Research Article

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Exploring the Broad Spectrum: Vegetal Inclusions in Early Neolithic Eastern Balkan Pottery

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Abstract: Why was "chaff temper" used in pottery production? The possible reasoning behind the practice of intentionally adding organic matter (various plant parts and plant-containing materials) to the clay paste when making pottery is explored by studying four Early Neolithic open settlements. Located in contrasting regions, northwest and southwest Bulgaria, they have contrasting geological settings, altitude, climate, and "pottery styles." Ceramic fragments containing vegetal remains (charred, semi-charred parts, imprints, and phytoliths) found both on the surface of the vessels and within the body clay are studied in hand specimens, thin-sections and by using scanning electron microscopy. Whether the addition of "organic temper" was an actual functional prerequisite (e.g. caused by technological limitations of the local clays, the vessels' use, etc.), and how to interpret the variable contents and types of vegetal remains within the clay fabrics, are the main questions discussed within a broader context. The observed variability raises awareness of a series of potential biases when interpreting vegetal remains in Early Neolithic Southeast European pottery. This study not only tackles the interrelation between two major Early Neolithic cycles – ceramic technology and agriculture – but also reveals the potential to examine the synergies between specifically technological, agricultural, and environmental study aspects. It demonstrates the intrinsically intertwined crafts and husbandry activities, technological landscapes, decision-making strategies, and subsistence patterns, all within site-specific environment. It also frames a debate on such inclusions' strictly technological significance, their role as a cultural factor embodied in social behaviour, or completely accidental presence in the clay fabrics, and a whole spectrum in between.

Keywords: vegetal inclusions, organic temper, Early Neolithic, pottery production, eastern Balkans

1 Introduction

Organic or chaff temper has been considered among the hallmarks of the Early Neolithic Balkan pottery production (Elenski, 2006; Kreiter et al., 2014; Spataro, 2009, 2010, 2011; Starnini, Szakmáni, & Madella, 2007; Todorova & Vajsov, 1993; Vuković, 2016), and yet, in many regions, little is known about the precise characteristics of the vegetal remains.

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This article tackles the possible reasoning behind the practice of adding organic materials (plant parts) in the clay paste when making pottery. The main question is whether the addition of organic temper was a functional prerequisite because of technological limitations of the local clays. If so, then a series of further questions follow, including: What factors shaped the preference of domesticated over wild plants? How should we interpret the occasional occurrence of organics in minimal quantities, as opposed to the intentional addition of large amounts of vegetal material as functional temper – i.e. such that can adequately modify the properties of the clay fabric? Indeed, should sporadically present inclusions, single plant parts within the clay bodies, be considered as deliberately added temper at all (see Arobba, Panelli, Caramiello, Gabriele, & Maggi, 2017; Doherty, Beavitt, & Kurui, 2000)?

By tackling the questions of why such vegetal inclusions were characterised as "chaff temper," were they an actual functional temper; and if so, then why chaff was the preferred vegetal type intentionally added to

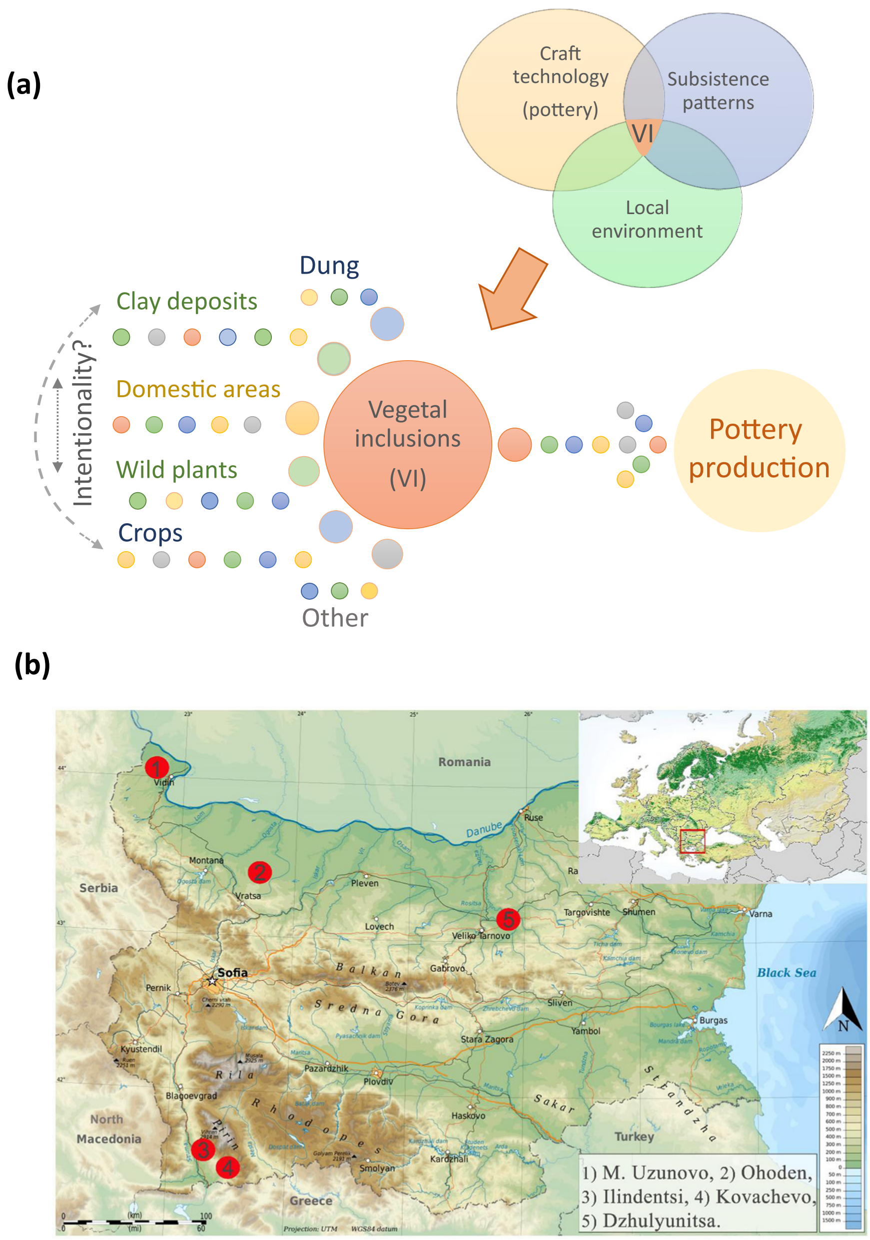

Figure 1: Parameters of the study. Vegetal inclusions in ceramic vessels: complexity, origin, variety and study aspects (a). Early Neolithic settlements mentioned in the text (b).

the clay pastes, the study of plant-tempered Early Neolithic pottery elucidates the interplay between crafts and husbandry activities. Furthermore, it sheds light on the connection between pottery making and subsistence patterns, intrinsically intertwined with everyday activities, domestic spaces, technological, and natural landscapes in site-specific context (Figure 1a, see Dzhanfezova, 2020 and references therein).

On the basis of a systematic approach that integrates several analytical techniques, this article elaborates on the debate regarding the presence and the origin of vegetal inclusions on the surface and within the fabrics of ceramic vessels. The approach is based on a combination of binocular, thin-section, and scanning electron microscopic analyses focused on specifics of the plant remains and the properties of the clay fabrics. Rather than aiming to reach definite conclusions at this stage, the paper raises the awareness of potential issues and a series of biases when interpreting vegetal inclusions present in Early Neolithic Balkan pottery (Figure 1b).

2 Materials and Methods

This study examines charred and not fully charred vegetal parts, plant impressions, and phytoliths. Preserved plant remains, and imprints may indeed be indicative not only of genuine temper added to the clay paste but also of plants used at various stages of the *chaîne opératoire* (including "tools," for smudging, etc.), or such occurring naturally in raw materials deposits. Furthermore, there may also be occasionally present organics entrained within various domestic areas; components of dung and its derivatives; or combinations of these, amongst the rest (see Mariotti Lippi & Pallecchi, 2016; Rice, 1987; Skibo, Schiffer, & Reid, 1989).

The attempts to distinguish between these also require consideration of the "location" of the plant remains within the various zones of the pottery fragments. As these may refer to different stages of the *chaîne opératoire*, various approaches towards shaping the vessels, additional surface treatments, and specific procurement strategies or particular areas of pottery production, the observations on the ceramic sherds include their (a) outer surface, (b) inner surface, and (c) body clay. Special attention is paid to state, preservation, concentration (frequency of occurrence), sorting of the vegetal remains, their clustering or regular dispersal within the clay, the level of consistency and the extent of their variability, the combinations of plant parts, possibly their type and genus, etc. The plant parts are considered in connection with the characteristics of the fabrics and the rest of the organic and mineral inclusions present in the clay paste.

