each of these processing stages results in a clear separation between the 'heavy chaff' (straw fractures eliminated at the early processing stages) and the 'light chaff' separated further in a series of steps (second threshing and dehusking, secondary winnowing and grain dunking) (ibid.).

Aided by the lightly blowing wind, winnowing further separates the loose cereal husks, thus affecting chaff composition (Hillman 1984a, 55; Jones 1984, 45). It separates the light straw and chaff from the grain – for free-threshing wheat, the chaff is removed during the first round of primary winnowing, together with the light

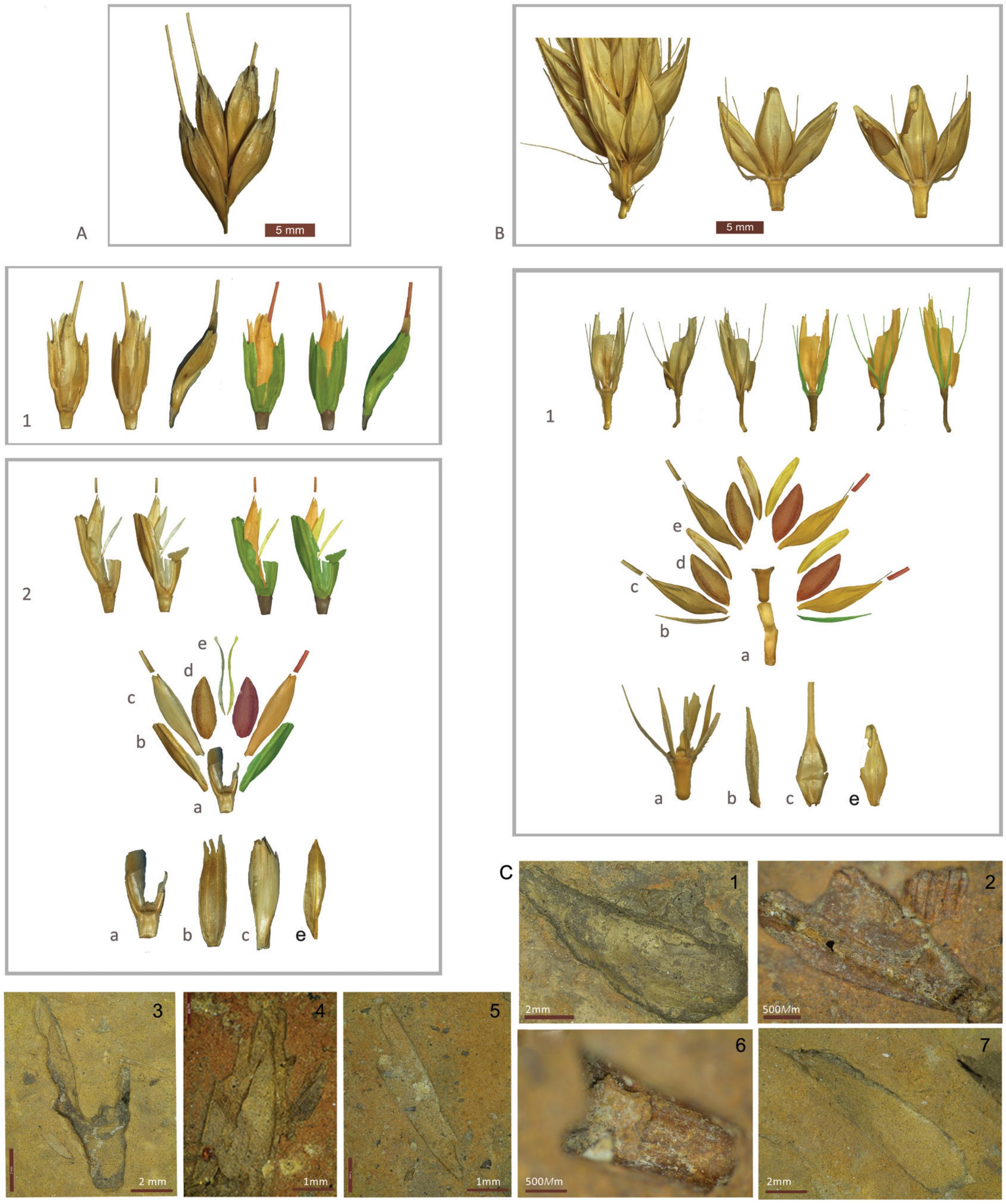

Fig. 4. Processing stages of glume wheat (A) and free-threshing plants (B). The types and components that are remaining after (1) threshing and (2) second threshing/pounding (modified after Hillman 1984; Jacomet 2006; Zochary et al. 2012; Bogaard et al. 2017). A1 - glume wheat spikelet after threshing; A2 - glume wheat spikelet components (after second threshing/pounding). 1 - individual spikelet comprising the grains; 2 - individual spikelets, fragmented: a - rachis (the stem within the ear) with glume base (where the glume is attached to the rachis) and spikelet fork (where two glumes join); b - fragmented glumes (the structures that are enclosing the spikelet); c - fragmented lemma (a membrane on the dorsal side of the grain) with part of the awn (projection); d - grain (primary product); e - palea (a membrane on the ventral side of the grain). C - imprints of cereal chaff components on studied ceramic fragments (spikelet fork with glumes - 3; glumes - 1, 2, 4; paleas and lemmas - 5, 7; rachis - 6).

straw (Hillman 1984b, 128). The next steps, coarse and fine sieving, separate the components further according to size (Jones 1984, 48), the light chaff by-product usually resulting from secondary winnowing. Collected before sieving and stored separately from the straw, this light chaff is used as fine temper, fuel or fodder (Hillman 1984; Jones 1984).

The variable archaeobotanical sampling strategies applied during the excavations at different prehistoric sites may result in a dominance of grains in the assemblage (collection of the visible plant remains) or presence of both grains and chaff (systematic sampling) (Marinova 2006; Bogaard & Halstead 2015). At understudied sites and regions, previously the focus was usually on the better preserved charred prime products (grains and spikelets) (Hillman 1981,11-12, 32); however, this record can be broadened by the analysis of the organic temper comprising well-preserved cereal processing by-products. The short-lived coarse and fine-sieve by-products were often used as fodder or fuel (Jones 1984, 47), but the finest chaff perishable parts (straw internodes and lighter nodes, leaf fragments, light chaff components, together with most of the lighter weed seeds) (Hillman 1981,11; Boardman & Jones 1990) can also be present in chaff-tempered pottery.

Depending on the plant types and the processing stages, the by-products may include various chaff parts: the stem of the cereal plant below (culm) and within the ear (rachis); whole or fragmented individual units of the cereal ear comprising the grains (spikelets) (Jacomet 2006; Zochary et al. 2012; Pearsall 2015) (Fig. 4). Fine chaff components present can also include the glumes surrounding each spikelet, a glume base attached to the rachis, the parts holding the grain (dorsal side membrane lemma and ventral side palea), the awn projections and a spikelet fork joining the glumes at the bottom of the spikelet (ibid.). The first threshing of glume wheat results in a mix of spikelets and trodden straw; the primary winnowing is associated with spikelets, heavy straw fragments, weed seeds and heads; re-threshing and re-winnowing are reflected by the light straw, some spikelets and straw nodes; and finally, coarse and fine sieving includes spikelets and small weed heads (Hillman 1984a; 1984b). As should be apparent, each process leads to different chaff products.

Nevertheless, even when identifiable, the plant types and parts found in clay body do not reflect a closed system. While each stage produces different products, often, it is not only the type but also the abundance of chaff remains that is informative of the various processing steps. For example, the higher quantity of spikelet forks and glume bases may indicate parching and third sieving, whereas their lower number is associated with the fourth sieving and hand sorting (Hillman 1984, 10, Table 1). Although these typically signal the third sieving, they still may occur sporadically in other cereal processing stages. Similarly, the higher number of intact non-basal spikelets is characteristic of a parching stage. In contrast, only a few of these are present after the first and especially after the second sieving. Rachis internode segments, on the other hand, can be found in similar amounts in a range of steps (from parching to the third and fourth sieving), and basal spikelets, too, are present from the raking to the second sieving.

Once fully processed, the storage of clean grains ready for consumption differs from that of spikelets or semi-processed grains that need further dehusking at the household level (cf. Hillman 1984a, 8-9; 1984b, 126). However, when attempting to study storage practices, plant temper would not provide unidirectional data. The presence of glumes in organic-tempered pottery should not be indicative of the scale of the outdoor activities seen in contrast to daily piecemeal processing or the timing of dehusking, as glumes can be removed either before the storage or after it, immediately before the consumption of cereals. Furthermore, although glume wheat was bulk-stored as spikelets in various regions (Bogaard et al. 2017, 13, 16 for Anatolia; Jones 1981 for Greek North Macedonia; Marinova 2006 for Bulgaria), the presence of single preserved spikelets and sporadic grains in clay fabrics may be, but are not necessarily, related to specific storage practices.

Additionally, another variant of chaff-containing temper technically refers to the use of animal dung for pottery production (e.g. Ganetsovski 2015). However, its origin and characteristics demonstrate a completely different technological approach and pottery-making traditions. Therefore, in order to interpret plant parts in ceramics, it is essential to differentiate between pure chaff (as resulting from cereal agriculture) and dung, which happened to contain semi-digested cereal husks. Since dung of various locally grazing and browsing domestic animals includes a variety of vegetal types, depending on the animal species and the season, it comprises not only variable proportions of chaff but also wild plants (see Charles 1998; Vergès et al. 2016).

