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Understanding diversity in Early Neolithic pottery production: a study case from Southwest Bulgaria

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ABSTRACT – *By recovering and interpreting the hidden technological variability in the first pottery at Ilindentsi-Massovets, this paper reveals the innovative adaptations to local conditions that the adoption of pottery production, as a new technology, must have involved. Seventy-one samples were analysed using low-resolution binocular microscopy and high-resolution petrographic and scanning electron microscopy. The variety established within each of the major components in pottery production at the site is interpreted in the context of the local raw materials (availability) and technological approaches (decision making), thus reaching beyond the traditional interpretative models that suggest large-scale uniformity in Early Neolithic pottery production across extensive European regions.*

KEY WORDS – *pottery technology; Southeast Europe; Early Neolithic; raw materials; tradition; innovation*

Razumevanje raznolikosti v zgodnjeneolitskem lončarstvu: študijski primer iz jugozahodne Bolgarije

IZVLEČEK – *S pridobivanjem podatkov in njihovo interpretacijo o skritih tehnoloških spremenljivkah pri prvih lončenih posodah na najdišču Ilindentsi-Massovets v članku predstavljamo inovativne prilagoditve na lokalne pogoje, ki jih je moral vključevati prehod na lončarstvo kot nove tehnologije. Analizirali smo 71 vzorcev z binokularnim mikroskopom z nizko ločljivostjo ter s petrografskim in vrstičnim mikroskopom z visoko ločljivostjo. Raznolikost, ki smo jo prepoznali pri vsaki od glavnih komponent pri izdelavi lončenine na tem najdišču, razlagamo v kontekstu lokalnih surovin (razpoložljivost) in tehnoloških pristopov (odločitve), s tem pa presežemo tradicionalne interpretativne modele, ki nakazujejo na obsežno enovitost v zgodnjeneolitskem lončarstvu na območju širše evropske regije.*

KLJUČNE BESEDE – *tehnologija lončarstva; jugovzhodna Evropa; zgodnji neolitik; surovine; tradicija; inovacija*

Introduction

While numerous studies have explored how the first pottery was made at Neolithic sites, relatively little attention has been given to the demands that the adoption of this introduced technology would have made on its new practitioners and their responses to these challenges (*cf. Ingold 2000; Michelaki* et al. *2012; 2015*). Pottery-making was a signature component of the Neolithization process in the region (see *Todorova, Vajsov 1993; Özdoğan 2009; 2016; Çilingiroğlu 2009; 2012*) and involved the transmission of a new technology adaptive to new settings. Communities would have been tasked with

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producing stylistically acceptable and functional forms for the first time by working with the raw materials present in their local landscapes. In this paper we consider the significance of fabric diversity shown by the first pottery at a key site for the transmission of pottery-making during the Neolithization of Southeast Europe. Specifically, this aims to establish whether the introduced technology advanced conservatively with an adherence to traditional production methods and materials (*i.e.* adoption), or whether innovative decisions were made as adjustments in response to local raw material constraints or other, non-technical preferences (adaptation), (*cf. Baldi, Roux 2016; Shott 1996; Bogaard* et al. *2017; Maran, Stockhammer 2017*).

The site and its pottery in the context of the Neolithization

In Southeast Europe, the Neolithic way of life started around 6700/6500 cal BC in the southern areas the Balkan Peninsula (*Reingruber* et al. *2017; Urem-Kotsou* et al. *2017*) and gradually spread north. The Struma River Valley has been considered as a major Neolithization route towards the Central Balkans, which connected the Eastern Mediterranean and the European hinterland around the end of the 7th and beginning of the 6th millennia BC (*Nikolov 1989; Lichardus-Itten 1993; Todorova* et al. *2007; Chohadzhiev 2007; Krauß 2011; Krauß* et al. *2017*).

Two Early Neolithic sites are known in the Middle Struma River, south of the Kresna gorge (Fig. 1). The earliest, Kovachevo, dates to the end of the 7th millennium BC and had continuous development (6120–5640 cal BC), (*Demoule* et al. *1994; Lichardus-Itten* et al. *2002*). Thirty-five kilometres to the north, Ilindentsi-Massovets (6510±60 BP or 5500 cal BC) was settled some 500 years after the start of the Early Neolithic period in the Middle Struma River area at Kovachevo (Ia-Ib), placing it in the so-called developed stage of the Early Neolithic period in Bulgaria (5700/5600–5460 cal BC).

The site is located at 246–264m above sea level, on the western slopes of the Pirin mountain and 4km east of the Struma River. This open settlement covers an area of thirty decares, its cultural accumulation reaching between 0.50m in the west and 1m in the east, with a maximum of 1.80m in the dug structures and the ditched enclosure (*Grębska-Kulova* et al. *2011; Grębska-Kulow 2017.250–253; Grębska-Kulow* et al. *2018*). Situated on agricultural land, only an area of 350m^2 in the periphery of the settlement, located between the river and modern fields, has been excavated. Two chronological periods are registered: the Early Neolithic settlement Ilindentsi I developed in the western zone of the terrace, whereas the Middle Neolithic Ilindentsi II enlarged towards the east and north.

Ilindentsi-Massovets provides an excellent opportunity to test biases such as the broad compositional uniformity of the first pottery and to examine the relative influence of conformity to traditional approaches versus the introduction of innovative pathways while spreading the new technology. The studied region offers a wide range of raw materials that can potentially be used for preparation of earthenware bodies and the characteristic Early Neolithic red-and-white-surface decoration. Understanding the actual choices allows us to examine the decisions made by the first Neolithic potters at the site, and what influenced pottery transmission.

The Ilindentsi material culture reveals complete correlation with the later Early Neolithic stages established at Kovachevo – Kovachevo Ic-Id (see *Lichardus-Itten* et al. *2002*). The site is considered to have been founded by Kovachevo groups arriving in the new region at the time when the largest settlement of Kovachevo experienced the peak of its development. The new dispersal areas towards north were carefully chosen, taking into account the mineral resources (marble, flint, fluorite, *etc.*) and topographic advantages, allowing for natural connection via the Tsaparevska River Valley with the region of the Vardar River Valley. The connections with the neighbouring regions include the Vardar River Valley, Northern Greece, Upper Struma River Valley (the Galabnik group), the Starčevo culture area to the north and the Karanovo I culture to the east (*Grębska-Kulow 2017.250–255*).

The data from Ilindentsi suggest much greater complexity of the cultural processes that developed in the Early Neolithic Struma River Valley, thus questioning the models only limited to a rapid, linear and unilateral (from south to north) Neolithization process. The settlement reveals multiscalar and complex connections maintained in various directions, from west to east and also from north to south – a situation analogous to other areas of the Balkan Peninsula (*e.g., Özdoğan 2016*).