The plant remains were examined by low-power optical microscopy (EZ4 Stereo Microscope, 8× to 35× magnification range), high-power polarised light optical microscope (using 30 µm thick vertical thin sections and a Leica DM 2500 P, 5× to 50×), and scanning electron microscopy (Jeol 5910 scanning electron microscope with an Oxford Instruments INCA 300 energy dispersive x-ray spectrometer, SEM-EDX, <10,000 × magnification) in combination with selected reference collection specimens. A set of 20 samples from each of the sites was chosen to represent a spectrum of inclusion types, concentrations, and arrangements on the surface and in section, of both coarse undecorated, and fine high-quality painted vessels (where available), with various shapes and thickness (0.5–2.3 cm).

This initial sample collection includes fragments with various thickness from: (1) Mayor Uzunovo – 2 × 5 mm, 3 × 7 mm, 10 × 10 mm, 3 × 15 mm, 2 × 20 mm, all undecorated; (2) Ohoden – 3 × 6 mm, 5 × 7 mm, 7 × 10 mm, 2 × 12 mm, 3 × 17 mm, all undecorated; (3) Ilindentsi – 3 × 5 mm, 10 × 7 mm, 2 × 10 mm, 3 × 15 mm, 1 × 20 mm, 1 × 23 mm with 10 decorated fragments, and the same ratio at (4) Kovachevo, all from the earliest Neolithic phase explored at each settlement. These were observed as hand specimens and in thin sections, and selected fragments were prepared for further SEM analysis.

The observations on the shapes and frequencies of preserved vegetal parts and voids, plant imprints, and preserved remains on the surface and within the clay body are based on adapted comparison charts. The distribution concentrations range from "rare," "very few," "few," "common," and "frequent" occurrences (e.g. Rice, 1987; Whitbread, 2016 for mineral inclusions). Specific features of the voids left in the clay paste (Whitbread, 1995, 2016), their boundaries, and clay porosity (van Doosselaere, Delhon, & Hayes, 2014) were also taken into account, at present without a reference to specific taxa (cf. Moskal del-Hoyo, Rauba-Bukowska, Lityńska-Zając, Mueller-Bieniek, & Czekaj-Zastawny, 2017), based on the characteristics of the generally poorly preserved vegetal parts in the analysed thin sections. Here, the adapted descriptions of the state, level of preservation, and degrees of distortion vary from not noticeable to gross after Hubbard and Al Azm (1990).

Identification of plants and plant parts on the basis of the clearer imprints was attempted following plant atlases (including Jacomet, 2006; Zochary, Hopf, & Weiss, 2012) and macro- and micro-botanical reference collections consisted of crops and wild plants. With regards to the suggested use of chaff, special attention was focused on the morphology and the ways of disintegration of the plant parts typical of threshing and non-threshing crops (Figure 4b).

The observations on vegetal remains and phytoliths made at higher magnification (<10,000×) (Ball, Gardner, & Anderson, 1999; Ball, Ehlers, & Standing, 2009; Heiss et al., 2020; Lanning & Eleuterius, 1992; Piperno, 2006; Vrydaghs & Devos, 2020) were based on the International Code for Phytolith Nomenclature (ICPN) ver. 2.0 (Neumann et al., 2019). Plant reference collections in the Archaeobotany Laboratory at the School of Archaeology, University of Oxford, were used to aid the identification of vegetal macroremains and microremains (*Triticum* sp., *Hordeum* sp., and *Phragmites* sp. plant parts).

3 The Study Sites

The two earliest known Neolithic open settlements in northwest Bulgaria (Figure 1b – 1 and 2) are located in a generally flat and homogenous area dominated by reworked fine loessic deposits gradually becoming thinner towards south and naturally containing variable quantities of sand (Jipa, 2014). The southwest Bulgarian pair of sites, on the other hand, is located nearby or within the mountainous areas (Figure 1b – 3 and 4) – within a region with more complex geology consisting of Neogene sediments and weathered materials subdivided into various formations and proportions (conglomerates to fine clays; Westaway, 2006; Zagorchev, 2001).

The **northwest Bulgarian** sites are located in the Lower Danubian plain with fertile, grey, and brown forest soils, temperate continental climate, 10–11°C mean annual temperature, and 600 mm precipitation with spring maximum (Marinova, 2009, p. 76).

The Early Neolithic open-air settlement at **Mayor Uzunovo – Gradets** (**1**), ca. 1.6 hectares, "Protostarchevo I–II culture," contains disturbed remains of fireplaces and pits, and also complete vessels were found *in situ* within the limited excavated area of 55 m^2 (Ganetsovski, 2015). Complete publication and achaeobotanical analyses are still anticipated, but according to the available descriptions (Ganetsovski, 2015, p. 7), the organic temper in greyish-black pottery was seen as either heavy chaff or dung, whereas the "slipped" pottery included fine organics, and yet again the thicker vessels (>1.2 cm) were associated with the addition of "coarsely chopped organic inclusions."

The settlement at **Ohoden – Valoga** (**2**), ca. 10 decares, is situated on a slope alluvium floodplain near the Skut river, at about 196 m a.s.l. (Ganetsovski, 2009, p. 7). Remains of dwellings, domestic contexts, and graves from two registered stratigraphic layers were dated to (a) the "final monochrome stage," Protostarčevo phase 2, with one date 5710 ± 40 cal. BC (68%) and (b) phase Starčevo II (Ganetsovski, 2009, pp. 8–11). The earlier phase pottery contains a slip and "fine organics" in the fabrics (Ganetsovski, 2009, pp. 16, 29, 42).

Open woodland (wooded steppe), oak forests, and riparian vegetation surrounded the site, including moist habitats, wetlands, and riverine forests – wet places near the rivers (*Hyoscyamus niger*) and shallow bodies of slow-flowing or stagnant water (*Trapa natans*). The forest edge/open vegetation and open landscapes in the surroundings included steppe species grassland (e.g. feather grass, *Stipa sp.*), indicative of the presence of open vegetation nearby the Early Neolithic settlement (missing today; Marinova, 2009, p. 76; Marinova, Filipović, Obradović, & Allué, 2013).

The identified crops include einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*), and barley (*Hordeum vulgare*), which were cleaned and prepared for consumption at the site, and pulses (*Pisum sativum, Lens culinaris*) (Marinova, 2009).

Within the broad region of northwest Bulgaria were present temporarily or permanently wet areas and flooded land near the settlements (Marinova et al., 2013). Along with deciduous oak forests, there were also patches of open landscape vegetation – wooded steppe or open oak woodland. The available wide spectrum of wild plant resources thus consisted of taxa occupying diverse habitats – riparian/wetland, dry/open woods (wooded steppe), oak woodland, and pinewood stands (Marinova et al., 2013).

Southwest Bulgaria consists of variable plain and mountainous terrains related to the continental-mediterranean climate (sub-mediterranean), with 14°C mean annual temperatures, 600–650 mm precipitation, and slightly cooler summers and milder winters in prehistory (Marinova, 2006, pp. 13–14). The canyon-like landscape specifically along the narrow Middle Struma River banks belongs to the sub-mediterranean-Aegean biogeographic region – a microregion influenced by the mediterranean climate and comprising thermophile species (Cikovac, 2002; Krauß, Marinova, De Brue, & Weninger, 2018).

The flat settlement at **Ilindentsi – Massovets (3)**, ca. 3 ha, excavated 350 m^2, is dated to the second half of the Early Neolithic (5700–5460 BC) and the Middle Neolithic period (Grębska-Kulow & Zidarov, 2020, pp. 171–172). It is located on a slope with a western exposure at the foot of the Pirin Mountain, at 250 m a.s.l. and near a tributary of the Struma river. Within each of the variable pottery groups and styles, there is a small percentage of vessels that also include organic temper (representing a total of 17% of the statistically processed fragments; Grębska-Kulow & Zidarov, 2020, p. 187).

The studied plant remains at the settlement include cereal crops such as einkorn (*Triticum monococcum*) and barley (*Hordeum vulgare*), legumes (*Lathyrus* and *Lens culinaris*), and wild plants (plum, cornelian cherry, hazelnut, juniper, and oak) (Grębska-Kulow et al., 2018).

The open settlement at **Kovachevo – Podini (4)**, 450 m a.s.l., in the foothills of the Pirin massif, lies on the bank of a mountain river, on the sloping edge of a Quaternary alluvial terrace. It is about 6 ha large, with a 1,500 m^2 investigated area and up to a 2 m thick accumulated cultural layer (Early Neolithic-Early Bronze Age), containing house constructions and burial contexts (Demoule & Lichardus-Itten, 1994; Lichardus-Itten, Demoule, Perniceva, Grebska-Kulova, & Kulov, 2002). The earliest obtained dates (Kovachevo Ia) refer to 6159–5926 cal. BC and 6064–5808 cal. BC (Lichardus-Itten, Demoule, Pernicheva, Grebska-Kulova, & Kulov, 2006). Among all categories of studied ceramic vessels, 17% contain organic temper – usually big undecorated vessels, with thicknesses exceeding 1.2 cm – and only 2% of the painted wares (Salanova, 2009, p. 23).