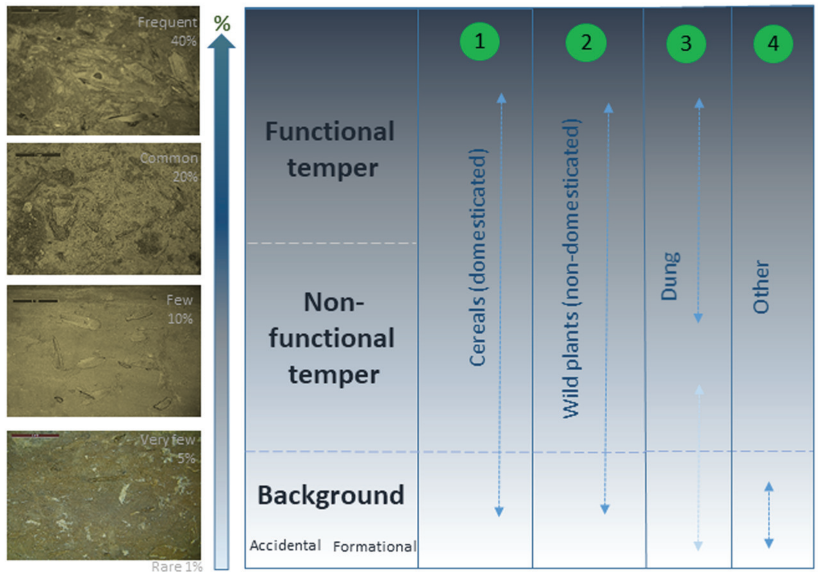

Fig. 5. Identification of temper: complex boundaries. Variability in the quantities and the types of organic (vegetal) inclusions in the clay fabrics used for pottery production.

The specific features of the chaff do echo certain agricultural practices and grain processing sequences, but what if the vegetal inclusions present in the fabrics were not cereal husks? Wild plants have also been intentionally used as functional temper (grasses, cattail fuzz, algae, rushes, chopped reeds (e.g. Rice 1987, 407; Hunt 2016; Doherty 2020, 54)). Importantly, wild plants still could well have been natural constituents of the raw clay sources (e.g. Ting & Humphris 2017), or present by chance in the clay paste (e.g. raw materials stored in various settlement contexts). Further complexity is introduced by the possible random occurrence of arable weeds, which cannot be considered as intentionally added temper. As arable weeds are connected with field management and the immediate natural environment, they must be examined with the crops (Jones 1984; Bogaard et al. 2017; Green et al. 2019).

Plant inclusions in pottery provide data on different agricultural and husbandry systems and their connection to the newly emerging technology of pottery making. For analysts, the awareness of the various possible vegetal types helps to identify potential non-chaff sources and calls for site-specific methodological requirements for identification of both chaff and temper. As interpretation depends on the types of the plants present in pottery, it is essential to distinguish between the crop processing by-products, the organics naturally present in clay deposits, the wild plants that can be intentionally used as temper, those arable weeds that are found in combination with cereal chaff inclusions and the plants ingested by livestock, resulting from foddering and grazing and deposited on-site/off-site as dung.

IDENTIFICATION OF FUNCTIONAL TEMPER

To evaluate the technological significance of the organic temper and to distinguish between the functionally sufficient amount of organics and occasional occurrences (insignificant amount in terms of modifying the technological properties of the clay), the organic-containing fabrics are examined as a system of interdependent constituents (clay matrix – mineral inclusions – organic inclusions).

Temper is a non-plastic material added by the potters to modify the fabrics, thus satisfying specific techno-functional requirements – to control plasticity, to prevent shrinkage and cracking from drying and firing ceramic wares, etc. (Rye 1981; Rice 1987). By mixing clay and temper, it is possible to achieve the proper texture, consistency, hardness, improving the clay properties when wet or dry, both during and after firing. As plant temper is expected to burn out and does not contribute to the stability of the ceramic body, it has been considered as providing a reducing environment and serving as a plasticity modifier (Velde & Druc 1999). Nevertheless, other factors, such as porosity/impermeability, cooling properties, beneficial properties for storage vessels, as well as the improved transportability of 'weightless' organic-tempered vessels have also been discussed (e.g. Skibo et al. 1989; van Doosselaere et al. 2014).

Before commenting on the various aspects of the study of 'organic temper', it is necessary to establish, for each site, if plant inclusions found in the clay body should be considered as temper (Fig. 5). To enhance the inherent properties of the raw materials, a certain amount of added material (temper) may be required, and if so, it must be present in sufficient quantities, since the sporadic or inadequate quantity of inclusions would not change the characteristics of the primary raw material (cf. Rice 1987; Doherty et al. 2000). Functional temper is thus different from non-functional inclusions and background noise (single organics found in the clay body). Furthermore, plant temper cannot be considered alone, without reference to the properties of the clay fabric and the mineral, inorganic inclusions. The complex integrated system of clay fabrics – consisting of various components with specific properties – may reveal the reasoning behind the practice of adding organic materials in the clay paste. The contrast between deliberately added plant material and 'background noise' (inclusions having no technological bearing on the clay properties) thus sheds light on why organic temper was added and how to interpret its variable quantities.

Although the intentional addition of vegetal parts as temper may well refer to the wild plants, the latter can also be naturally present as organic-containing clay deposits. For example, the presence of fine roots as natural inclusions in the raw material may be indicative of preferred clay deposit areas but does not refer to a potters' technological extra step of deliberately adding plant parts to the clay fabrics. The occasional presence of fossil plants (cf. Cleal & Thomas 2019), of natural plant inclusions in coal-rich soils and fine-organic inclusions in mountainous clay deposits is evidence of similarly unintended organic inclusion. The occurrence of such vegetal parts differs from the intentional use of wild plants as temper (see above). Both the type of plants and the amount of organics in the clay paste (concentration) are thus indicative of the reasons for adding organic temper.

The variable quantity of vegetal inclusions in the clay fabrics is of crucial importance, as to whether intentionally added or occasionally present, too few plant inclusions do not affect the technological properties of the clays. Sporadic organic inclusions in the clay paste – meaning in very low frequency (1-5%), or as single plant fragments, do not affect the fabric quality due to their exceptionally low quantity, i.e. their presence most probably does not reflect purely technological requirements. Interpreting the reasoning behind the intentional addition of too few organic inclusions thus becomes more complex.

The interrelation between the properties of clay fabrics and the added organics (or the lack of such) is also important. The silty and the fine-grain sandy clays (Rice 1987; Velde & Druc 1999) do not usually require the addition of temper – their technological qualities are sufficiently high, even when the raw materials were used unmodified, in their natural state. Consequently, the addition of organics to fabrics that would not require tempering was not technologically necessary *sensu stricto*. Given the typical amounts accepted for 'the actual temper' (above 17% for organic temper, cf. Velde & Druc 1999, 145), the added temper here is expected to range between at least 10-15%, but more often falling between 20-30%. To interpret the addition of too little/too much organic temper, and to reveal the actual sources of plant material, many factors have to be considered, including the local environment, the agricultural and husbandry practices, the site-specific clay deposit characteristics and the archaeobotanical evidence.

METHODOLOGICAL BACKGROUND AND MATERIALS

The ubiquitous plant-containing and low-temperature fired Early Neolithic pottery may include: (a) domesticated and wild plants added as temper, (b) 'background crops' indicative of various activities taking place in a domestic setting and/or in areas of production, (c) 'background wild plants' that reveal the environment from where the raw materials were sourced. To understand the integration of agricultural and technological activities, together with environmental and cultural contexts at each site and regionally, a set of criteria is required.

In bonfires, when a clay vessel is not uniformly oxidised throughout, the organics may not burn out completely – resulting in the *preservation* of lightly to heavily charred plant fragments captured between the outer and the inner surfaces of the vessels. With higher firing temperature, it is the void plant impressions on the surface of the vessels and the microfossil remains (opal silica phytoliths) within the clay body that can possibly inform on the type of added organics. Here, the preliminary observations refer to two locations: the first is the very surface of the fragments, revealing void negative impressions (a), and the second is the clay paste within the walls of the vessels, containing charred fragments (b), microfossil remains (c), and positive and negative plant impressions (d). Within the walls, the two-dimensional imprints of vegetal parts often have skewed, smashed, turned and twisted shapes resulting from the origin of the plant temper and its specific preparation and mixture with the clay, thus differing from the usual form and state of plant components.

Though otherwise crucial when reconstructing past agricultural practices, contexts and processing stages, the *abundance of indicative plant parts* is not the primary factor when studying organic temper in pottery. Meticulous counting of specific vegetal parts or species per fragment would reflect a series of chance factors (size and thickness of the analysed fragments, clay-organics mixing properties, cross-section location, etc.). The observations on the plant temper and the ratios between a) various crops identified within a pottery fragment, b) crops and wild plants, and c) specific plant parts are to be considered as only a partial snapshot on just some of the chaff stored in the households, used in pottery production and registered archaeometrically.

Here, the data are used opportunistically and qualitatively, rather than quantitatively and according to counting-based analysis. Not just the quantity but the *distribution* of the vegetal parts within the studied zones may also vary depending on the degree of homogeneity of clay-organics mixture, the location of the cross-section, the chosen surface area and the level of effort when smoothing the surface of the vessels – factors that may result in varying concentrations of organic parts within a single fragment. The clay matrix characteristics and the mineral inclusions contained in the paste also have a bearing on the distribution modes of the plant parts within the fabric, whereas forming techniques and the pressure used to shape the vessels may additionally affect their *orientation*.