Considered in the context of the settlement's multilateral connections and the variable abundant and suitable raw materials, an examination of the technical approaches used in pottery production can potentially expose any tension between tradition and innovation. Variation in pottery fabrics can help trace and interpret the actual decision-making that took place at progressive technological stages, ranging from the body clay preparation to the final surface treatment.

The pottery

White-on-red pottery is considered a hallmark of Early Neolithic Balkan production (*e.g., Lichardus-Itten* et al. *2002; Nikolov 2002*), and dominates the decorated Ilindentsi assemblage across all archaeological contexts investigated so far (Fig. 2). Three main region-specific Early Neolithic decorative styles are present at the site: (a) the Kovachevo cultural group (Kovachevo Ic-Id); (b) the Upper Thracian valley Karanovo I style; and (c) the Abstract style, characteristic of the Upper Struma and the Vardar River Valleys and the vast area between Albania, Northern Greece, Southwest Bulgaria and the Western Rhodopes.

The Ilindentsi pottery is attributed to the syncretic *Kovachevo cultural group* style (Kovachevo Ic-Id). The latter was formed in the Sandanski-Petrich Valley – the area where the Thracian *Karanovo I style* and western Abstract style meet. Generally, the Ka-

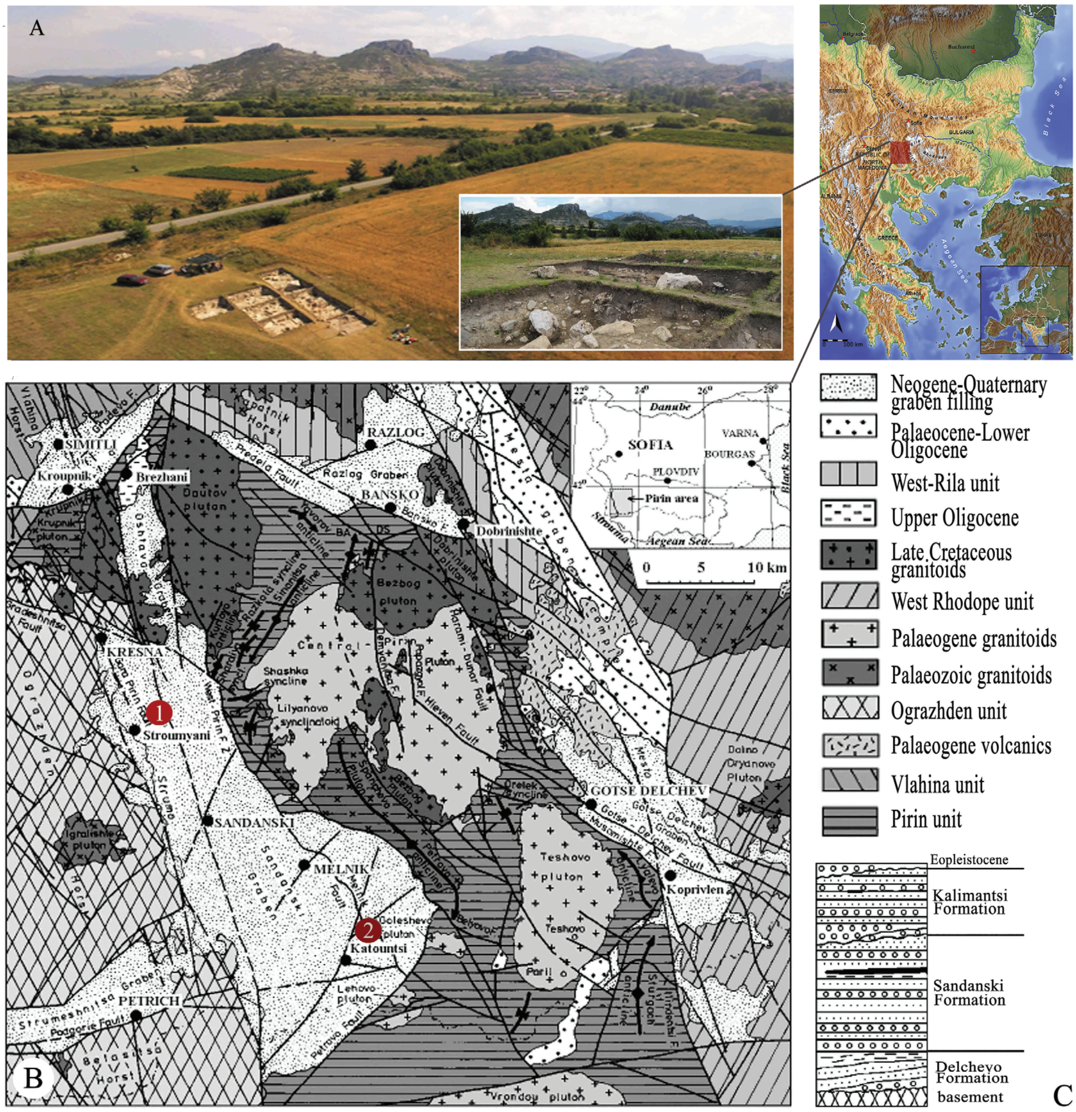

Fig. 1. Location of Ilindentsi (1) and Kovachevo (2) and immediate geology of the region.* A *excavations at Ilindentsi, Southwest Bulgaria, in the Middle Struma River Valley (looking north-eastwards). Marble white-paint raw materials outcrop in the low hills (middle distance) and as boulders on site (inset);* B *location and immediate geology of the Struma River Valley (Sandanski graben)(after* Zagorchev 2001. Fig. 22*);* C *stratigraphy of the Neogene Sandanski sedimentary infill (after* Zagorchev 2001.Fig. 26*). Map of the Balkan Peninsula by Captain Blood~commonswiki – Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=675499

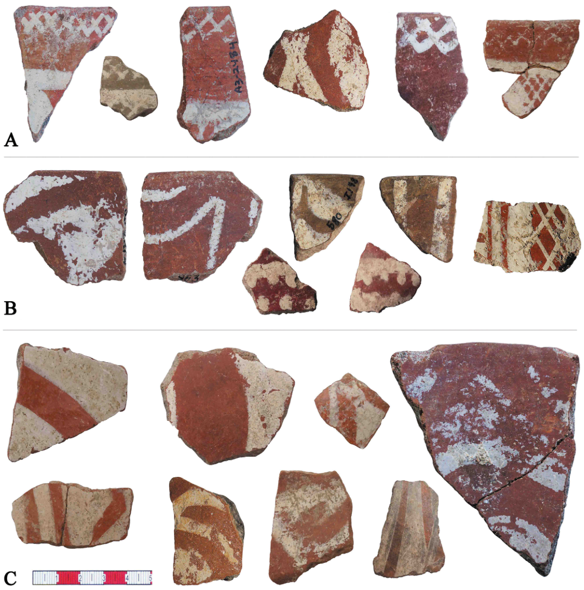

Fig. 2. Ilindentsi sherds representing the three major decorative white-on-red painted styles:* A *Karanovo I;* B *Kovachevo;* C *abstract style.

ranovo I style spreads to the east of the Struma River Valley; it is occasionally present in the Middle, and almost missing in the Upper Struma River areas. Its typical rectilinear and reticulate painted motifs cover the vessels' rims, bodies and pedestals. *The 'Abstract' style*, on the other hand, is unknown to the east, in the Upper Thracian Valley (the Karanovo I style area), and consists of curvilinear abstract and floral, often 'positive-negative' motifs, shaping compositions that cover wider areas of the bodies but are missing under the rims (*cf. Nikolov 2002; Lichardus* et al. *2002; Sanev 2009*).