Emmer (*Triticum dicoccum*) was predominant, followed by einkorn (*Triticum monococcum*), durum wheat (*Triticum turgidum/durum*), and barley (*Hordeum vulgare*), as well as lentils, chickpea, bitter vetch, and pea; wild plants – cornelian cherry, raspberry, plum, grape, and hazelnut (Lichardus-Itten et al., 2002, p. 127); and Eastern Mediterranean type weeds (Lichardus-Itten et al., 2002, p. 127, Marinova, 2006, pp. 56–62). Fairly open deciduous oak forests, a damp zone near the river banks (poplar), and pine forests (Marinova, 2006, pp. 56–62) were spread within the immediate surroundings. The majority of domestic animal remains comprises sheep/goat (65%) and domestic pig (21%) (Lichardus-Itten et al., 2002, p. 126).

A great range of available wild grasses, sedges, and rushes, as well as crop processing by-products, were thus available at each of the study sites and their surroundings, allowing for a variety of choices in terms of selection of organic temper sources – i.e. dung, crops, wild plants, and, either intentional or not, combinations of these. Furthermore, the variable clay raw materials available at these sites may have also been associated with fabrics that contain naturally present vegetal parts (see below).

4 Preliminary Results

Starting with low-resolution and continuing with high-resolution microscopy (thin section and SEM analysis) on the vegetal inclusions, observed both on surfaces (Figure 2) and in body clays (Figure 3) at the sites, are presented in order, as introduced in Section 3.

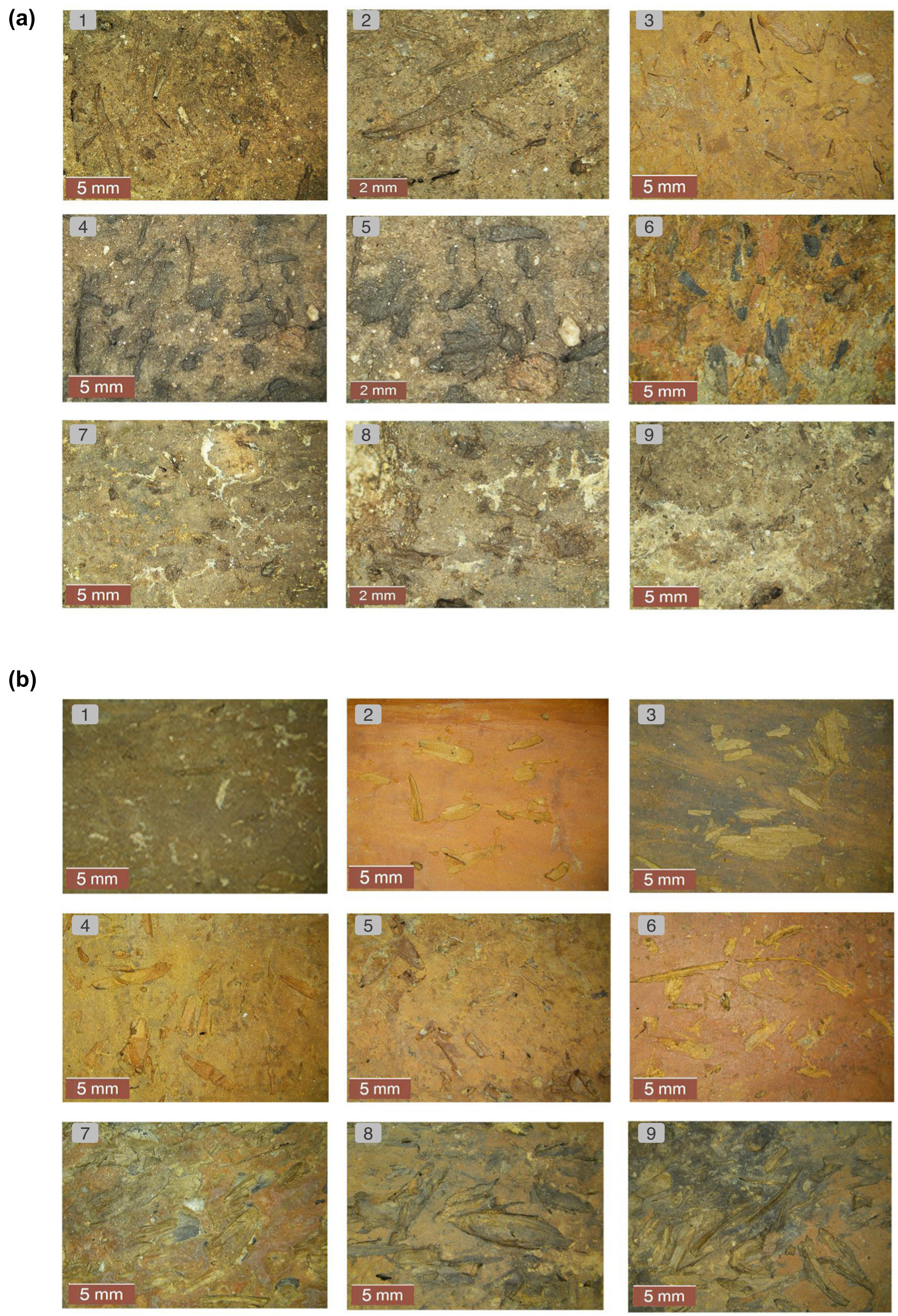

Figure 2: Variability of surface imprints. Plant inclusions of variable size and sorting (a): from poorly (1–3) to well sorted bigger (4–6) and smaller (7–9) plant parts at Mayor Uzunovo (3 and 6) and Ilindentsi (the rest). Plant inclusions showing variable frequency ranges (0–40%) at Mayor Uzunovo (b): very rare (<0.5%) to rare (0.5–2%) = 1; very few (2–5%) = 2; few (5–15%) = 3; common (15–30%) = 4, 5, 6; frequent (30–50%) = 7, 8, 9 (adapted from Whitbread, 1995; Whitbread, 2016, see also Figure 3).