The *identification* of plant morphology with the help of low-power microscopy is often hindered by the modified appearance, the possible fragmentation or the ‘clustering’ of different plant components, especially when these are placed one on top of another. However, potential identification biases when examining the plant parts and species, especially within the walls of the fragments, are compensated by the possibility to study the actual sources of the plant remains (original state vs processed; dry state vs wet). High-resolution microscopy can potentially identify microremains indicative of specific plant taxa or vegetal parts. However, various vegetal parts may also have similar phytoliths, and different plants may produce identical opal silicates (Piperno 2006). Although phytolith assemblages can be identified and there are recommendations towards standardisation concerning morphometrics (Portillo et al. 2006; Ball et al. 1999; 2016), various limitations should be considered, including the similarities between the silica skeletons of different plant parts, the resemblance of cultivars to some grasses and the range of micromorphological features within parts of the same plant, as well as modifications caused by heat (see Lu et al. 2009; Out et al. 2016, Fig. 7; Portillo et al. 2020). Whereas the plant remains are usually poorly preserved in the thin sections of pottery fragments, the scanning electron microscopy (SEM) allows for a detailed examination at very high magnification; yet, it may refer to modified shapes without the flat plane position which is necessary for making precise measurements.

In this study, both macro-and microorganic inclusions are considered within complex system of the fabric, in particular the variable ratios between clay paste, inorganic and organic inclusions. The plant remains are examined by low-power optical, high-power polarised and scanning electron microscopy in combination with selected reference collection specimens. A set of sixty samples from three Early Neolithic settlements (20 samples per site) was selected as representing a spectrum of inclusion types, concentrations and arrangements on the surface and in section, of both coarse undecorated and fine, high-quality white-on-red painted vessels, of various shapes and thickness (0.5-2.5 cm). The freshly broken pottery fragments have first been examined in both sagittal (longitudinal) and coronal (frontal) plane by using a low-power Leica EZ4 Stereo Microscope (8× to 35× magnification range) according to the adapted approach for pottery studies (Whitbread 1995). The descriptions of the shapes and the concentrations (frequency) of void plant imprints on the surface and the plant remains preserved in the clay paste are based on adapted comparison charts (e.g. Rice 1987). Identification of the clearer imprints was attempted following Jacomet (2006) and Zochary et al. (2012).

Examination of the fabrics and the vegetal remains was then performed at higher magnification – on 30 µm thick vertical thin sections, using polarised light optical microscope Leica DM 2500P (5× to 50×), in the sagittal plane and according to Vrydaghs & Devos (2020), allowing observation of the surface-core interaction, the oxidation transitions resulting from differential firing, and the distribution of the inclusions due to forming techniques. These interactions would not be visible if analysing the wider areas displayed by the coronal thin sections (more vegetal parts per cm). Specific features of the voids (mostly vesicular empty areas) left in the clay paste, estimation of the porosity and evaluation of the boundaries, were also taken into account (cf. Doosselaere et al. 2004), rather than focusing on the morphology of the plant inclusions as indicative of surviving distinctive features of various taxa (cf. Moskal del-Hoyo et al. 2017), which were usually moderately to poorly preserved in the thin-sections analysed in this study.

Fragments containing plant parts were studied further as carbon-coated resin blocks and stub mounts using a Jeol 5910 scanning electron microscope with an Oxford Instruments INCA 300 energy dispersive x-ray spectrometer (SEM-EDX, <10000× magnification). As no high-precision chemical analysis was needed, and the settings were defined according to the delicate organic structures, the acceleration voltage of 15 kV was preferred with the filament current of 40 µA. The SEM observations were focused on the fabrics and the preserved phytoliths also according to (Lanning & Eleuterius 1992; Ball et al. 1999; Ball et al. 2009; Piperno 2006; Heiss et al. 2020), following the International Code for Phytolith Nomenclature (ICPN) ver. 2.0 (Neumann et al. 2019). Plant reference collections in the Archaeobotany Laboratory, School of Archaeology at the University of Oxford were used to aid identification of both vegetal macro- and microremains. The latter was prepared using sodium hypochlorite to remove the plant tissue, and mounting the phytoliths on standard glass slides (*Triticum* sp., *Hordeum* sp. and *Phragmites* sp. plant parts).

THE STUDY SITES

The pottery fragments were collected from three Southeast European open settlements with contrasting geological setting, landscape and microclimate (Fig. 2).

(1**)** *Măgura-Buduiasca* consists of pits attributed to Early Neolithic Starčevo-Criş culture, representing the initial occupation of the site and dated to the final part of the 7th mill. BC (Andreescu & Mirea 2008; van As et al. 2004; Thissen 2005; Walker & Bogaard 2010). Located in the wide and open Danubian plain – low and alluvial homogeneous region with massive loessic accumulation, it occupies a prominence on the secondary eastern Teleorman River terrace, about 300 m from the river course (Andreescu & Mirea 2008; Macphail et al. 2008). The site is situated atop of relatively hard bedrock, with a thick sedimentary mantle comprised of gravel and sand deposits, and is covered by up to 20 m thick loess and loess-like layers (ibid.), showing the natural range of alluvial deposits. Accentuated mineralisation of the soil organic matter, evidence of gleysation and salinisation processes are demonstrated by the local transitional steppe and silvo-steppe soils (Pârvan et al. 2011, 109-111; Blaga et al. 1996). The middle-upper Pleistocene loess deposits consist of reddish, yellowish clay, sandy silts and carbonate concretions overlying the marly alluvial-lake deposits (Coteţ 1973, 371; Macphail et al. 2008). Considering the production of pottery, the organic temper used has been reported as typical component of the fabrics at the site (van As et al. 2004).

(2) *Dzhulyunitsa* (6100-5700 cal BC) (Krauß et al. 2014) is located on a natural prominence – a plateau-like terrace above the Zlatarishka River (Veliko Tarnovo region), between the valley and the foothills, with several freshwater sources available immediately nearby. The river emerges onto the flat ground of a loess-filled depression and erodes sandstones and calcareous clays, combined with washed-in weathered loess from the hills (cf. Hristov et al. 2010). The Lower Cretaceous marl-limestone-sandstone facies and the Pleistocene and Holocene alluvial and colluvial deposits underlie the loessic sediments (black soil parent material) (Fotakieva et al. 1976; Hristov et al. 2010). The weathering of fine wind-blown loess in the region produced the naturally fine-grain clays around Dzhulyunitsa. Vegetal inclusions in variable quantity are registered in about two-thirds of the fragments (Elenski 2006; Dzhanfezova et al. 2014).

Fig. 6. Charred plant parts in the clay body and plant imprints on the surface of the vessels: a-c - a spikelet from Dzhulyunitsa; d-f, h, i - imprints of glume wheat inflorescence bracts components from Măgura-Buduiasca; g - wild plant imprint (*Avena*) on a fragment from Ilindentsi.

(3) *Ilindentsi-Massovets* is dated to the final stage of the Bulgarian Early Neolithic period (5700-5460 BC) and located in a valley surrounded by mountains, at 264 m asl, on the western slopes of the Pirin mountain and 4 km to the east of the Struma River (Blagoevgrad region) (Grębska-Kulova et al. 2011; Grebska-Kulow 2017; Grebska-Kulow et al. 2018). Metamorphic and granitic rocks are the components of the higher terrain around the area that immediately borders the Struma valley (Zagorchev 2001; Westaway 2006). The rocks are eroded from the uplands bordering the Struma Graben on three sides, whereas finer constituents of the Neogene sediments are exposed at shallow depth near the site. Generally, vegetal inclusions are not characteristic of the pottery technology in this region; only a small number of fragments containing organic temper was registered (Grębska-Kulova et al. 2011, Grebska-Kulow et al. 2018).

FIRST RESULTS

Preliminary low-resolution stereomicroscopic observations

The studied fragments from the three sites reveal well-preserved and distinctive surface imprints and organic inclusions in clay body. At (1) Măgura-Buduiasca the undecorated thick (up to 15 mm) fragments contain about 20% organics, corresponding to the percentage of the mineral inclusions within the fabrics. The maximum length of the preserved organics is usually 2 mm, sometimes reaching 6 mm. The light chaff parts are present on the surface (imprints) and within the paste (imprints and charred material). Intentionally added mineral temper was not registered in the first set of studied fragments. According to the morphological specifics of the imprints, at this stage, the registered remains are associated with