This meeting of three major Early Neolithic white-painted pottery styles in the southern Middle Struma River Valley provides an opportunity to examine the degree to which the raw material used for the first pottery at a site (Ilindentsi) was influenced by existing traditions or involved innovation.

Apart from being emblematic for the period in the region, the 'white-on-red-slip' surface decoration represents the possibly longest technological chain, thus allowing for investigation of numerous technological stages and the choices of artisans. As this style of pottery spread across the region, potters at each site would have had to make three fundamental raw material selections to make a successful pot.

❶ The first requirement would have been to choose a body clay including any organic or mineral temper deemed necessary for performance or cultural purposes. Any inclusions, whether temper or not, would have had to be prevented from reaching the outer surface to avoid degrading the required red surface decoration.

❷ There is a series of choices regarding the red surface. For example, this can result from careful burnishing or from rubbing in a little ochre. Alternatively, a higher quality red surface could be achieved by applying a red clay slip, again with the option to enhance this with ochre increments or other combinations.

❸ Finally, a suitable white pigment would be needed to complete the decoration – *i.e.* the choice of white-paint material (considering its quality to be used and preserved), and how to apply it.

Table 1 illustrates how these possible choices combine to offer a variety of ways of making white-on-red pottery at any new site in the region. Even this minimalist breakdown highlights the risks of assuming that the first pots at successive Neolithic sites were always made conservatively – *i.e.* in the same way as in the earlier sites in the region or homeland. In this simple outline there are many possible ways (64, *i.e.* 4x4x4) by which body, red surface and white paint options could be combined – and the complexity would rapidly expand by considering the many other variables in the overall production sequence (temper sources, temper quantities, firing schedule, *etc.*).

Given such a wide range of choices, it seems valid to ask just what happens when pottery is transmitted into new areas and raw-material landscapes and/or into new communities? Should it simply be

Option	Body fabrics	Red surface	White paint
1	clay used unmodified	simple burnish	high whiteness
2	+ mineral temper	burnish with ochre	variable/ low whiteness
3	+ organic temper	red slip ('engobe')	unfired (+/- binder)
4	+ both tempers	red slip with ochre	fired on

Tab. 1. Possible combinations between body fabrics, red surfaces and white paints at Ilindentsi.

assumed that the first pots at the Neolithic settlements would have been made exactly the same way as in the earlier sites in the region or homeland, or would there be freedom to innovate, perhaps in response to the availability or performance of different raw materials?

This line of enquiry is justified through indications from other sites where local conditions required the first potters in the new region to innovate. For example, a pilot study of the earliest Neolithic pottery at Dzhulyunitsa in Central North Bulgaria (*Dzhanfezova* et al. *2014; 2015*) showed that the bodies were made from a type of clay (loess-derived) that potters arriving from the Anatolian heartlands (see *Mathieson* et al. *2018*) could not have been familiar with. It was the relatively high concentrations of very finely divided potassium mica in the loess that enhanced surface vitrification during firing, and allowed a simple burnished surface to appear as if having high-quality slips, regionally termed 'engobe' (see *Elenski 2006*). Furthermore, although mainly locally derived, a few white paints have mineralogy that could not have been sourced within the local Lower Danubian corridor (*Dzhanfezova* et al. *2014*). The site of Dzhulyunitsa therefore demonstrates the skilful but largely invisible adaptation to local raw materials by the potters in their visually successful re-creation of the authentic pottery style. The perhaps unexpected evidence of the occasional intra-regional movement of these early wares also reminds us that technology transfer in the Neolithic was not necessarily a unidirectional process. Located on another major Neolithization routeway, the Struma River Valley in Southwest Bulgaria, Ilindentsi provides an ideal opportunity to further test the role of innovation as pottery making advanced.

The traditional approach to studying prehistoric ceramic assemblages is to establish the production sequence, the *chaîne opératoire* (*cf. Darvill 2009*). However, this does little to take us beyond the essential mechanics of how pottery was made. In this paper we interpret raw material use as expressed through the resultant fabrics of the sites' first pottery to ask why a pot was made the way it was.

Materials and methods

Understanding the decisions involved when making pottery for the first time in a new region requires that we reconstruct the full range of choices that could have been made by the potters. Unless we have some understanding of the number of options that could have been selected, it is not possible to interpret the significance of observed fabric variation in a pottery assemblage. For example, it is obvious that a narrow range of fabrics in an area with a diverse range of raw materials can mean something very different than the same in an area of more uniform geology.

Interpreting the decision making implicit in early pottery-making begins with reconstructing the full range of choices that could have been made to provide the context within which the actual selection was made. This involves a multi-stage approach. The availability of raw materials in the area around Ilindentsi has to be modelled from existing geological maps and publications (see below), and verified by site visits and sampling. The earliest Ilindentsi pottery fabrics than have to be analysed to determine which of these possible raw materials were used and in what combinations.

Sampling and analysis

Excavations at Ilindentsi have yielded 45 669 ceramic fragments (800 569 kilograms) including 941 white-painted pottery sherds (*Grębska-Kulow* et al. *forthcoming*). Seventy-one of these were visually selected on the basis of key stylistic and technological variables, including: macro fabrics, wall thickness, surface treatment, painted decoration style and the quality of the white paint. The sampled sherds were usually too small, or represented wall fragments, thus hampering the reconstruction of the shape or dimensions of the vessels. As only the periphery of the settlement has been investigated, quantitative correlations are not considered feasible at this stage.