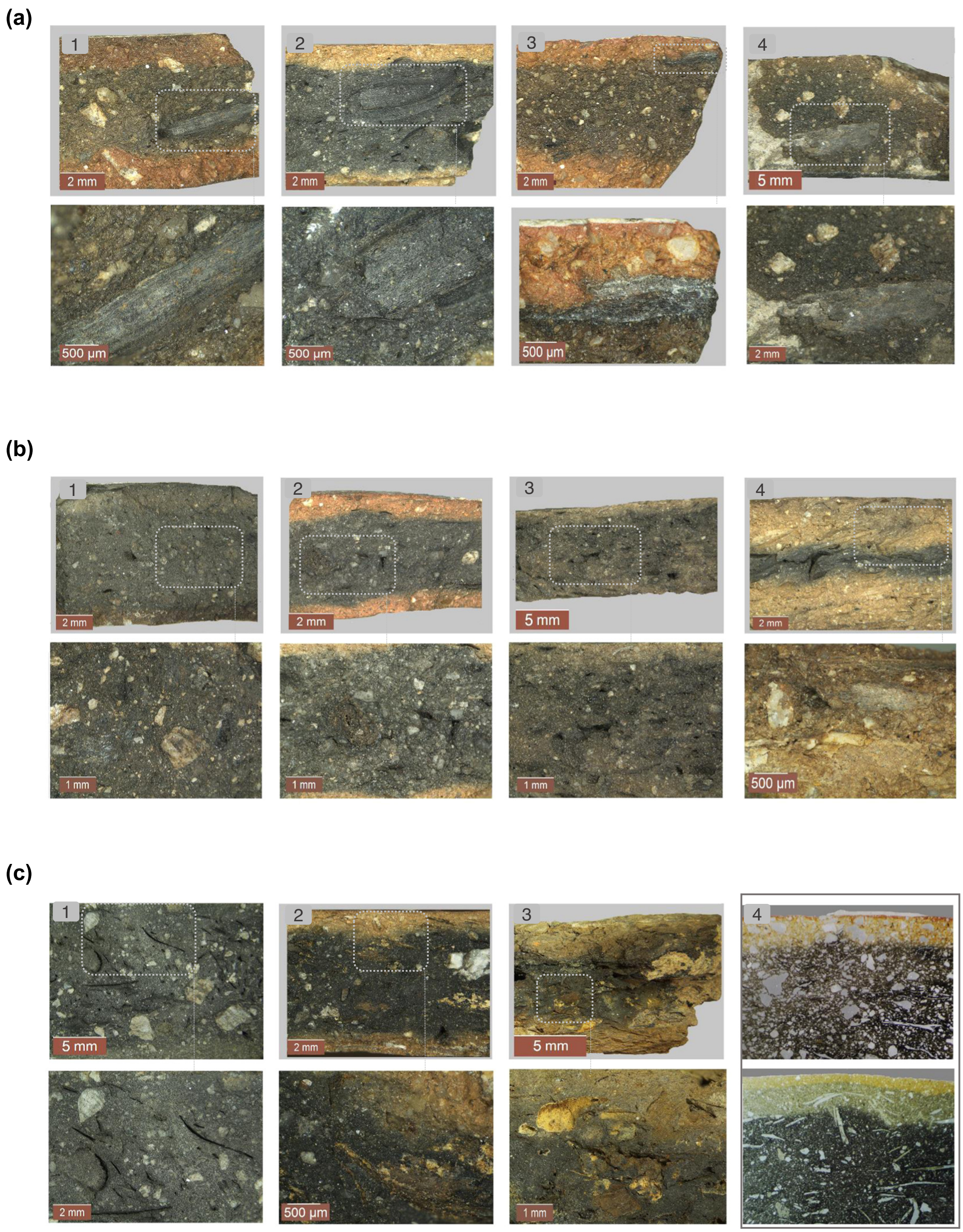

Figure 3: Variability of plant inclusions within body clays. Single bigger plant inclusions in body clay at Ilindentsi (a): probably crops. Variable frequencies of plant inclusions in body clay (b): (1–15%) = 1–4 at Ilindentsi. Variable frequencies and types of plant inclusions in contrasting regions (c): (<30%) at Ilindentsi = 1, Kovachevo = 2; and Dzhulyunitsa = 3; and typical southern (Ilindentsi = 4 up) and northern fabrics (Dzhulyunitsa = 4 down) containing vegetal inclusions in thin sections (field of view 9 mm). Note specific features of the voids left in the clay paste – long, narrow planar voids and wide channels (linear) and irregular vughs, and circular vesicles (rounded), see Whitbread, 1995, 2016.

4.1 Low-Resolution Stereomicroscopic Observations

The better-preserved pottery at **Mayor Uzunovo (1)** shows a range of vegetal imprints on the surface (5% to 35–40%) (Figure 2b) with a maximum length reaching 7 mm. Some vessels could have been additionally smoothed – resulting in less organic inclusions entrained into the surface layer. These could have been "naturally" removed (by burnishing frictions or self-slip), intentionally removed, or never added to the surface clay layer at the preceding stages of the *chaîne opératoire*.

The well-preserved imprints on the surface (Figure 4b right) reveal crops parts of the bract (spikelet fork, glume, palea, lemma, and even whole spikelets). There are also occasional imprints of different, smaller vegetal parts most probably indicative of wild plants (Figure 4a).

The percentage of organic inclusions in body clay is usually high, around 30%, their maximum size reaching 4 mm but sometimes also 8 mm. The vegetal inclusions are generally very poorly sorted. The plant parts can be randomly distributed (compared with those somewhat aligned and parallel to the walls at Ohoden, see below). However, when preserved in bigger sizes (length), or found in thinner fragments (5 mm), these can also be parallel to each other and to the walls, at least in some sectors in cross-section. Regardless of the thickness (5–20 mm) or the shape of the vessels (open and closed vessels), the addition of organic matter is always consistent and usually associated with similar quantities present in sufficient frequencies.

The quantities and types of organic inclusions visible on the studied surfaces at **Ohoden (2)** usually correspond to those within the body, i.e., often having similarly high concentrations (15–30%). Although the size of the vegetal pieces may vary depending on degree/extent/intensity of disintegration, these are generally fine inclusions – usually 2 mm on the surface, sometimes reaching a maximum of 5 mm.

With regard to potential more specific treatments of the surfaces (burnish, additional layers such as engobes and slips, etc.), the preservation of the pottery fragments is poor, which may also have an effect on the actual visual appearance of the top surface. Specific additional layers (devoid of any plant inclusions) that cover the organic-tempered body clay have thus not been registered yet (cf. Ilindentsi, see below).

The vegetal parts within the studied body clays of fragments with thickness between 5 and 15 mm are in consistent amounts – within the frequency of 15–30% range of inclusions in the clay paste, and commonly 25%. They usually vary between 1 and 2 mm length (cf. the greater variety at Dzhulyunitsa and Ilindentsi, Dzhanfezova, 2020); are regularly distributed within the clay fabric, with good preservation level, well mixed with the clay, and generally poorly to well sorted (bearing in mind the easily disintegrating plant parts).

Interestingly, however, on one occasion (5 mm thick fragment), the vegetal inclusions are very well sorted and considerably finer (<1 mm) when compared to the rest of the samples. The latter is indicative of the different origin of the vegetal temper material, i.e. of another pottery-making recipe probably based on dung-derivative materials (see discussion).

As the ceramic fabrics are fine and micaceous, bigger mineral inclusions within the body clay are usually missing. Currently, there is no consistent relationship between the types and concentrations of the organics, specific shapes or decorations of the vessels, and the presence of other mineral inclusions.

At both northwest Bulgarian sites, the organic inclusions are usually very well preserved. As will be shown below, this is unlike the southern sites, where the clays contain much more mineral inclusions and are generally better oxidised[1].

Ilindentsi (3) and Kovachevo (4) share quite similar characteristics regarding organic inclusions. Macroscopically, despite the presence of organic-tempered clay pastes within each of the vessels' categories, at these sites, this is not the common clay preparation recipe (see Section 3).

The fragments do not usually contain concentrations of plant parts present on the surface (especially patches of vegetal remains covering one another). The studied fragments with more carefully smoothed surfaces, and especially those having white-painted decoration, usually contain a "cleaner" surface layer

1 Specific details on the local clays and pottery fabrics at each of the sites will be presented elsewhere.

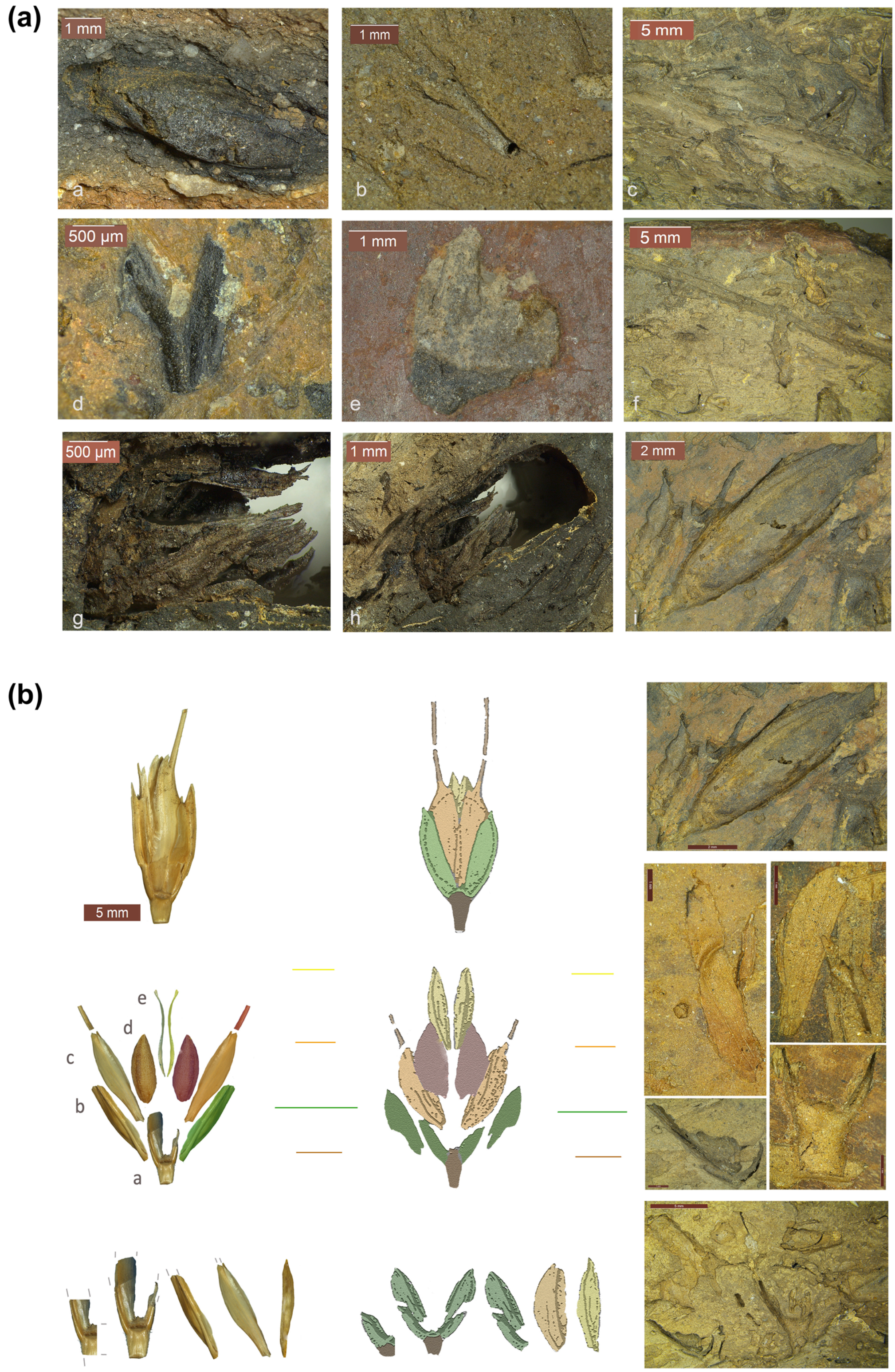

Figure 4: Variability of types of plants and plant parts (surface imprints and preserved parts in body clay). Crops and wild plants well-preserved as surface imprints (b–f and i) and in body clay (a, g, and h), (a): a cereal grain, Kovachevo (a), wild plant, Ilindentsi (b), occasional bigger straw, M. Uzunovo (c), possibly wild plant, M. Uzunovo (d), possibly wild plant, Kovachevo (e), sporadic bigger straw imprint, M. Uzunovo (f), charred spikelet, Dzhulyunitsa (g and h), spikelet imprint, M. Uzunovo (i). Crops components indicative of chaff-containing inclusions (b): components of a spikelet (einkorn, left) and chaff imprints found in studied pottery – e.g. spikelet fork, rachis, glume, palea and lemma (left). Drawing after Jacomet (2006). Note that there are no clear tool marks.

devoid of vegetal inclusions (provided there are such inclusions in the body clay below). It is more common for those not carefully smoothed/burnished surfaces to contain various size vegetal inclusions, from poor to well sorted (Figure 2a).