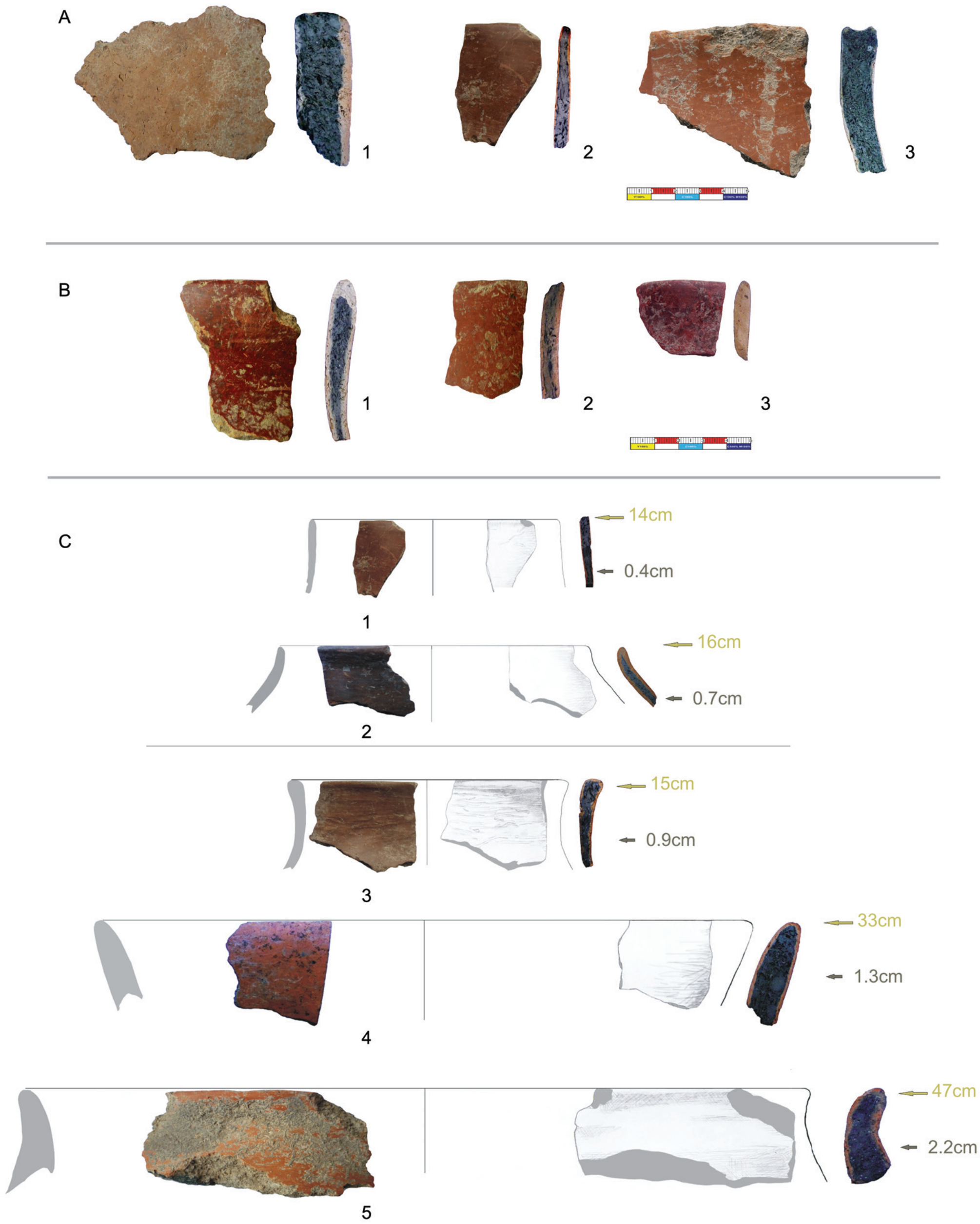

Fig. 7. Pottery fragments from Dzhulyunitsa (after Dzhanfezova et al. 2014). A - organic temper in pottery with various surface treatment (coarse to fine and decorated); B - variable quantities of organic temper in 'red-slip' pottery (from high in 1 to none in 3); C - organic-tempered vessels that display various size and diameter, organics in low (1-2) and high concentrations (3-5).

glume wheat, mostly einkorn (*Triticum monococcum*) and emmer (*Triticum dicoccum*) (Fig. 6d-f). So far, no intact charred spikelets nor grains were found preserved in the paste of clay bodies. Plant parts such as spikelet forks (Fig. 6d-f), together with the rachis and glumes, are common surface imprints, their maximum size reaching 2 mm. The glumes, paleas and lemmas dominate, and only occasional culm fragments were present both on the surface and within the walls. The inflorescence bract components are usually not found in coherent clusters or aggregates one on top of the other thus perhaps indicating continuous mixture and homogeneity of the clay paste, and possibly a not too wet state of the organic inclusions.

The sorting of inclusions is low to moderate; the longest inclusions tend to be parallel to the walls of the vessels, due to the forming techniques. Most often, the surface does not include an additional layer to cover the plant-rich paste and thus to form a more delicate finish. Organic inclusions are also found on the surface of smoothed/polished and decorated vessels. Although the coarser and thicker fragments tend to contain more vegetal parts, no discernible fixed ratios between the amount of temper and the type of fabric exist.

The plant material at (2) Dzhulyunitsa shows quite variable quantities. Some of the fabrics, having higher ratios of clay to silt and sand, tend to contain more organic temper, presumably to control the shrinkage, whereas sandier fabrics include less vegetal material. However, in some cases, only tiny additions of chaff temper are present. As in Măgura-Buduiasca, no correspondence was detected between the use of temper and the quality of the surface finish of medium- to thick-walled vessels.

No association whatsoever between specific fabric and surface finish/decoration was registered (Fig. 7). The same amount of vegetal inclusions is observed in pottery fragments with similar thicknesses but with traces of varying and distinctive surface treatment (coarse vs decorated). Heavily tempered vessels can either have very coarse surfaces or polished and finely worked decorated walls. At the same time, specific categories such as the quality 'red-slip' pottery also demonstrate significant variability, some examples showing lots of added organics, others – a small degree of plant inclusions, or none at all (Fig. 7B, 1-3). The surfaces of some of the white-painted wares contain sporadic plant imprints, too. Specific correlations were not established between the fabric, the thickness of the walls and the diameter of the vessel either.

The identified plant parts correspond to those registered at Măgura-Buduiasca, yet Dzhulyunitsa shows optimal preservation of sizeable vegetal temper components – such as the intact, charred spikelets with preserved glumes, paleas and lemmas found in the clay paste (Fig. 6a-c). The plant inclusions are often grouped in clusters, although their size and concentrations vary. The appearance, state and plasticity of the organic inclusions (in some fragments showing denser clustering of vegetal inclusions) suggest a possibly more liquid type of clay-temper admixture, at least in some of the cases. The variable concentrations of plant parts, usually ranging between 20 and 40%, prove no direct correspondence with the naturally variable fabrics, associated with the local clays.

Whereas the site of Măgura-Buduiasca and Dzhulyunitsa share certain similarities, the fabrics at (3) Ilindentsi-Massovets differed considerably. Although vegetal inclusions are usually considered as absent in the typical southwest Bulgarian Early Neolithic pottery repertoire, quite a few fragments analysed in this study contained organics, which were detected only microscopically. Often these occurred as single instances in very low quantities (1% to 5%); and when the technological properties of the clay are considered, such amounts would be indicative of non-functional temper.

The fragments showing higher quantities of plant parts (above 10%) are usually 9-20 mm thick, whereas occasional vegetal remains belong to the 5-10 mm thick vessels. The highest percentage of added organics, 30%, is registered in a 20 mm thick vessel. Still, even thicker fragments may contain only 7% organics, i.e. the relation between the thickness and the concentration of plant temper may not always be straightforward. Plant parts were also found in high-quality painted fragments, but unlike the two other northern sites, here the vegetal inclusions are hidden below an additional organics-free thin clay layer that covers the tempered body (i.e. very few visible imprints are usually present on the surface of painted wares).

The shape, sorting and size of organic particles also vary considerably – from poor (most often) to very well sorted (in rare cases). In cross-section, the sizeable inclusions are usually oriented parallel to the walls of the vessel as a result of the forming technique, and they rarely have a random distribution. The preserved length is usually between 1 and 10 mm. The association of organic temper and other mineral inclusions within the same frag-

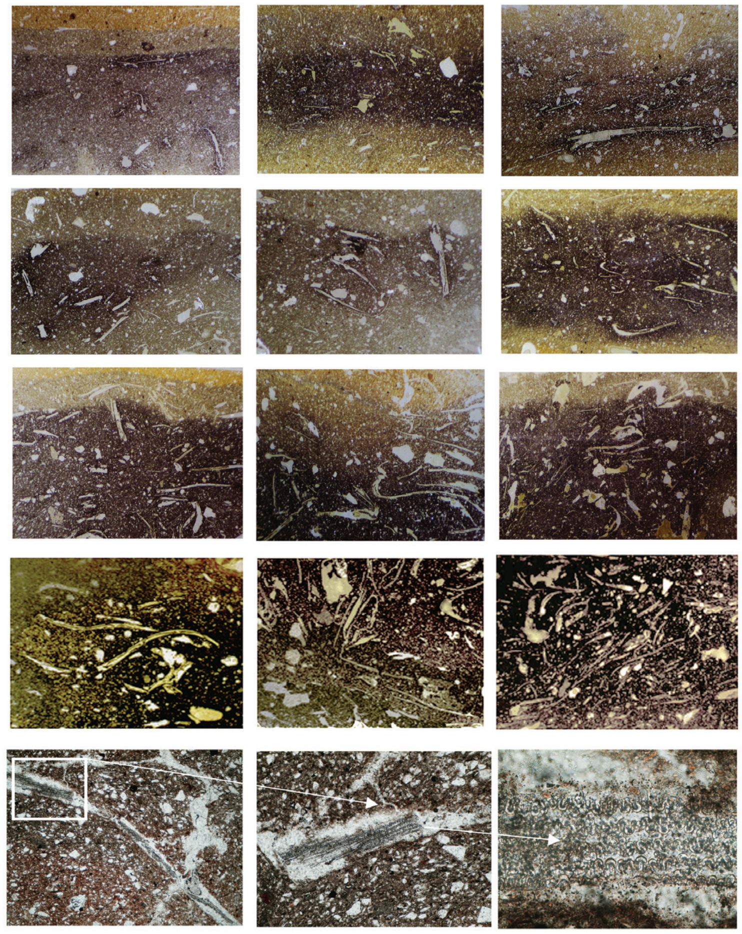

Fig. 8. Various shapes and concentrations of phytoliths (voids) in vertical thin-sections of pottery fragments. Examples from Dzhulyunitsa. Field of view - 9 mm, bottom right - magnification 40×.

ment reveals that fabrics having vegetal inclusions may also contain mineral grains of a bigger size. The usual 10% of other (mineral) inclusions, however, are not associated with any strict amount of added organics.