The surfaces and fresh breaks of the sherds (Tab. 2) were first examined under a stereoscopic microscope (Wild M400) to determine the general inclusions and matrix characteristics, the stratigraphy of the decoration, the type and quality of the white pigments. Correspondingly, 20 selected fragments were prepared as standard vertical thin sections and examined petrographically, using a Leica DM 2500P polarising microscope. These were supplemented where necessary by loose grain mounts made by dispersing detached pigment fragments in immersion oil (*Hutchison Cuff 1996*). A more detailed compositional and micro-textural analysis of the ceramic bodies, red colour treatment and white-painted decoration was performed on 21 polished epoxy resin blocks, using a Jeol 5910 scanning electron microscope with an Oxford Instruments INCA 300 energy dispersive x-ray spectrometer (SEM-EDX). Operating conditions were varied to suit the target area and task (spot analysis, backscatter imaging or X-ray mapping), with conditions for a typical spot analysis being 15vN, 2nA and a 150 seconds count time.

The raw materials geology of Ilindentsi

The site of Ilindentsi (Fig. 1a) is located on the east side of a major north-south valley corresponding to a down-faulted block (the Struma Graben) which is flanked on its east and west side by low mountain blocks of older crystalline rock (*Zagorchev 2001*), (Fig. 1b). The graben is infilled with relatively young (Neogene) terrestrial sediments that were deposited by the north-south flowing proto-Struma river and by lateral inputs of weathered material from the flanking horsts. Stratigraphically, these sediments are subdivided into three formations on the basis of their relative proportions of conglomerates, sands, silty clays and less frequent fine clays. There is significant overlap, but broadly the formations coarsen upwards to the east (*Westaway 2006*).

The composition of the Neogene sediments directly reflects the geology of the confining uplands, being the breakdown products of predominantly medium-grade regional metamorphic rocks (schists, amphibolites, calc-silicates, marble and gneisses, granites and granitoids) (*Zagorchev 2001*). The north-south horst-graben-horst structure is defined by major fault zones that give rise to local tectonisation of the parent rocks (this being represented in the Neogene sediments infilling the graben valley). Along the axis of the valley, the Struma River has deposited a thinner cover of Quaternary alluvium with slope deposits locally developed where the gradient steepens. Both lie above the Neogene formations with which they are compositionally similar, having been derived from the same parent rocks.

S#	Context ID	Method	S#	Context ID	Method
1	C5-46	OM, TS, SEM	37	C4-8	OM
2	C4-11	OM, TS	38	C5-9	OM
3	C4-7	OM, TS, SEM	39	C5-9	OM
4	C4-7	OM, SEM	40	A3-4	OM, TS
5	B5-8	OM, TS, SEM	41	B5-6	OM
6	C5-42	OM, TS, SEM	42	C5	OM
7	A5-2	OM, SEM	43	B4-13	OM
8	B4-2	OM	44	C4	OM
9	H5-2	OM	45	B4-1	OM
10	B5-18	OM, TS	46	–	OM
11	B5-12	OM	47	A5-7	OM
12	B5-12	OM	48	A5-11	OM
13	B4-11	OM, SEM	49	A5-11	OM, TS
14	A3-4	OM, SEM	50	B4-4	OM, TS
15	A5-11	OM	51	C4-1	OM
16	A5-11	OM	52	C4-7	OM
17	C5-9	OM, TS	53	A3-7	OM
18	H5-2	OM	54	A5-11	OM
19	A3-4	OM, TS	55	A5-22	OM
20	C5-9	OM	56	A5-11	OM
21	C5-15	OM, TS	57	B4-3	OM
22	A3-4	OM	58	C5-9	OM
23	B5-3	OM, TS, SEM	59	B5-22	OM
24	A5-9	OM	60	C4-3	OM, TS
25	C5-45	OM	61	B5-1	OM
26	A4-41	OM, TS, SEM	62	H5-2	OM
27	A3-15	OM	63	A5-11	OM
28	C4-5	OM	64	–	OM
29	B5-4	OM, TS, SEM	65	C4-1	OM
30	A3-4	OM, SEM	66	C4-11	OM, TS, SEM
31	C5-15	OM	67	C4-23	OM, TS, SEM
32	A3-4	OM, SEM	68	D4-16	OM, SEM
33	C4-8	OM, TS, SEM	69	C4-5	OM, TS, SEM
34	B5-6	OM, SEM	70	B5-15	OM, SEM
35	C4-3	OM	71	A5-11	OM, SEM
36	H5-9	OM			

Tab. 2. Studied fragments from Ilindentsi-Massovets.

The Ilindentsi geology thus provided three possible clay sources for exploitation by the early Ilindentsi potters. These are: (1) the Neogene alluvial and proluvial sediments that lie at shallow depths at all points in the Struma Valley and would have been readily accessible; (2) Quaternary alluvium associated with the Struma River and its small tributaries; (3) Quaternary surface sediments (colluvium) and soils.

Of these three, the Neogene sediments of the Sandanski formation are the most accessible option, as they lie directly beneath the site. Also, being represented by alternating thin beds of differing sand-silt-clay ratios (Fig. 1c) they would provide an opportunity for the potters to fine-tune the performance properties of the vessels by targeting specific beds. Almost all Neogene clayey sediments would be red-firing, as they are non-calcareous on account of their granitoid and schist-dominated parentage. It is important to note that, being predominantly colluvial in origin, these potential pottery clays do not show the morphological characteristics (overall angularity, sphericity, degree of sorting, particle size distribution) typical of alluvial sediments. This is an important consideration when it comes to deciding whether Ilindentsi pottery fabrics have been tempered or not.

Better quality red clay is also present as occasional fine beds within the Neogene Valley infill, and could be accessed as the latter was worked for bodies and red slips. The geological reports indicate that overall the Neogene sequence reddens towards its eastern border (the Kalimantsi Formation, Fig. 1c), thus the use of these better red clays may have required an additional short journey. Ochre sources would have been available along the fault zones that border the Struma Valley as hematite veins and encrustation along fault planes. Equally, any area of locally enhanced weathering of any iron mineral-bearing rock, such as the amphibolites on the west side of the Struma, or derived boulders thereof, would rot down to an iron-rich clay (saprolite) suitable for a low-grade red ochre.

A generic assumption would probably be that the white slip or paint would be limestone-based, since limestones and related lithologies (chalks and lime-rich clay or 'marl') are generally by far the easiest and most abundant sources of white pigments. However, for most of the Struma Valley the high quality (*i.e.* high whiteness) carbonate sources are the hard, crystalline marbles mainly restricted to along the western side of the mountainous Pirin horst. Ilindentsi, however, is an interesting exception, because it does have a very localized deposit of re-worked white marble at lower elevations close to the site – the Ilindentsi Formation (*Westaway 2006*). The distinctive cliffs around the modern town are resistant outcrops of a very coarse, chaotic marble-dominated conglomerate (olistotrome) that was transported from upland outcrops by landslides during the late Neogene (*Zagorchev 2001*). Both the talc-bearing marble boulders and the marble-derived matrix of these ultra-coarse conglomerates would be possible sources of white paint for the Ilindentsi potters.