Interestingly, many fragments contain only microscopically detectable organics in the body clay. These often occur in low (5–10%), very low quantities (1–5%), or even as only single plant parts (reaching 2 mm in length; Figure 3a and b). In their natural state, present in such low frequencies, small sizes, and without being components of more complex clay-paste preparation techniques, they would not represent an actual functional temper (i.e. cannot sufficiently modify the properties of the clay, the main function of added temper).

At these two southwest Bulgarian sites, the fragments containing vegetal inclusions in higher concentrations (>10%) are usually 9–20 mm thick, whereas the occasional vegetal remains are commonly found in 5–10 mm thick sherds. Still, no (obvious) consistent relationship is set between the amounts of added organics and the thickness of the vessels (among other parameters). For example, although the highest percentage of added organics, 30%, is registered in a 20 mm thick vessel, even thicker fragments may contain only 7% of vegetal inclusions.

At both these sites, the fabrics containing vegetal inclusions may include bigger mineral grains naturally present in the clay. The usual 10% of such mineral inclusions, however, are not associated with any strict amount of added organics. White-painted decorated fragments, too, may contain vegetal parts, but these are only in the body clay, i.e. concentrations of vegetal inclusions are not usually present or visible on the decorated surfaces.

The shape, sorting, and size of the organic inclusions (1–10 mm long) also vary considerably – from poor (commonly) to very well sorted (rarely). In body clay, the bigger inclusions are often parallel to the walls, rather than being randomly distributed. Regarding their state and preservation, no clinkered plant parts were found at present.

According to the morphology of the preserved plant parts and imprints at the studied sites, it is mainly cereal processing by-products that have been observed. Interestingly, however, occasional non-chaff plant parts and impressions, indicative of wild plant species, possibly also including arable weeds (e.g. *Avena*), have been observed as well at both Ilindentsi and Kovachevo (Figure 4a). Perhaps occasionally entrained, a single intact charred grain (probably emmer, without noticeable distortion) was also found within the clay paste of a Kovachevo fragment that otherwise contains no functional organic temper or crop processing by-products.

4.2 High-Resolution Stereomicroscopic Observations (Thin Section and SEM Analysis)

Thin-section microscopy (a) reveals better-preserved phytoliths within the north-western Bulgarian fragments, when compared with the fewer preserved phytoliths from the southwest Bulgarian sites (Figure 3c, right), the latter usually having moderate to bad visibility (according to descriptions in Vrydaghs & Devos, 2020).

The light-tanned to brownish phytoliths are sometimes well-preserved elongate dendritic phytoliths (see also Figure 5a and b). These are evenly distributed within the fabrics of the north-western Bulgarian sites (those devoid of big mineral inclusions). The voids are usually linear – clearly visible in the special fragment from Ohoden containing very well-distributed and small (<1 mm) organic inclusions. This probably dung-derivative material also shows some irregular short ends of the plant parts. Irregular, acicular shapes or even radial orientations are also common, especially in thicker fragments containing poorly sorted vegetal inclusions (Mayor Uzunovo and Ohoden). Often, these are combined with bigger amorphous patches containing non-linear shapes of the plant parts.

At the southern sites, the voids are linear or acicular, the original plant parts being also wavy or bent, whereas the northern sites often contain channel and crack voids. The boundaries between the matrix and

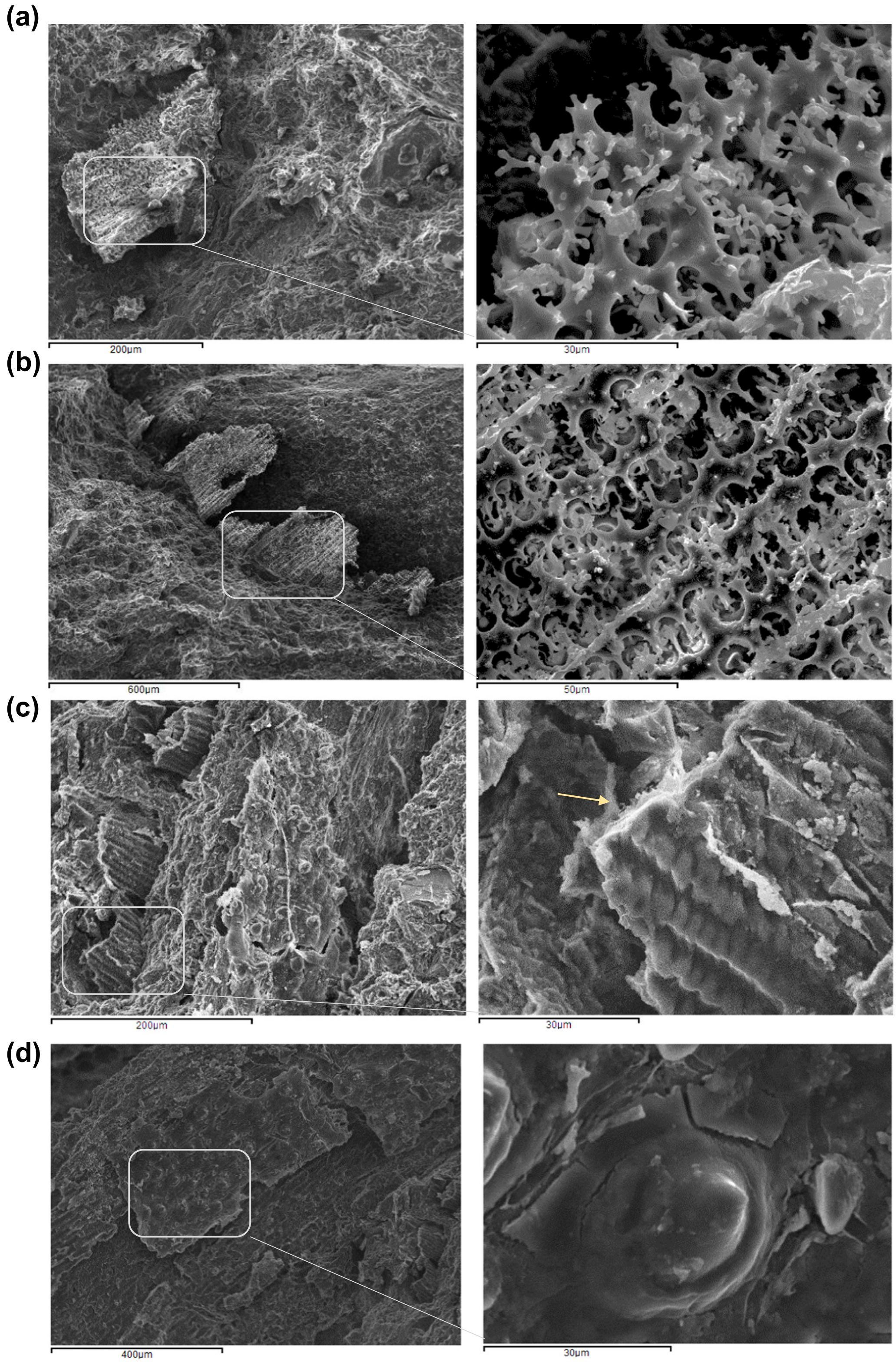

Figure 5: Phytoliths in body clays, SEM images (BEC). Vegetal micro-remains in pottery from Mayor Uzunovo. Dendritic multi-cell phytoliths (a and b); multi-cell vegetal micro-remains showing clear phytolith edges (c) and multi-cell phyotliths with papillates (d).