In this study, the sporadic single organic inclusions in the clay paste – those found in very low frequency – usually range between 5 to 10 % and sometimes even between 1 to 5% (Fig. 5). In extreme cases, only single plant parts (reaching 2 mm in length) can be detected, and these alone do not affect the clay properties due to their exceptionally low amount. Interestingly, at Ilindentsi occasional non-chaff plant parts and impressions, indicative of wild plant species, possibly *Avena*, have also been registered (Fig. 6g).

High-resolution microscopic observations

The observations on the first studied collection of petrographic thin-sections were focused mostly on the clay fabrics and the voids left by the organics, rather than examining in detail the surviving single phytoliths. In terms of the surrounding soil matrix, the few registered preserved phytoliths had moderate to bad visibility, following the terminology in Vrydaghs & Devos (2018). Given the function of plants in the fabrics and to the process of forming the vessels, the preservation of phytoliths derived from these plants refers mainly to technological fragmentation rather than showing traces of sedimentary transportation. The moderately preserved light-tanned to brownish phytoliths are sometimes accompanied by well-preserved elongate dendritic phytoliths (Fig. 8, bottom right).

The Ilindentsi vegetal inclusions in thin-section demonstrate lower quantity and variety of shapes of phytoliths – these are mainly acicular, but also often wavy and bent, whereas the Dzhulyunitsa and Măgura-Buduiasca inclusions demonstrate variable shapes, often combined with channel and crack voids. The boundaries between the matrix and the plant inclusions are usually sharp at the northern sites and sharp to merging at Ilindentsi. The circular and subcircular cavities are often accompanied by residual material, which in the northern sites occurs more regularly and from fragments of larger size.

Whereas the fabrics at Măgura-Buduiasca and Dzhulyunitsa are very fine and loessic-related, those at Ilindentsi are predominantly colluvial/proluvial and naturally containing high quantities of other, mineral inclusions. At Măgura-Buduiasca, despite the homogeneity of the fine loessic raw materials, there is a slight variation in the fabrics that reflects the availability of naturally sandier local areas. Mineral temper was not established in the first set of studied samples the naturally contained mineral inclusions being too small, usually well sorted and subrounded, reflecting the local geology and dominated by single bigger (< 0.02 mm) monocrystalline quartz and sporadic feldspar grains, as well as calcareous, iron-rich inclusions and mica. The registered added inclusions refer to vegetal temper, which is spread regularly throughout the walls of the vessels in cross-section and is better visible in the middle area of the cross-sections – dark grey to black due to reduction conditions and variations of oxidation during the firing.

The Dzhulyunitsa fabrics are similar but much more diverse, presenting a broad spectrum of the local geological continuum. They are fine-grained, deriving from wind-blown loess weathering. The mineral inclusions in the loess-based fabrics are tiny (< 0.2 mm), reflecting the local setting and upstream geology. They contain angular and subangular quartz grains, feldspar, muscovite mica and limestone as well as inclusions of iron oxide. In both textural and mineralogical terms, the local pottery fabrics match the natural sediments without showing signs of mineral temper. Only vegetal material is added in variable quantities to vessels of variable sizes, thickness, shapes and surface treatment. Some of the clay-rich fabrics tend to include more organic temper, but given the range of variable quantities, this is not a consistent relationship. Some of the thin-sections demonstrate that only small amounts of vegetal inclusions were present in specific fragments.

In line with its location, Ilindentsi represents the use of different raw materials and also various technological preferences. The mineral inclusions have high density and big size (< 2 mm), most often angular grains, medium to well-distributed, including polycrystalline quartz, weathered feldspars, iron-rich clay pellets, variable amounts of mica, predominantly biotite, occasional amphiboles, metamorphic and granitic inclusions. The continuous range of mineral fabrics is dominated by medium- to high-grade regional metamorphic facies and granitic material, consistent with the geology of the higher ground that immediately borders the Struma River valley. The clays belong to the finer grades of the Neogene sediments exposed at shallow depths nearby and eroded from the uplands bordering the Struma Graben on three sides. All mineral inclusions are natural and consistent with the locally available Neogene sediments. A very high proportion of angular mineral inclusions are indicative of the metamorphic and the granitic rocks that border the eastern area of the Struma Valley, and except for a small number of sherds that contain plant fragments, the fabrics are not tempered. The fragments refer mainly to proluvial valley side deposits.

According to the SEM analysis, well preserved and connected cells (silica microremains) are regularly observed at all three sites. The plant tissue is usually badly to moderately preserved at Ilindentsi (probably due to mechanical degradation or melting), and moderately to well preserved at the two other sites. The phytoliths were found mostly within the clay body rather than nearer the surface of the vessels. Predominantly sheet/multi-celled elements with articulated epidermal elongate cell and papillate phytoliths from inflorescence tissue, potentially also of *Triticum* sp. or *Hordeum* sp. plants, sporadic acute bulbosus (prickle) phytoliths from lamina tissue, and dendritic phytoliths from inflorescence tissue (see Ball et al. 2009) are registered at the three sites (Figs. 9, 10 & 11). Multi-cell and especially anatomically connected phytoliths (vs single or individual) (e.g. Shillito 2011, Portillo et al. 2017) are common, often consisting of more than ten parallel rows (Fig. 9) and sometimes revealing consecutive layers of various tissues (Fig. 9b). Prevailing kind is of the elongated dendritic cells, which are anatomically connected, but they are often distorted (Figs. 9 & 11d).

The cell structures and the phytolith assemblages are

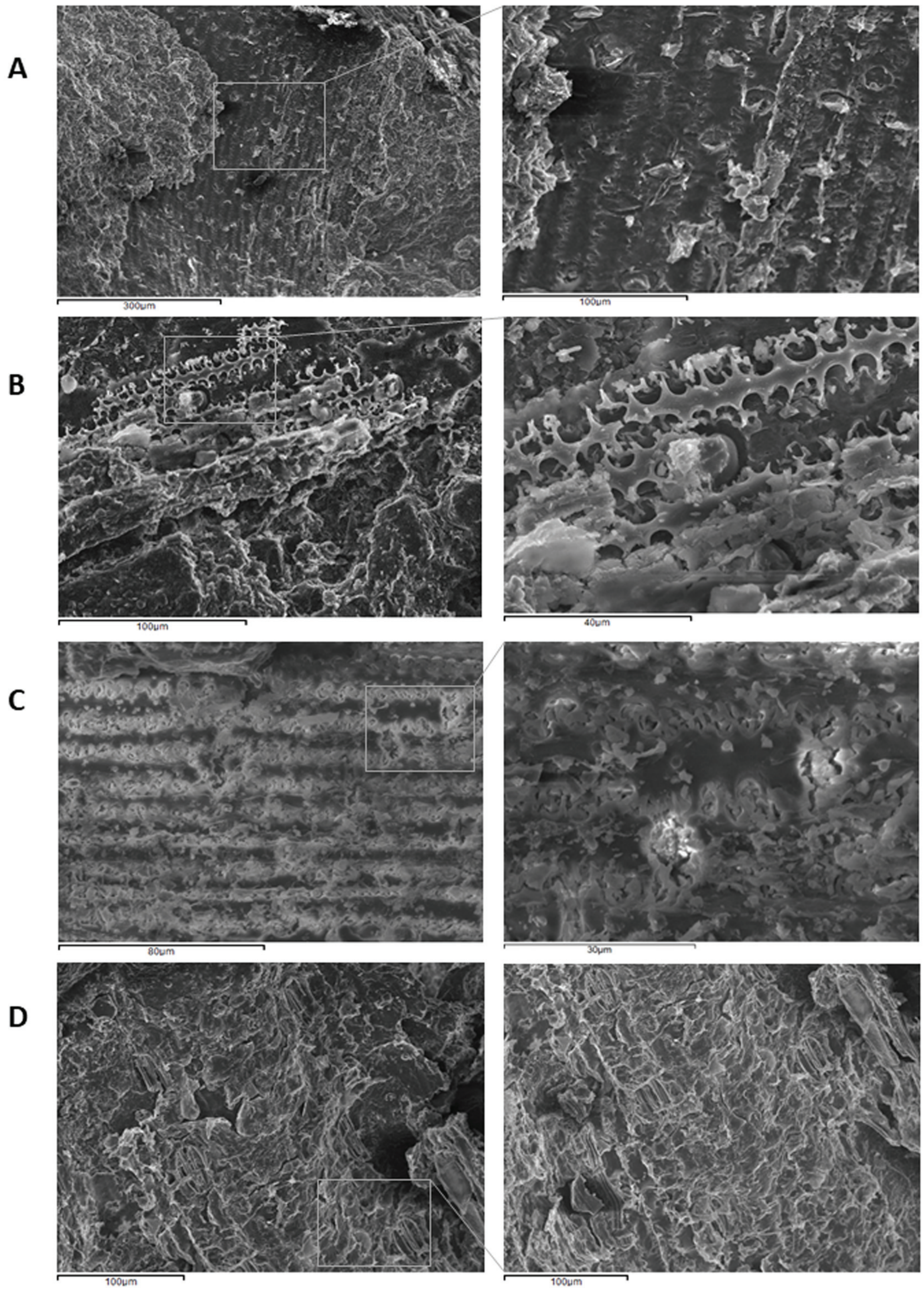

Fig. 9. Secondary electron image microphotographs of phytoliths registered in fragments from the studied sites, various scale. a - an assemblage of well-preserved phytoliths, Dzhulyuintsa; b - layers of phytoliths and a dendritic phytolith, Dzhulyunitsa; c - moderately preserved phytolith assemblages, Ilindentsi; d - phytolith assemblages with stomata, Dzhulyunitsa.