Two other potential sources of non-carbonate white paint sources are also present, though in very restricted quantities. The first is the highly localized talc serpentine-magnesium amphibole assemblages associated either with calc-silicate members within the metamorphic horsts, or with the very localized greenstones (meta-ophiolite) bodies. The second, more widespread though less pure alternative source of white paint, points to the veins or segregation of mica and/or altered feldspars with the older crystalline rocks that flank the Struma graben.

When the use of these three possible body clays and three or four possible white paints is considered with the different ways white-on-red ware can be constructed (Tab. 1), it is clear that there was potentially a lot of variation for making the first pottery at Ilindentsi. As such, the possibility for on-site innovation would have been very real and a conservative approach for transmission of fixed pottery-making to this location should not be assumed as the only possible option. Decoding the Ilindentsi pottery fabrics in this local raw material context provides the opportunity to identify whether tradition or innovation prevailed, especially given the presence of several stylistic variations.

First results

The body fabrics

Petrographic analysis shows that the Ilindentsi pottery assemblage has a continuous range of mineral fabrics dominated by medium to high-grade regional metamorphic facies and granitic material (Fig. 3).

Compositionally, the fabrics are consistent with the geology of the higher ground that immediately borders the Struma River valley. The combined inclusions population and microtextures indicate that these clays are from the finer members of the Neogene sediments which are exposed at shallow depth at Ilindentsi and elsewhere. Any detailed fabric classification made on the basis of either composition of microtexture would be somewhat arbitrary since there is a complete continuum. In terms of decision making by the Neolithic potters, these Neogene sandy clays form essentially one very broad fabric group. Furthermore, the Struma River valley wide distribution of the Neogene infill means that there is no unique provenance signal that would allow us to determine precisely where the body clays were being worked from.

The only notable exception here, which does qualify as a separate fabric, is represented by a few relatively fine buff-coloured sherds that stand out from their coarser and red-firing (when oxidized) counterparts. These represent true alluvial sediments and are not associated with the modern Struma River but its Neogene predecessor (Fig. 3c). Their use signals a definite decision having been taken, since they would not develop a quality red surface on firing.

The main points arising from the body fabrics of the analysed 71 samples are:

❶ All mineral inclusions are natural. No mineral temper has been added.
❷ All fabrics are consistent with the locally available Neogene sediments.
❸ All fabrics have essentially the same inclusion types and clay type. Proportions differ as a natural continuum. Most are members of a single fabric group.
❹ Most fabrics are sandy. The inclusion *vs.* clay matrix ratio is high (estimated above 3:1).
❺ Some, including few paler, buff-coloured fabrics, have organic inclusions. Quantities vary, but are nearly always low (1 to 20%).
❻ The organic containing fabrics also have numerous mineral inclusions. In some cases, these are finer (than those in the fragments without organic inclusions) and show evidence of alluvial working. It is justified to consider them as a second though minor fabric group.
❼ A relatively wide range of clay paste inclusion *vs.* matrix ratios were clearly acceptable. This points to: (1) no attempt to be selective when digging clay; (2) no attempts to achieving a standard fabric, say for optimized performance. If the clay worked, that was sufficient.

The red surface treatment

Allowing for post-depositional modifications, four main different red surface treatments have been observed (*cf. Middleton 1987*). These are indicative of different intentions and sequences in preparing the surface and obtaining the red-colour finish (Fig. 4). The most fundamental difference pointing towards dissimilar actions of the artisans is between the actual red engobe, the main distinction being in the presence of a general compositional planar boundary.

In *Group 1*, the red surface was produced simply by the oxidized outer surface of the body: there being no difference in chemical composition between the body and the outer red surface. The composition and distribution of mineral grains in the red oxidation zone correspond to those observed immediately below the red layer (Fig. 4b).

Group 2 contains fragments with a burnished surface in which there is a slight change in chemical composition towards the outer surface, most notably a small increase in iron. This could either result from simple densification of the outer surface by the mechanical action of burnishing, or represents surface enhancement by the addition of ochre (Fig. 4f).

Group 3 sherds have a definite red slip (Fig. 4a). Unlike Group 2 there is a marked chemical difference between the body and red layer. The latter contains fewer inclusions, most probably due to simple elutiation, and shows a clear and planar boundary against the body.

Group 4 shows a red engobe, but in this case the body outer surface was worked with a tool beforehand, resulting in a slip/body interface boundary that is sharp but not planar (Fig. 4c-e). Using the same approach, the result may vary in thickness, consistency, *etc.* producing thicker and wider (Fig. 4c) or thinner and finer red layers (Fig. 4d). Thus, it may be a layer proceeded by conspicuous tooling (*i.e.* an extra step in the preparation of the surface finish) or a layer of dense body with sharp boundary which was just pressed on without the tooling.

Despite the possible group boundaries crossover, making only the end members of the category easily recognizable, this is an interesting category suggesting the use of two dif-

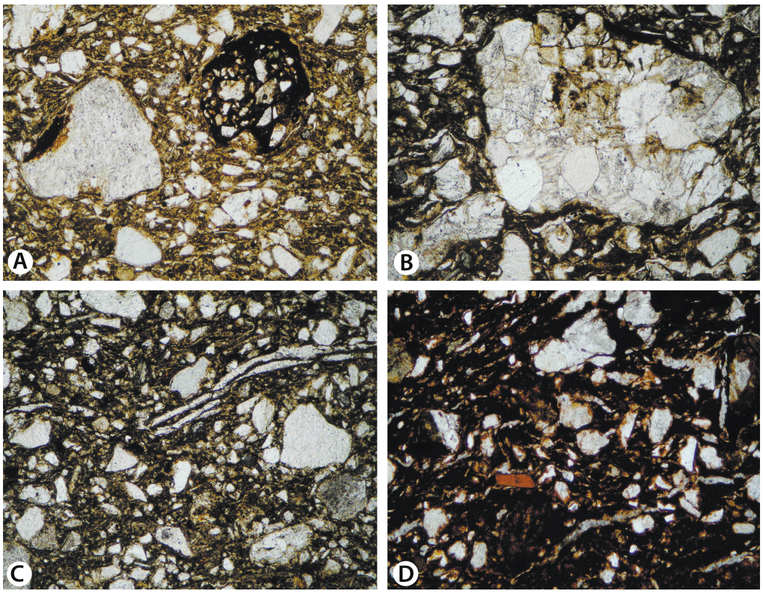

Fig. 3. Typical Ilindentsi fabrics. All inclusions are natural, no added mineral temper. Plain polarized light, magnification x50. **A** ***large potassium feldspar and clay pellet in poorly sorted angular sandy matrix;*** **B** ***detail of tectonized granite inclusion;*** **C** ***sporadic organic inclusions, low frequency suggests natural, not temper;*** **D** ***iron-rich variety possibly from fault zone (eastern margin of Sandanski graben).***

ferent raw materials – the body clay and red ochre/clay to produce the red surface, without the one being derivative of the other.