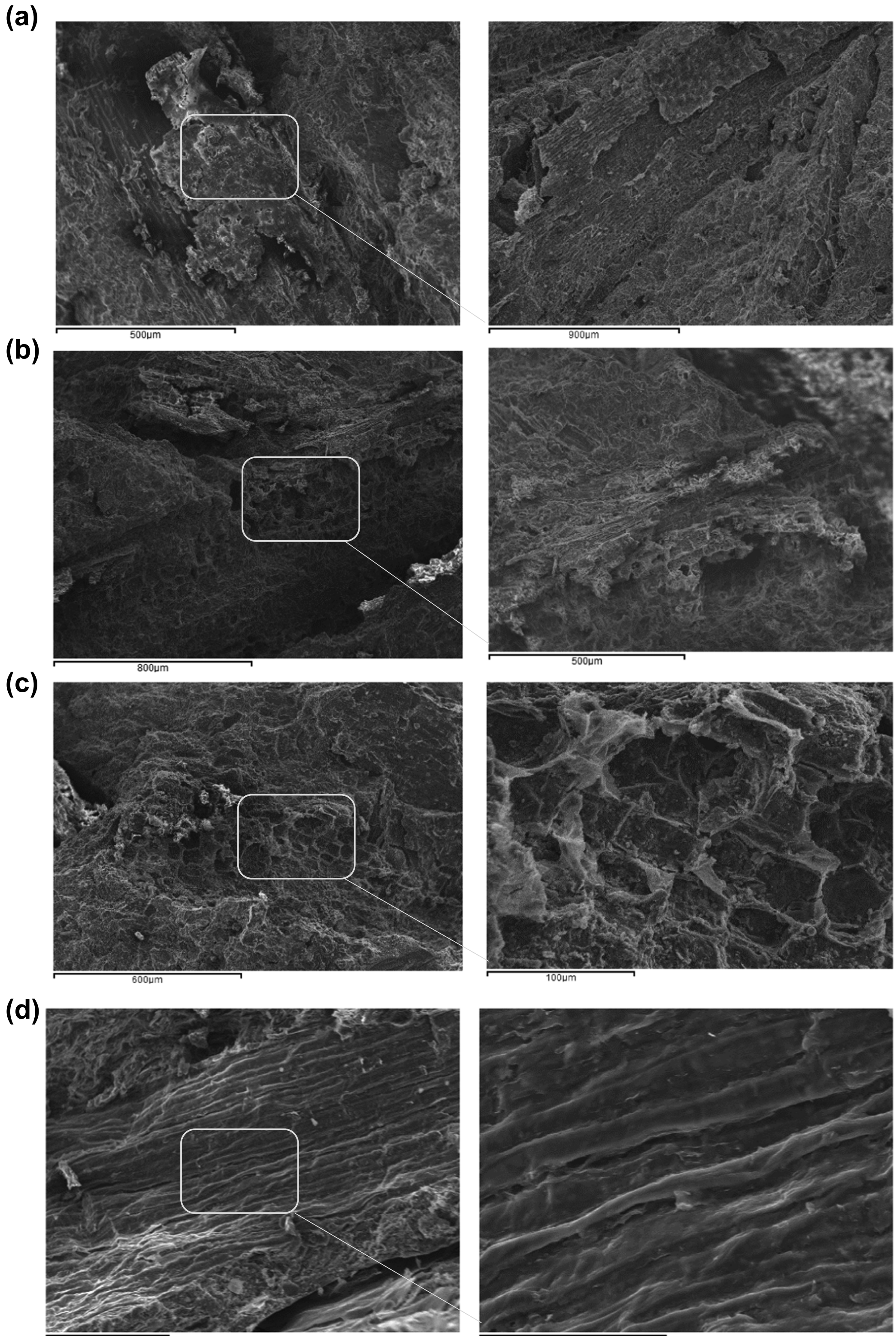

Figure 6: Phytoliths in body clays, SEM images (BEC). Vegetal micro-remains in pottery from Ohoden. Multi-cell phytoliths representing various plant tissues (a) and non-dendritic phytoliths (b–d).

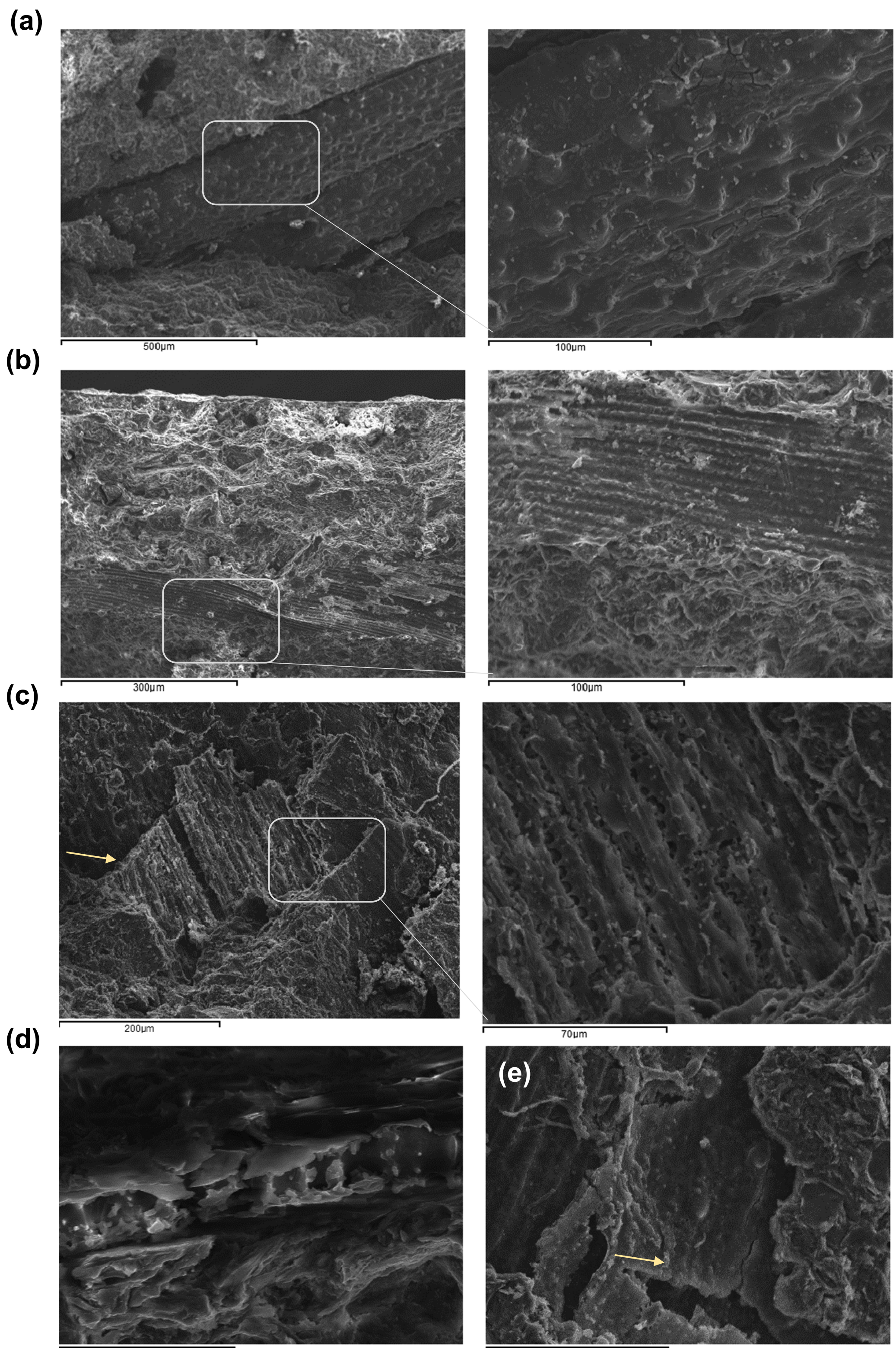

Figure 7: Phytoliths in body clays, SEM images (BEC). Papilates (a) and possibly wild plant (b) from Ohoden. Multi-cell tissues with even short edges (c). Tissue possibly indicative of aleuron components (d). Short edges of a phytolith, indicative of natural breakage (e).

the plant inclusions are usually sharp at the northern and sharp to merging at the southern sites. Although the vegetal inclusions in northern sites' samples are spread more regularly and present in higher concentrations throughout the fragments, those from the southern sites are usually present in lower percentages. Interestingly, those frequencies ranging around 5–10% may also be considered as representing regularly distributed vegetal parts.

The ratio between the clay and the mineral inclusions at the northern sites (homogenous fabrics, better-sorted inclusions and no bigger mineral grains) is higher than that at the southern sites (naturally containing mineral grains).

The SEM observations (b) on selected samples reveal connected cells present within the fragments of all studied sites – more abundant, consistent, and intact at the northern and usually moderately preserved at the southern sites. All sites (Figures 5–7) commonly have the sheet elements with articulated epidermal elongate cell and papillate phytoliths from inflorescence tissue, as well as dendritic phytoliths from inflorescence tissue (see Ball et al., 2009).