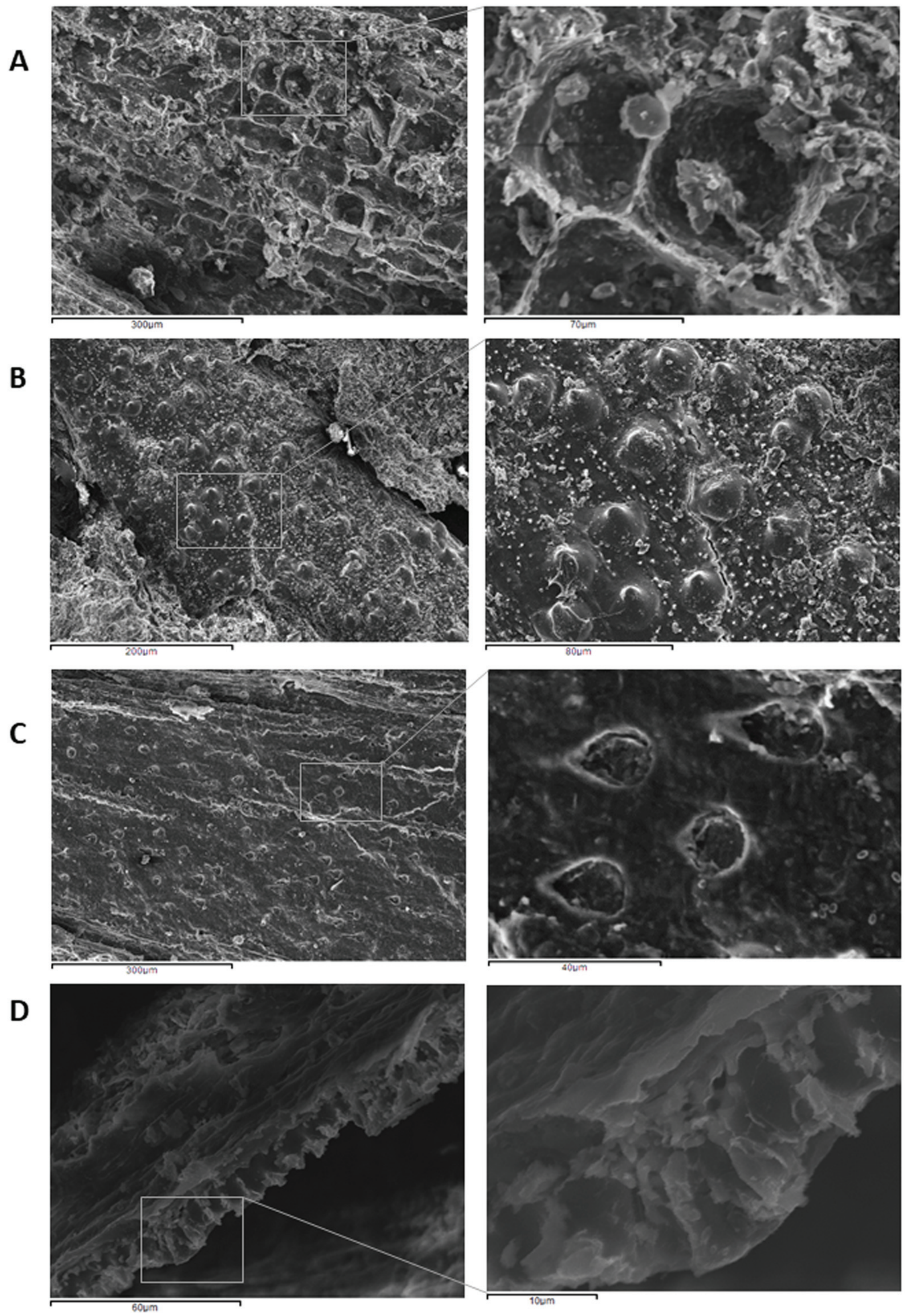

Fig. 10. Secondary electron image microphotographs of phytoliths from the studied sites, varying scale. a - cell assemblages in fragments from Dzhulyunitsa; b - papillates in fragments from Ilindentsi; c - papillates in fragments from Dzhulyunitsa; d - transverse cells possibly associated with the aleuron layer and the endosperm.

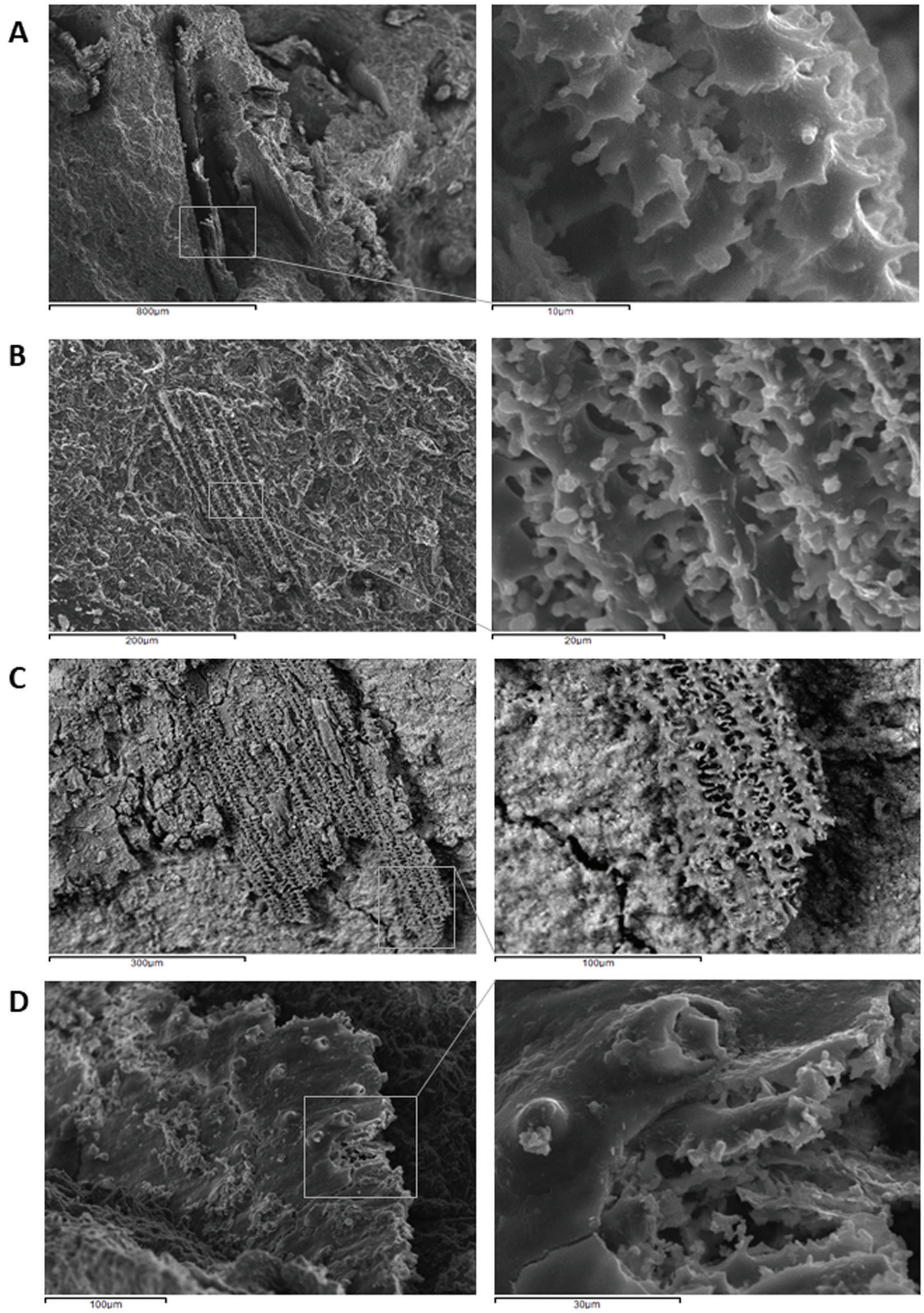

Fig. 11. Secondary and backscatter electron image microphotographs of phytoliths registered in fragments from the studied sites, varying scale. a-b - secondary electron image of well-preserved phytolith assemblages, dendritic phytoliths, Dzhulyunitsa; c - backscattered electron image microphotograph of dendritic phytoliths assemblages, Dzhulyunitsa; d - secondary electron image of preserved layers of phytoliths.

indicative of the inflorescence bract components of cereal plants, probably mostly glume wheat (Figs. 9a-c & 11). Well-preserved phytoliths frequently include areas with a higher concentration of papillate (Fig. 10b-c) without epidermal appendages such as acute bulbosus/hairs (micro-hairs or prickles), which, in combination with surrounding cells and according to the used phytoliths reference collection of crops can be found in the central zones of glumes, paleas and lemmas in *Triticum* and *Hordeum* species. However, small depressions or pits near the edges of the papillate, typical of *H. vulgare* and *T. aestivum* (Rosen 1992; Tubb et al. 1993; Moskal del Hoyo et al. 2017; Hayward & Parry 1980), have not been registered. Plant parts containing stomata, characteristic mostly of the culm/leaves (Fig. 9d), are rare. Transverse cells, potentially associated with the aleuron layer and the endosperm (bran) (Heiss et al. 2020) were also occasionally present (Fig. 10d), whereas single trichome (hair) base phytoliths were not detected at this stage.