White-painted decoration

The low-power microscopy indicates that the white paint differs considerably in terms of the raw materials used, its uniformity and the method of application. The outer appearance of the paint varies between lustrous, glittery and matt, with the paint layer either strongly adhering to the red surface or being more friable and loose. The thinner white paints are more homogenous and have fewer breaks, whereas the thicker ones tend to be grainy and less continuous. Allowing for post-production degradation, these differences point to variable paint viscosities and degrees of dispersion of the white particles.

The shades of white vary between very bright or yellowish white to dark grey (*Munsell* codes 10YR 8/1 – 7.5 YR 8/2 – 10 YR 6/1). Some fragments show a clear and high-contrast white paint-red surface boundary, whereas on others the white paint edges are more gradational and blurred. Most white paints contain a few residual coarser inclusions (up to 0.5mm) that have survived processing. Immersion-oil grain mounts of the latter and thin sections of the complete sherds examined using a research-grade petrographic microscope confirmed the presence of two fundamental white paint groups at Ilindentsi: (1) marble-based and (2) mica-based.

The marble-based white paints (Group 1, n=4, Fig. 4b; Fig. 5a-c) have a fine calcareous matrix and contain a range of residual angular crystalline calcite grains (<0.5mm), with the larger grains exhibiting well-developed cleavage traces. Petrographic criteria for identifying marble are: (1) the complete absence of any sedimentary textures (clastic, biogenic, cement phase, *etc.*), which precludes the well-crystalline calcite being a coarse diagenic sparite; (2) the presence of a variable magnesium-equilibrated non-carbonate impurity assemblage of talc, magnesium chlorite and serpentine and in some cases magnesium carbonate (dolomite).

Two further subgroups are recognized. Group 1a (n=2) is characterized by relatively fine-grained evenly-distributed calcite (marble) grains with occasional large (<0.3mm) talc laths that show little or no evidence of mechanical disturbance despite their low hardness (Fig. 5a). Group 1b (n=2) is characterized by talc-serpentine grains which are both larger and more abundant than the associated marble. Here the latter are supported by a calcareous matrix with finer talc and chlorite/serpentine grains (Fig. 5b).

The Group 2 paints are mica-based (n=28, Fig. 4a,c, d,e; Fig. 5d-f). Scanning electron microscopy with energy dispersive analysis provides further details

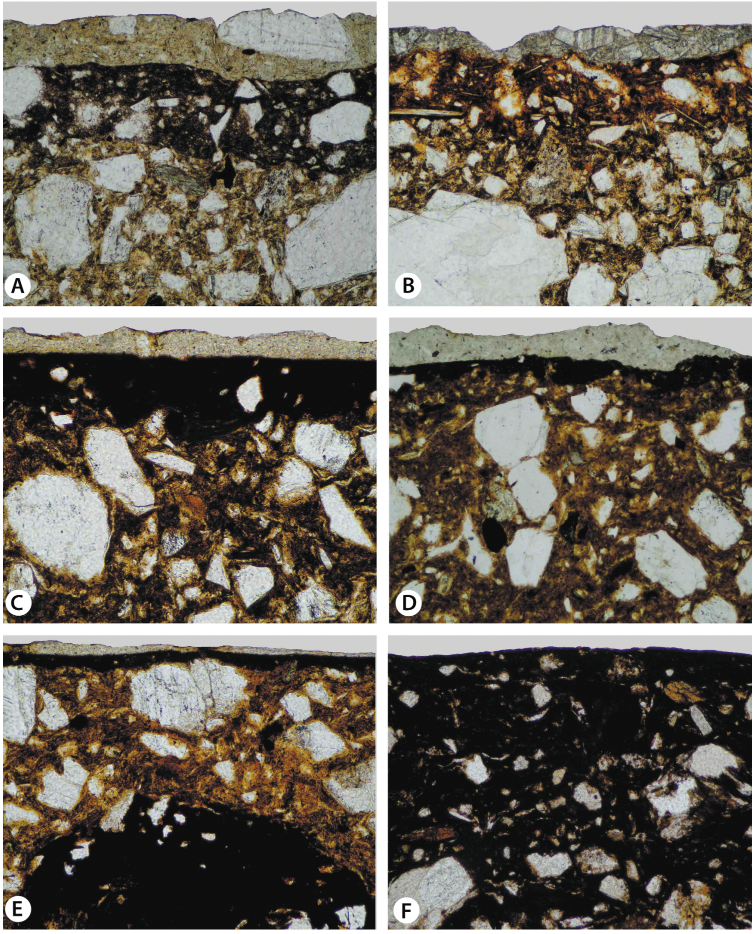

Fig. 4. Contrasting surface decorations. Plain polarized light, magnification x100. **A** *Mica-based white paint and red slip derivative of the body clay;* **B** *marble-based white paint and red surface resulting from oxidation;* **C** *mica-based white paste and thick red impressed slip with tooling;* **D** *mica-based white paste and thin red impressed slip with possible tooling;* **E** *very thin mica-based white paste and thin impressed red slip, note large iron-rich segregation in the body;* **F** *clay-rich fabric with burnished red surface, body and surface compositionally continuous.*

for the group, the detail being largely beyond the resolution of optical microscopy. These are dioctahedral potassium micas, but they consistently show significant alkali loss and concomitant hydroxylation; they are in the process of being transformed into hydromica, and occasionally to kaolinite. Two subgroups can be distinguished on the basis of their microtextures. In the larger subgroup the potassium micas show partial expansion of their layers (diagnostic fan-shaped terminations with potassium loss) as a result of weathering (hydroxylation and kaolinization) (Fig. 5e,f). A less common variety has much finer mica grains in which sub-grains are non-orientated, that is they show less evidence of a metamorphic parentage and less evidence of weathering. Carbonate is completely absent from the Group 2 white paints or is present in very minor amounts that can be considered as a background.