Multi-cell and anatomically connected phytoliths (see Portillo, Llergo, Ferrer, & Albert, 2017; Shillito, 2011) are very common (Figure 5a and b), sometimes revealing consecutive layers of various tissues (Figure 6a and b). Prevailing are the elongated dendritic cells – anatomically connected, but often distorted at the southern sites. Well-preserved phytoliths frequently include areas with a higher concentration of papillate without epidermal appendages such as acute bulbosus/hairs (microhairs or prickles), which can also be found in the central zones of glumes, paleas, and lemmas in *Triticum* and *Hordeum* species (Ball et al., 2009) (Figures 5d, 6a, and 7a). Small depressions or pits near the edges of the papillate, typical of *H. vulgare* and *T. aestivum* have not been registered (see Hayward & Parry, 1980; Moskal del Hoyo et al., 2017; Rosen, 1992; Tubb, Hodson, & Hodson, 1993). Transverse cells, potentially associated with the aleurone layer and the endosperm (bran; Heiss et al., 2020), were also occasionally present (Figure 7d), whereas single trichome (hair) base phytoliths and stomata were not detected yet. The cell structures and the phytolith assemblages are indicative of the inflorescence bract components of cereal plants, probably mostly glume wheat and very occasionally, phytoliths with different morphologies (potential wild plants, Figure 7b).

5 Discussion: Detecting Variability, Exploring Intentionality

By characterising the plant remains preserved in the clay used for pottery production at four different Early Neolithic Bulgarian sites, this study explores whether the presence within the clay fabrics of vegetal inclusions, usually broadly described as plant temper, refers to practical technological aspects reflecting intentional decision-making, it represents cultural factor embodied in social behaviour, results from combinations of these or associates with some other reasoning.

5.1 Variable Frequencies of Vegetal Inclusions and Possible Factors of Occurrence

In terms of plant parts used in pottery production, considerable variability has been registered between and within the studied sites. Despite the limited excavated area within the settlements, and the small number of fragments that shape the initial study collection, a wide spectrum of types and frequencies of vegetal inclusions have been observed within the clay pastes, especially in higher altitude areas. Although the northern sites show more consistent frequencies and higher concentrations of vegetal parts (mostly various crop-processing by-products) intentionally added to the clay fabrics, the organics registered at the southern sites fall within a wide range – between 0 and 40% of plant parts inclusions (Figure 8).

Various approaches towards clay paste preparation for Early Neolithic pottery production were thus practiced. These resulted in the observed lack of added temper (missing vegetal parts); the presence

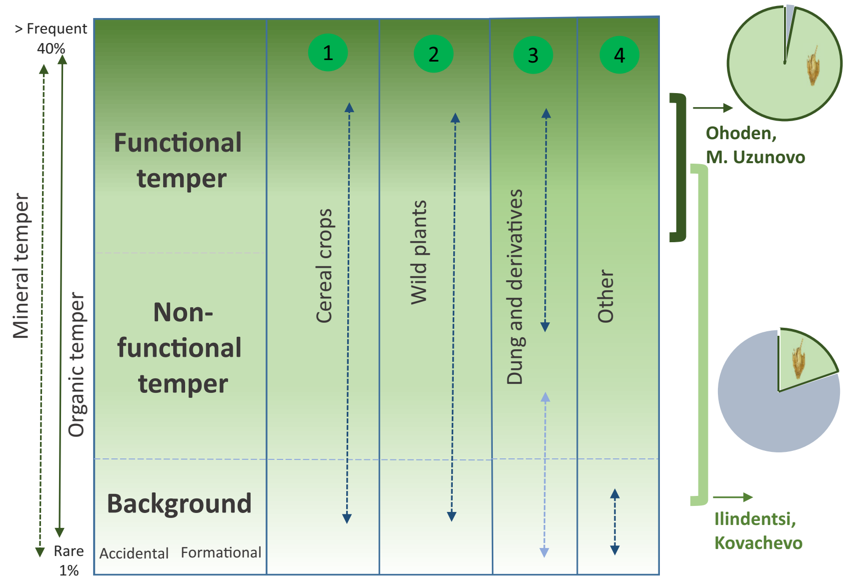

Figure 8: Vegetal inclusions in body clays from the studied sites, indicative of variable frequencies and degrees of intentionality. These fall within a wide range of formational inclusions, background noise and actual functional temper.

of occasional inclusions (background noise, single grains, etc.); and the addition of actual functional temper (mostly chaff-based inclusions, and possibly even dung-derivative plant remains), noting that the "southern" common recipes are not usually based on chaff-tempered clays.

The low frequencies of plant inclusions (insufficient to modify the original clay properties as in natural state) observed at the southern sites may have resulted from various factors – e.g. intentional use of refined dung-derivative materials, natural occurrence of plant parts in pottery production spaces or within natural raw-materials sources, etc.

These could also refer to plant parts unintentionally entrained on the surface or within the body clay, which have been introduced during various stages of clay preparation and manufacture of vessels. Possible scenarios thus include pottery production locations (either *intra* or *extra murum* areas); tools, devices, and materials used for preparation of clay pastes and shaping of vessels; and to a lesser extent – firing constructions and fuels, including wood, dry grass, dung, charcoal, and ash (see Gabasio, Evin, Arnal, & Andrieux, 1986; Johnson et al., 1988); to name few options. Given that the vessels are usually well dried before firing, the latter would mainly affect their surface appearance, rather than introducing vegetal matter in body clay, as seen in the core of the fragments.

Leaving aside potential intentional post-firing treatments by the application of vegetal matter (which does not usually leave morphologically clear separate plant imprints on the surfaces), the vegetal parts entrained by chance within the pastes do not specifically associate with technical decisions made by the potters during the initial stages of the operational chain – especially when preparing clays and modifying properties of the fabrics. As certain inclusions may rather reflect occasional circumstances, external sources, and chance factors (here, post-depositional environments of ready products are not seen as major factors), consideration of both body clay and surfaces is necessary.

Although pottery vessels devoid of actual vegetal temper may sometimes contain occasional plant parts entrained on the surface, or even within body clay (e.g. arriving from work spaces/pottery production areas and other external conditions), the opposite is also possible. For example, pots having clay bodies that contain sufficient amounts of organics (actual temper) may sometimes show surfaces devoid of any plant parts (e.g. Ilindentsi). The latter is indicative of the extra technical step taken towards shaping and surface treatment, still at the pre-firing stage, by adding an inclusion-free top clay layer. Due to final shaping effects and surface treatment approaches, plant parts (imprints) found in variable frequencies on the outer surface of the vessels may thus not necessarily perfectly correspond to those in body clays.

Bearing in mind such biases, body clays could better indicate clay preparation recipes associated with the construction and the shaping of vessels that involve the addition of actual organic temper. In essence, whereas surface plant part imprints could also reflect side factors (see above), those inclusions within the core/body clay usually point more directly to the main clay paste preparation recipes that involve tempering, and less often to construction techniques, shaping tools, etc. Specifics of pottery production and various factors of occurrence of the plant parts – either intentionally or occasionally present – thus show how various zones in both horizontal (clay body core, inner and outer surface) and vertical plan (base, middle, and top part of the vessels) may sometimes reflect different scenarios of occurrence of plant inclusions, possibly associated with procurement strategies, production locations, technological steps and technical approaches, additional surface treatments, usage, etc.

5.2 Intentionality and Temper Types

As mentioned earlier, the percentage of vessels with body clays containing actual organic temper is usually very low at the south-western sites, and often only occasional vegetal inclusions are present in the pastes. In contrast, the commonly observed consistent amounts of plant parts within clay fabrics at the north-western sites are clearly indicative of intentionally added vegetal matter.

At Mayor Uzunovo (1), the studied plant inclusions within the body clays are always present in consistent and sufficient quantities, within both thin- and thick-walled fragments. Since finer, white-painted sherds had not been found, it is unknown whether distinctive recipes were used specifically for such decorated wares.

The situation is similar at Ohoden (2), where no decorated/painted wares were sampled either. Importantly, some of the observed irregular edges of the plant remains (Figure 6c and e) are probably irrelevant to activities such as cutting plants using a tool, and there are no traces of grinding the plant material either (see Section 3), thus rather pointing to natural breakage, at least in some of the cases. A major question awaiting a definitive answer is whether dung or dung-derivative materials were actually used.

Considering the bigger-size and better-preserved plant parts, it is not highly probable that these plant parts were actually digested, as clear and obvious traces of maceration (Quinn, 2013) have not been identified (nor visible traces of exposure to digestive fluids of the Kovachevo seed). Importantly, conclusions based only on the size of the plant parts may be subjective, as smaller-size plant parts could also be indicative of mechanical decomposing resulting from consecutive agricultural procedures and stages, aiming to separate grains from by-products (coarse to very fine chaff) (Hillman, 1984a, 1984b; discussion in Dzhanfezova, 2020).