DISCUSSION

Origin of the plant materials in the clay

The studied regionally-specific fabrics are all local and expected to contain local (vs imported) vegetal inclusions. The surface of the vessels (imprints) and the clay body (imprints and charred plant parts) of fragments from the three studied sites yielded cereal chaff macro-remains (glume bases, spikelet forks, whole spikelets, rachis fragments) indicative of *Triticum* and possibly *Hordeum* species. The study of the plant remains at micro-level revealed the absolute predominance of phytoliths typically associated with the inflorescence bracts of cereals, potentially glume wheat. It should be noted that such cell structures may be very similar to those of the wild *Hordeum*, *Aegilops* and other wild grasses (Poaceae – especially genus *Bromus*) and crop progenitors (cf. Acedo & Llamas 2001; Moskal-del Hoyo et al. 2017). Still, even if the crop imprints on the surface of the vessels are not taken into account, the identifiable macro-remains in the fabrics, and especially the preserved crop spikelets in the clay paste, point towards the addition of wheat chaff.

Past environmental conditions at Ilindentsi and Dzhulyunitsa reveal that up to 60% of the wood charcoal assemblages consisted of light-demanding or riverside woodland taxa (Marinova & Ntinou 2017; Kreuz & Marinova 2017). As in present times, the immediate vicinity of Dzhulyunitsa was associated with riparian forests and shallow water bodies with standing or slowly running water (Marinova & Krauß 2014, 190), and wild plants and wetland vegetation, such as water chestnut (*Trapa natans*) and club-rush, were used at the site (ibid.). According to the present preliminary observations, their exploitation in the domestic activities did not extend to pottery production – at this stage, there is no evidence for the addition of wild plants as functional temper in the studied pottery from the three sites. Instead, undigested crop components (cereal chaff) were used in pottery production and presently, apart from the cereals, no other crops (e.g. leguminous crops, flax) were found in the clay paste. Still, the presence of wild plants was identified at Ilindentsi. Their sporadic occurrence and the plant type, *Avena*, are not indicative of the use of wild plants as a temper; they instead point to species defined as arable weeds, which should be considered along with the cereals.

Concerning the potential confusion of fossil plants and the vegetal parts naturally contained in clay deposits, or fine root parts in the soil, the well-preserved and connected cells frequently observed in these samples are not likely to be purely sediment-derived plant material, as such bioclasts are usually considerably altered (see van Doosselaere et al. 2014) and do not reflect the micromorphology of the roots.

At this stage, no traces of chaff digested by animals (see Charles 1998; Valamoti 2013) have been registered in the studied collection. Although the absence of recognised calcitic spherulite-rich assemblages (cf. Canti 1999; Portillo 2020) may not necessarily indicate the lack of dung components (as these are not always preserved), the size, preservation and intactness of the vegetal remains, as well as the type of the organics-fabrics correspondence rather point to the presence of unprocessed chaff in the clay matrix. Charcoal or ash-derived plant materials can also be excluded as the source for the organic temper, according to the presented preliminary observations.

The opportunistic qualitative observations of the plant inclusions in pottery are not sufficient to comment on the specific percentage correlations between different crops: einkorn, emmer and barley. According to targeted archaeobotanical studies at Măgura-Buduiasca, einkorn and (hulled) barley are well attested throughout the Neolithic (and possibly 'new type' glume wheat spikelets, at least in the later contexts) (Walker & Bogaard 2010). It

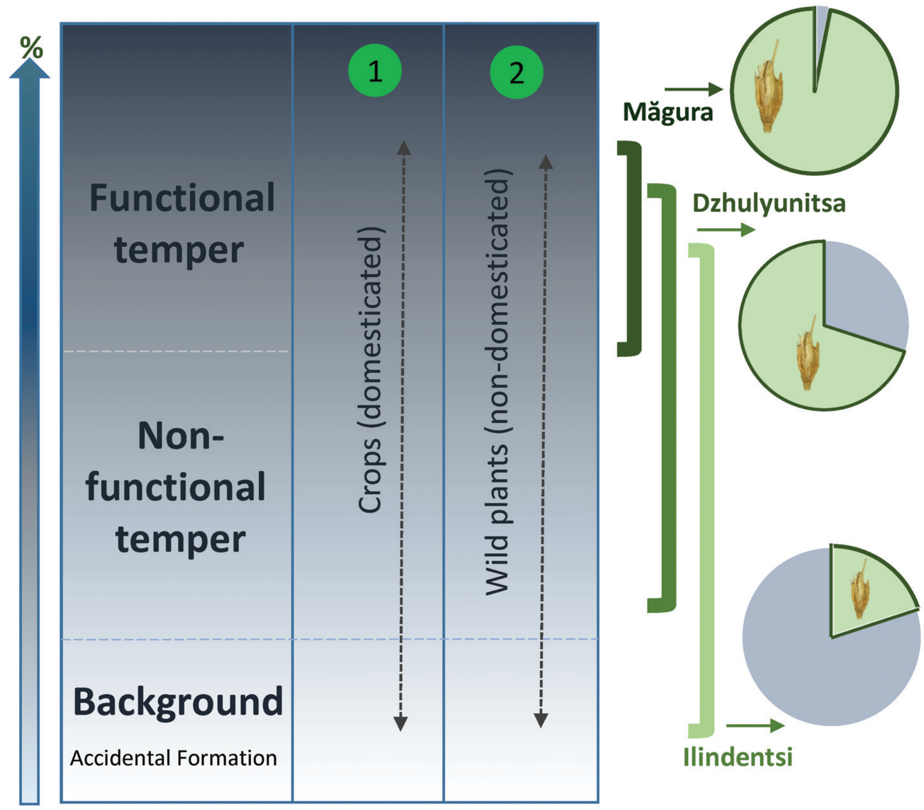

Fig. 12. Variability of organic inclusions in pottery from the three sites (per fragment: percentage of organic inclusions) according to the preliminary study. The three plots to the right represent the variable concentrations of organic inclusions (per site: percentage of fragments containing organic inclusions).

was einkorn that was established as the dominant Early Neolithic crop in Bulgaria (Kreuz & Marinova 2017, 645, 647) and preferred as a more winter hardy plant that survives heavy rainfall (unlike emmer, Kreuz et al. 2005, 246-250). Although naked wheat and barley had a higher yield than emmer and einkorn, they needed more nitrogen than the hulled wheat species (Kreuz et al. 2005, 254). At this stage, the previously observed pattern for the Early Neolithic north Bulgarian regions, a preference to hulled barley (*Hordeum vulgare var. vulgare*) as a drought-resistant crop with lower requirements to growing conditions, followed by einkorn (*Triticum monococcum*) and emmer (*Triticum dicoccum*) (Marinova & Krauss 2014), does not correlate with the organic inclusions in Dzhulyunitsa pottery. However, the domination of einkorn and emmer in southern Bulgaria may seem correspondent to the plant inclusions in Ilindentsi pottery. Notably, barley (and naked wheat) rachis remains are rarely found, which may also reflect free-threshing cereal processing outside the villages, perhaps resulting in smaller chaff quantities in the settlements (see Kreuz & Marinova 2017, 647). In pottery, such macro-remains may also be very rare (Dzhulyunitsa) or omitted simply due to their size. A detailed examination of possible free-threshing chaff parts in pottery is in process, especially concerning the north Bulgarian loess-based geological setting.

Regarding the processing stages, the plant parts related to fine chaff most probably resulted from secondary winnowing or coarse sieving. Significantly, specific interpretations of the chaff inclusions in pottery also depend on the storage practices. If temper consists of a mixture of plant parts that belong to different species, this cannot automatically be associated with maslins (growing mixed crops). The suggestion that einkorn and emmer (and pea) could have sometimes been grown as maslins in some regions of Early Neolithic Bulgaria (Kreuz et al. 2005, 243) cannot be assumed from evidence coming from ceramic temper. Storage practices are also a factor regarding seasonality studies. Temporality and lifecycle rituals are to be considered when examining prehistoric organic temper (Kreiter et al. 2014), but chaff present in ceramic vessels does not necessarily indicate that pottery production coincided only with the harvest season. Chaff remaining immediately after the harvest can easily be used, especially for making small clay objects (ibid.). However, chaff temper itself is not a proxy for seasonality in pottery production because of the storage component – i.e. chaff could be stored and available whenever needed. Other inclusions possibly present in the clay paste still may contain some data about seasonality.

Weeds found in pottery could give a hint on both seasonality and the harvesting methods (ear-plucking vs sickles) (Kreuz et al. 2005, 255), provided we take into account eventual biases stemming from the storage practices. Winter crop cultivation was practised, at least for some of the cereals, and generally, the winter annual weed species are the dominant group at the Bulgarian sites. Domination of perennial weeds may suggest that parts of the fields were not cultivated intensively (see Jones et al. 1999; Bogaard 2004; Kreuz et al. 2005, 253); however, at this stage, the intensity of field management cannot be estimated based on single *Avena* imprints registered in pottery, as found at Ilindentsi.

Technological significance: functional temper

In both textural and mineralogical terms, the local pottery fabrics perfectly match the natural sediments, i.e. no raw material processing beyond organic tempering has been registered so far at the three sites. However, specific features of the vegetal inclusions, and especially their abundance, show inter-and intrasite differences.