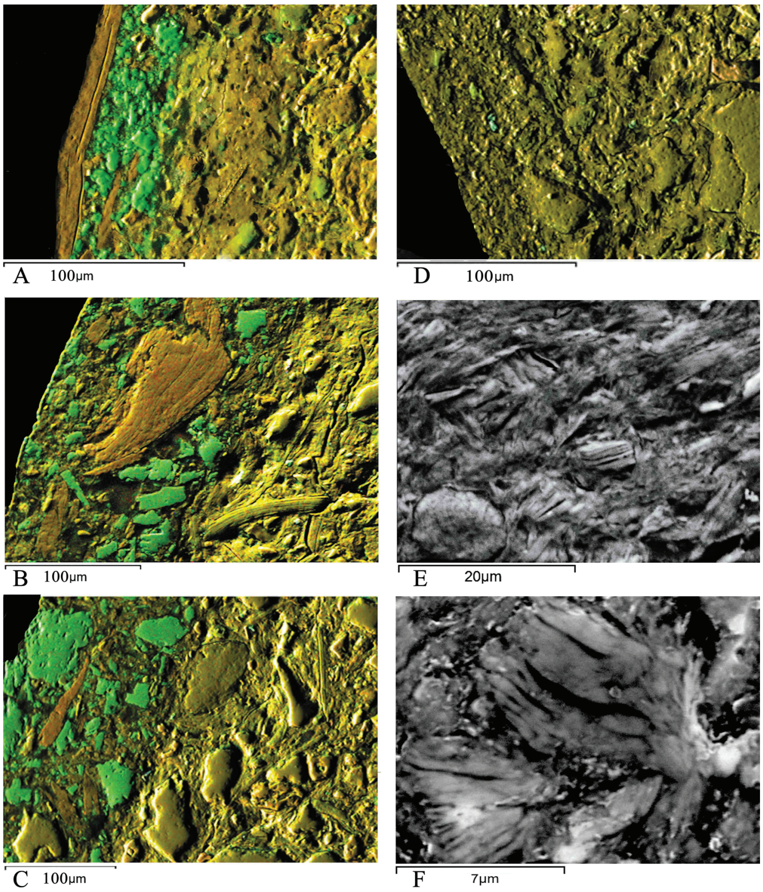

Fig. 5. Details of variable white paints (SEM backscatter microphotographs, false colour emphasizes compositional contrast). **A** ***granular marble variety (in green) showing large talc flake on surface (in orange);*** **B** ***granular marble variety (in green) with magnesium chlorite flake (in orange-brown);*** **C** ***granular marble variety, thick slip showing poorly sorted angular marble with talk and serpentine;*** **D** ***mica-based white paint, low contrast in false colour;*** **E** ***micaceous white paint showing microgranular texture;*** **F** ***potassium mica undergoing weathering, edges hydrating to give fan form with incipient kaolinite.***

According to our preliminary observations, the observed technological types do not associate with any particular ceramic categories, shapes or sizes (see also *Spataro 2006; 2011; 2019*). At present, a correspondence between the technological approaches and the specific decorative style has also not been observed.

Discussion

The aim of this paper is to understand diversity in the Ilindentsi pottery production, using the raw materials to look at the balance between adoption (received tradition) and adaptation (innovation). The body fabrics vary widely, though their differences are mainly in the proportions and shape characteristics of a common set of mineral and rock fragments that collectively point to essentially the same local source rocks. On first appearance this fabric diversity could suggest complexity of production. For example, it might suggest a period of experimentation as pots are being made at the site for the first time; or it could signal the involvement of several potters, each using a slightly different clay; or a single potter using a variety of sources. These would be valid interpretations, since three different white-on-red styles are represented at Ilindentsi, so a standard body should not be expected.

However, having demonstrated that Ilindentsi is located directly on thick deposits of Neogene sands, silts and clay that are present as relatively thin alternating beds, the body fabric variation can be more easily explained. The observed fabric variation is natural and simply reflects the same action rather than indicating complex decision making. Because of the frequently alternating sediment beds, the single act of digging a clay pit would be capable of producing the observed fabric variation, as combinations of clay beds were encountered and batched each time clay for pottery was dug.

Therefore, apart from the organic-tempered fabrics (already known in the earliest Early Neolithic Balkan sites), the potters appear to have been following a single decision – that is to collect the finer clays immediately available at the site below the surface soil and use these without further mineral tempering. As Ilindentsi is considered to have been populated by expansion of the earlier Kovachevo community, and the Kovachevo potters used essentially the same Neogene clays without special tempering (see *Lichardus-Itten* et al. *2002*), there seems to be a direct continuation of how to make pottery bodies at Ilindentsi and no temptation to change this by adding mineral temper.

The situation is slightly different with the organic inclusions. These are found in about thirty per cent of the examined 71 Ilindentsi sherds, but mostly in very small amounts (<5%), usually registered microscopically, and often represented by only a few larger plant fragments (<2 mm). When found at such low levels, these non-temper inclusions were either originally present in the near-surface clay deposits or became entrained during pottery making. However, there are some fabrics with significantly larger quantities of organic inclusions (around 30%), in which the organic material is finely divided and uniformly distributed. Representing about 10% of the studied fragments in the assemblage, these fabrics are interpreted as having been intentionally tempered with plant material. Interestingly, even these tempered fabrics also have the usual high concentration of mineral inclusions, which would suggest that the organic temper was not an entirely functional requirement, since the pots made with just the same sandy clay performed perfectly well.

Organic tempering at Ilindentsi represents a less common way of making a suitable pottery body, but it cannot be claimed this was an innovation to work around technological limitations of the local clay, since the latter already had natural sand inclusions as not to need (organic) temper. Furthermore, just as there is no correspondence between the presence of organic temper and the fineness of the natural clay, there is no correlation with the type and quality of the final surface decoration either. Although most organic tempered fragments have a plain surface, the organic tempered white-painted and very high-quality red slipped fragments show that there are no strict rules for the use of organic tempered clay for making either fine painted or unpainted coarse vessels.

The production of the red surface at the site shows wider decision making, as four different types are observed. Group 1 represents the simplest, least-effort approach that involved just a light burnishing to produce a red surface on oxidation during firing. The Group 2 surfaces are also burnished but are of a higher quality, indicating a higher investment in time to create a better burnish since the underlying body clays are essentially the same as those of Group 1, and do not naturally develop a higher polish without a greater effort. There is also a tentative suggestion in some cases that small increments of red ochre may have been rubbed into the surface, which clearly would point to greater investment of time and perhaps 'special' materials, though the evidence is still equivocal here. To produce the Group 3 red surfaces, the potters have committed to refining a red slip either from the body clay or from redder clays interbedded with the local sources. The reward is a much higher quality surface, both in colour and reflectance terms, because the slip better hides any body inclusions that might otherwise disrupt the red surface. Finally, Group 4 shows attempts to further improve the basic red slip effect. In these cases, there is clear evidence that unlike Group 3, here the body surface had been lightly tooled or scraped, presumably to produce a better adhesion between slip and body, and so a more durable finish. Whereas the Group 3 slips show a planar contact against the body, the Group 4 boundaries are irregular in the infill holes, where the scraping has pulled out inclusions from the outer surface of the body.