If dung or dung-derivative materials were actually added, the specific features of the examined plant inclusions (morphology, size, consistency, distribution, preservation, etc.) are not, at present, considered typical for the use of ovicaprine dung temper – at least not in fresh, unmodified natural state. Given that mastication processes of sheep are more intensive, compared with that of cattle (Anderson & Ertug-Yaras, 1998), it is notable that the studied bigger plant parts (mainly crops by-products) are actually very well preserved. Cattle dung and its derivatives, on the other hand, could have also served as a component successfully modifying the properties of the original raw materials; however, characteristic spherulites unequivocally pointing to the use of dung have not been identified yet either.

Still, one pottery fragment contains very well-sorted and regularly spread, extremely small and fine vegetal inclusions (<1 mm) with similar linear shapes, some of which also showing somewhat uneven short edges embedded in lower-fired, reduction spots within the fragment. This combination of specific features neither exists in nature (raw-materials) nor reflects any type of grazing animals' dung in natural state. It could be associated with intentionally added dung-derivative temper materials. Although further analysis is required, specific dung processing practices, resulting in producing a (liquid) component devoid of bigger inclusions, and eventually mixed with the clay paste (see below), may refer to the peculiar features of this Ohoden fragment.

Given that the vegetal inclusions were intentionally added at the studied north-west Bulgarian sites, the local raw materials (clays) should also be considered. There, characteristic are the weathered loessic soils with increased clay content – representing fine plastic materials with good forming properties, adequate for successful production of ceramic vessels, even without required addition of temper. However, taking into account clay properties such as "yield value, water tolerance, binding power and workability" (Worrall, 1982, p. 63), temper could have contributed to reduction (Rice, 1987; Velde & Druc, 1999, p. 140) of the clay pastes potentially having higher plasticity. Whether these fabrics were too plastic, thus requiring the addition of materials for better control of the shrinkage, to strengthen the shape during construction, or to extend durability, amongst the rest of the options, will be explored further in details elsewhere.

At the studied south-western sites, Ilindentsi (3) and Kovachevo (4), the plant parts found in body clays often occur also as single inclusions or in very low quantities (1–5%). As mentioned earlier, in natural state, such amounts would not be indicative of intentionality, i.e. the addition of functional temper according to specific technical requirements. Importantly, although the vegetal inclusions found within body clays usually convey information about certain clay-preparation technological choices, these may also be naturally present within the raw materials in frequencies varying between 1 and 17% in secondary clays (Worrall, 1968, p. 33) or even reaching 20% in quarried clays and clays from muds (Gabasio et al., 1986, pp. 712–713).

There, the variable frequencies of vegetal inclusions within body clays thus most probably reflect the whole range between occasionally entrained parts and consistent actual temper. Currently, there is no proved relationship between the end members of this spectrum, the thickness of the vessels, or the presence of decoration. If, however, certain practices involving the use of specific plant or dung-derivative materials, in either dry or liquid state, are to be considered (see Vasilieva & Salugina, 1997), the plant remains would indeed be preserved in lower, hardly detectable quantities. This option will be explored further elsewhere, especially bearing in mind that some of the single plant inclusions refer to crops.

With this regard, although the potential use of liquid plant-based materials or organic solutions (not necessarily only dung-derivative) could be suggested for certain fragments from other sites (Dzhulyunitsa, see Dzhanfezova, 2020, and here Figure 3c, middle), the mineral grain-rich clays available nearby Ilindentsi and Kovachevo differ considerably from the north Bulgarian ones. Furthermore, the southern fabrics are better oxidised, which often obscures detection of preserved plant parts within the clays. Given that the clay raw materials near the southern sites naturally contain mineral inclusions, thus making the fabrics suitable for pottery production, it is intriguing why organic temper would be added at all (with the reminder that this "recipe" is not the common technological approach in the region).

With regard to the decorated wares at Ilindentsi and Kovachevo, in some cases, already tempered clays could have been used for making both plain, coarser vessels, as well as painted wares (provided that there were no taboos or specific requirements). This would not affect the finer visual appearance of the white-on-red painted vessels, as usually an additional thin red-background layer is present on their surfaces. As it underlines the white paint, the organic-tempered clay bodies remain hidden by the finer red surface, which should also be considered along with the social implications associated with this practice.

5.3 Wider Implications

To answer the main questions, on the basis of the observed Early Neolithic sites, chaff is present, but sometimes wild plants (including arable weeds) are also registered. These are found as imprints on the surfaces, as well as in body clays. The latter reflects more directly the procurement strategies and technological approaches, rather than only pottery production locations and random circumstances.

As regards the systematically and intentionally added vegetal inclusions (actual functional temper) – this, at present, is the usual case at the northern sites. There, crop-processing by-products were added to the clay paste in sufficient/considerable quantities, whereas being found at other sites in amounts and frequencies, that (if added in natural state) would not have affected the properties of the original clays.

Despite the fact that there were natural resources of potential plant temper – aquatic zones and standing water (containing rushes and reeds), and open areas with variable types of wild grasses (including steppe species) – it seems at present that mostly used were the crops processing by-products. Wild plants were not specifically targeted and those present in the body clays are mostly occasionally entrained or associated with the cereal crops harvested near the Neolithic settlements.

Not disregarding other possible interpretations, including symbolism, chaff might have also been preferred because of its availability – as stored within the settlement. At least at some sites, the grain processing (removal of by-products) was done within the area of the settlement (see Section 3), thus accumulating amounts of both coarser and finer chaff. Furthermore, the practice of adding vegetal parts during household and building activities (architectural and cultural traditions) might have also played a role in shaping these pottery-making recipes.

Seasonality of pottery production, *sensu stricto*, is thus not necessarily strictly correspondent to harvesting regimes. Provided that chaff was stored for various purposes within the settlements, such vegetal inclusions could have been used whenever needed. Similarly, dung and dung-derivatives, when used fresh in pottery production, could be a higher probability seasonality marker. However, drying and storing dung, as known elsewhere (e.g. arid treeless zones, Anderson & Ertug-Yaras, 1998), sets certain limitations and also introduces further complexity (complex taphonomy resulting from storing and combining various dung cakes, possibly similar to potential mixing of stored chaff).

Despite the examples of potential use of animal faeces derivatives (see earlier), smaller-size vegetal inclusions found within clay fabrics may not necessarily always signal dung. Decreased sizes and better sorting (finer plant parts) may also refer to advanced steps of grain processing (from threshing towards weaving and sieving). Here, the small vegetal inclusions do not necessarily result from cutting, either, as presently clear signs of cut edges of the vegetal remains were not identified by low-resolution microscopy. The observations on thin-section samples are currently inconclusive, and irregularities observable using SEM point rather to natural breakages – the edges being morphologically correspond to those resulting from simple breaking of plant parts, rather than reflecting regular intentional cuts (Figure 7c and e). Such high magnifications, however, require specifically developed study parameters (cf. Valamoti, 2013), for more detailed clear-cut observations.

As per other possible vegetal inclusions (e.g. at Dzhulyunitsa), the spots, patches, and voids within the core body clay filled in by organic materials may reflect, at least in some cases, moist conditions. Bearing in mind the wavy and bent shapes of the organics, these could also refer to such state of the added plants or that of the clay fabric. Importantly, at present, none of the samples contains inclusions related to ash bedding or specifically targeted ash-containing materials.

Both studied regions include clays that would not necessarily require the addition of temper. The North Bulgarian loess-like soils provide fine clays suitable for pottery production. If temper was actually required specifically to "open" the fabrics (Whitbread, 2016), then it has been used consistently, in making vessels of various shapes and sizes. Still, the fine raw materials had good workability properties – allowing for successful making of pots by following various recipes (cf. Dzhulyunitsa, showing from zero to consistent amounts of plant inclusions, Dzhanfezova, 2020).

Similarly, despite having different, locally specific characteristics, the range of the studied south-western raw materials is also suitable for pottery production without necessarily requiring additional temper. If temper was needed indeed, no specific instruction of adding mineral, inorganic matter was followed, and the complexity behind why precisely vegetal temper was added in some of the cases is yet to be explored.

6 Conclusion

Vegetal inclusions, a hallmark of the Early Neolithic Balkan pottery production, represent a spectrum of variable features, ranging from sporadic occurrences to actual functional temper, even within the same settlement. Given the suitable properties of the locally available raw materials, the addition of organic temper most probably was not a strictly functional prerequisite caused by serious technological limitations (e.g. poor qualities of local clays).

The observed variables – such as the various possible origins, the wide range of factors of occurrence determining the presence of plant parts within the fabrics, the irregular frequencies in the clay paste – reflect a bond between specifically technological, agricultural, and environmental aspects. This more complex and dynamic picture reveals connections between a wide range of spheres – everyday lifestyle intertwined with production activities and considered within local settings.

Explored in the broader context, plant-tempered pottery has the potential to reveal the interplay between crafts and husbandry activities, technological landscapes, decision-making strategies, and subsistence patterns within site-specific environment. Detailed studies on bigger collections of fragments, implementation of holistic approaches, and cross-disciplinary procedures will shed light on strictly technological significance of the vegetal inclusions, their role as a cultural factor embodied in social behaviour, and the whole spectrum in between.

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