The preliminary observations on the studied fragments from Măgura-Buduiasca reveal consistent concentration ranges of the vegetal inclusions (> 10%-15%), indicative of plant temper intentionally added in sufficient quantity (Fig. 12). All components of the cereal spikelets are registered in the ceramic sherds. The demonstrated consistent use of plant temper corresponds with the location of the settlement in the extensive and alluvial low Danubian plain – a homogenous region with massive loessic accumulations providing for similar raw materials. Within this uniformity, the availability of sandier local areas explains the natural variation of sand distribution in the fabrics used for pottery production. Still, instead of adding non-organic sources as functional temper, if and when necessary (sand, crushed rocks, etc.), only chaff was used in pottery production to temper the clay. As regards the ceramic technology, and especially the firing, the sandier clays would not necessitate the addition of organic temper, and strictly technologically, perhaps the reason to add organic temper was the shaping of the higher plasticity clay.

Similarly, at Dzhulyunitsa the only registered temper was plant-based – mostly cereal inflorescence components. The site illustrates inconsistent use of organic temper, the added plant materials showing quite a variable abundance (0-30%). As fabrics-size-shape-surface finish correspondence was missing, the question becomes more complex. Given the properties of the clay body, for all organic inclusions to be categorised as clay temper, we would expect to see them in similar proportions/sufficient percentages. The presence of fewer inclusions would have had minimal impact on the forming, the firing or the use of the wares, and perhaps reflects cultural preferences rather than practical requirements. Although there may be a tendency for the more clay-rich fabrics to contain consistent amounts of plant parts, there are still cases where local fabrics were used without any addition of organic temper. At this stage, the plant macro- and microremains may be referred to specific crops, and especially the light chaff components of crop spikelets (predominantly einkorn and emmer). Neither cut plant parts, nor pure ash or accentuated dung features have been detected so far.

Whereas Măgura-Buduiasca and Dzhulyunitsa share some common features, the fabrics at Ilindentsi-Massovets differ considerably. The site, located in a valley within the mountains, shows geological continuum reflected by the microtextures of the fabrics and a range of vegetal inclusions. Although plant parts are usually reported missing in the typical southwest Bulgarian Early Neolithic pottery, some of the studied fragments contain actual vegetal temper. Furthermore, specific fragments include organics detectable/recognisable only microscopically. They are often single or few (1% to 5%) – amounts that do not contribute to the technological properties of the clay (i.e. non-functional temper). The range of plant inclusions are thus correspondent to a) actual functional temper; b) ‘inconsistent’ use of plant parts and c) a sporadic presence of organic inclusions.

The available local sandy clays, containing natural inclusions, are suitable for pottery production even without further processing, i.e. they would not necessarily require the addition of temper. The reasoning behind the presence of organic matter in some vessels is thus intriguing, especially given the (a) sporadic wild species and (b) the amounts of crop parts contrasting with the functional temper ranges. Based on studied pottery from one excavation unit (Square A), previous ceramic analyses refer to about 60% of organic tempered vessels at the site (Grębska-Kulova et al. 2011). The present assemblage collected from various contexts shows a considerably lower percentage of fragments containing more than 10% of plant inclusions in the clay paste (12 fragments out of 100). In this study, the percentage of plant parts considered as possible temper is above 10% (usually between 10 and 20%), reaching a maximum of 30%. Since functional temper would exceed at least 10% of the organic inclusions, the very low percentage of vegetal material contained in some of the fragments (1-5%) is probably indicative of non-functional temper but requires further explanation. The high variation in the compositional amount of organics at Ilindentsi (from 1-5 to 30%) poses the question of how much organic addition is required to change the clay properties (if added for technological reasons). At the lowest frequencies, the addition of plant parts, in their natural state, would not act as functional temper and their presence requires further examination.

Even without the addition of adequate amounts of temper, the selected clay raw materials – the silty and the fine-grain sandy clays – both meet the technological requirements at each stage of the operational chain; forming, drying, firing**.** Interestingly, a similar amount of organics – as percentages of plant parts in the ceramic fragments – were added both to fabrics perfectly suitable for pottery making in their natural state, and those that required additional materials to achieve the desired quality of the clay paste. It can thus be expected that the reasoning behind the presence of very few organic inclusions, along with the question of how these appeared in the clay paste, is more complex, not limited only to technological aspects.

The location of the sites within the sub-Mediterranean zone (Ilindentsi) and the Danubian plain with more continental climate (Dzhulyunitsa and Măgura-Buduiasca), results in differences on all key parameters of crop yield potential (see Kreuz & Marinova 2017, 642). The local landscape and geology, contributing to the available raw materials (respectively the selection of suitable clays), complement the observed variation. Whereas the area of Măgura-Buduiasca in the Danube River region generally delivers the same clay opportunities (correspondent to the similar compositional amount and types of vegetal temper), the site at Dzhulyunitsa had access to both loessic low ground and high ground raw materials. The latter revealed considerable variability in pottery technology at the settlement, expressed in the addition of none, just some or lots of organic temper. The Ilindentsi potters also had a choice of raw materials – ranging from the alluvial areas to the higher mountainous terrain, and these were suitable for pottery production in their natural state. In terms of technology, the organic temper was added in higher proportions and more frequently to the stickier, perhaps too plastic smectite clays at Măgura-Buduiasca and Dzhulyuntsa, and in lower proportions and more seldom to the drier illitic clays at Ilindentsi.

The tempering practice at Ilindentsi differs from that at the two other settlements. The proportion of pottery with organic inclusions is considerably lower; and when present, the temper, correspondingly, is found in lower quantities. So far, no semi-charred whole spikelets have been detected, no plant parts in high concentrations or placed in clusters, one on top of another were found there. Generally, the preservation of the phytoliths is worse (compared to Dzhulyunitsa), whereas the northern settlements demonstrate better-preserved plant parts.

Although local geology is among the key technological factors, the decision making when working towards the desired technological properties of the clays also depends on important social and cultural aspects – hence the problematic interpretation of the observed variability in type and quantity of organic temper. The subsistence patterns (agricultural and husbandry practices) may also have a more direct bearing on specific pottery technological approaches, especially when dung is considered. Although Ilindentsi is located in the mountainous regions and dated to the developed stage of the Early Neolithic, and the two earlier sites in the Danubian valley occupy areas perfectly suited for agriculture, there is a similar predominance of sheep and goat over the cattle (see Grębska-Kulow et al. 2015). Even though dung of caprinae, at least in its natural state, is usually not very common in pottery production (in contrast to that of cattle, cf. London 1981), the question of its inclusion or absence will be investigated in detail in the future. According to ethnographic data (Vasilieva & Salugina 1997), dung-derivative temper may sometimes be used in either dry or liquid state. The presence of small and sporadic vegetal inclusions thus needs to be carefully explored, as single plant parts may have passed through the mesh when practising the latter method. Future analysis will focus on this possibility, taking into consideration the specifics of the dung of various animals and their eating habits (wild plants and fodder). Such examples of plant-based technological components in pottery production may be revealed by some fragments containing single, sporadic or a very low percentage of organic inclusions, e.g. Ilindentsi. Dzhulyunitsa, on the other hand, contains fragments probably showing the addition of moist plant parts – a possible indication of different technological approach, a hypothesis also to be tested.

Finally, whether the newly registered intra- and inter-site variation in the 'organic temper' use is meaningful, i.e. having the same importance to the ancient artisans, is another central question. Do the differences observed by the application of high-resolution magnification techniques reflect intentional variations or these are artificially created classifications referring to otherwise naturally flexible components? Understanding the reasons behind the addition of organics as a technological component, and differentiating between the major and the secondary features of the added materials requires a spectrum of elements to be considered, rather than choosing single components. Here, the observations are based on a series of features, all pointing to the variability of the use of 'organic temper'. Local pottery-making practices are best interpreted when studied in context – the environmental conditions, subsistence patterns, land use strategies and ceramic traditions. The variation established according to several criteria may thus also reflect the variability between contrasting practices (e.g. the colder Danubian conditions and Chernozem soils vs the hotter and drier south Bulgarian area).

CONCLUSION

The detected inter-and intrasite variability in using plants for pottery production evolves from the origin, the source of the plant parts, the types of processing and the relation to the clay fabric, all these, in turn, resulting from specific human decision making. A multi-layer approach and higher-resolution site-specific contextualised analysis of the vegetal inclusions can be used to re-consider broader definitions, such as 'organic temper'. The plant inclusions from the three studied sites demonstrate the variability of an important Early Neolithic ceramic technology component. The potential to reveal various plant sources and crop processing steps archived by specific features of the plant inclusions lies in the examination of their preservation, original state when added: wet vs dry, processed vs unprocessed, origin and source, type and amount, correspondence to the mineral inclusions, combinations with wild plants.

This article is a starting point for further detailed research on the complexity of the interpretation of the organics present in pottery fabrics in Early Neolithic Balkan context. Whereas at Măgura-Buduiasca the plant parts are found in quantities correspondent to functional chaff temper, Dzhulyunitsa shows a far greater variety. At Dzhulyunitsa, not all vessels are tempered, and the presence of organic inclusions varies between functional temper and non-functional inclusions (or no temper at all). An even more complicated situation is illustrated at Ilindentsi, where plant matter can be used as functional temper, but at the same time, there are very sporadic inclusions of plant parts, as well as single wild plants. Using the vegetal component in pottery production, the set of commented features that signals this variation, reminds us once again that Neolithisation processes were much more complex and multi-layered than expected.

The three examples reveal a high degree of complexity, which is further evident when interpreting ceramic production features in a broader context. Understanding human technological choices require the study of the interrelation between organic and mineral temper and the specific properties of the local clays. This combination allows us to test if the presence of plant parts in the clay fabrics was a strictly technological requirement or also a cultural factor embodied (with)in social behaviour. Based on the study of ubiquitous archaeological material, the examination of the variety in plant use in pottery production thus has the potential to reveal how local subsistence patterns intertwine with various aspects of material culture technologies in the context of site-specific surrounding landscapes.

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