The variety of technical approaches for making the red surfaces at this site could be interpreted in several ways: (1) as an indication of the production of various craftsmen, each associated with different pottery traditions; (2) as a presence of 'imported' wares from other sites nearby – though the mineralogy of the body inclusions means that this would still be within the Struma River Valley; (3) as a gradually changing, very slight chronological progression – perhaps as the potters became more skilled; (4) as evidence for experimentation. Work is ongoing to resolve these possibilities.

While the exact reasons for this diversity of red surface production for Ilindentsi cannot be easily pinned down, we can conclude that several different approaches were accepted, provided these gave the desired effect. This suggests that fixed rules on how the 'red slip' should be made were not transferred to Ilindentsi as part of a pottery-making package. Innovations, or at least different ways of enhancing the locally available red-surface raw material, were acceptable and certainly, there was more experimentation with the red surfaces than with the body preparation (*cf.* the more complex body clays processing in Neolithic Greece in *Dimoula* et al. *2014; Pentedeka, Kotsakis 2014; Dimoula 2017; Urem-Kotsou* et al. *2014; 2017; Saridaki* et al. *2019*). Still, whether these variable red surfaces involved true local innovation is difficult to conclude, given the presumed high mobility of the Ilindentsi population in all directions and the active multilateral connections with other sites that also produced red-slipped wares (see *Grębska-Kulova* et al. *2017*).

The true local innovation is a more convincingly demonstrated by the white paints. Previous work on pottery from Kovachevo and Ilindentsi has identified the white-paint raw materials as 'white clay' (*Grębska-Kulova* et al. *2011.32, 36; Lichardus-Itten* et al. *2002*), though exactly what this term refers to is not clarified. According to the observations in our current study, the main white paint at Ilindentsi is based on altered mica or sericite, which is broadly equivalent to the term 'white clay' paint. We can go further by asking where this white paint would have been sourced from and what degree of processing, if any, would its use have required of the potters.

The simplest possibility would be that the white mica is made from ground rocks which are themselves mica-rich, specifically the mica schists and gneisses that form the bulk of the medium- to high-grade metamorphic uplands (*i.e.* the Pirin and Ograzhden horsts) that flank the Struma River Valley (Sandanski graben) to east and west, respectively. The understanding that such rock could be ground to produce a very serviceable white paint would translate to a readily portable decorative tradition, given the widespread availability of this parent rock near all points in the Sandanski graben, and indeed across the metamorphic terrains of Southwest Bulgaria and Northeast Greece in general. If so, the use of a mica-based white paint from ground rocks would not be an Ilindentsi innovation.

However, our SEM-EDA observations argue against a fresh rock source. A consistent feature of these white paint mica grains is their partial loss of potassium and a tendency for the interlayer spaces to increase to give fan-shaped terminations (Fig. 5e, f). Both features suggest the *in situ* weathering of primary dioctahedral mica, which, through the alkali loss, is gradually being replaced by kaolinite. The delicate fan-shaped morphologies point to a complete lack of transportation, which leads us to suggest that these white micas were worked from weathered outcrops of schist or mica-granite or, more likely, given the lack of iron-staining and the presence of incipient kaolinization, from highly leached sections of the Neogene Sandanski formation. Such conditions are found near Ilindentsi, where these loose and porous sandy sediments are exposed and deeply incised by the west-flowing tributaries of the Struma River, an example of which flows just past the site. The resulting steep gradients and low water table provide the ideal conditions for leaching the granite and schist derived micas *in situ*, involving the mechanical transport that would disrupt the delicate hydromica fans. The petrography therefore suggests that for the main white paint group the Ilindentsi potters were making selective use of these highly leached micaceous beds of the Neogene formations. This mica-based white paint technique at Ilindentsi could have been a continuation (adoption) of a Kovachevo technique, as the latter site is earlier than Ilindentsi and also lies on the same Neogene sediments.

The review of the white-paint raw material landscape around Ilindentsi suggests that the two marble-based white paints could be interpreted in several ways. They could represent the acquisition of marble and the addition of two different (but related) combinations of 'impurities'. This would imply a special journey or an extra stage in the overall *chaîne opératoire*, since the usual talc-based rocks ('greenstones') are not immediately local and have a very limited outcrop. A second possibility is that the talc-based impurities were introduced accidentally, as a by-product of crushing and grinding marble to produce a white ground. The impurity assemblage of talc, serpentine and magnesium chlorite could also be introduced by using low-grade greenstone tools to process the marble. However, the larger and very fragile talc laths were observed to show no evidence of mechanical damage (Fig. 5a). Finally, these impurities may have been present in the marble collected and processed by the potters, and the two groups simply may refer to the opportunistic use of available material, and thus that the potters were unaware of the presence of these talc-serpentine-chlorite impurities as they were primarily after crystalline (sparkly) calcite.

Detailed petrographic analysis supports the latter possibility and is an example of true local innovation. Our preliminary observations indicate that the marble-based white slips are present in the preceding site of Kovachevo, with source material being the *in situ* marble outcrops that are nearby. Being impure, this marble contains talc as a sporadically distributed impurity, and the working of such material would give the Group 1a marble-based paints – whose use at Ilindentsi is merely a continuity (adoption) of this Kovachevo tradition. As Figure 1a clearly shows, large white boulders of marble are actually found across the excavation area and would have been very convenient to use.

However, the Group 1b white paints are an Ilindentsi specialty. The levels of talc and serpentine in these paints exceed that expected, if marble boulders were simply being worked. Talc could have been added as a supplement, perhaps to increase the sparkly appearance, but this may not have been necessary. As discussed above, the marble source at Ilindentsi is not an undisturbed primary metamorphic rock but an ultra-coarse landslide deposit (the Ilindentsi Member) that forms easily accessible low cliffs (Fig. 1), consisting of fractured boulders of marble set in a powdery matrix of marble-derived sediment. The latter, which is not present at the earlier Kovachevo, is naturally talc-enriched and seems to have been targeted as a highly localized source for the Group 1b white paint raw material.

Conclusion

Conventional *chaîne opératoire* studies focus on how the first artifacts were made, but the questions that need to be asked are why they were made this way and what this implies in terms of craft transfer. The approach advocated here for Ilindentsi is based on the observed variation in pottery production compared within the raw material context, and thus the choice available to the potter, with a focus on the three major components of the white-on-red painted ware – the body, surface and white paint.

This brings us closer to the task of distinguishing the processes of technology adoption or adaptation, including any experimental phase. If pottery-making was adopted without any local innovation, we can look at the ways in which bodies, red surface and white paints were combined to point to the source of technological transfer. However, if local innovation was dominant, and traditional approaches discarded, this would argue for pottery moving involving an experimental stage. Furthermore, this also opens new avenues for consideration of the reasons for such local modifications of traditional 'recipes'.

This review shows that, from a purely raw-materials basis, the Ilindentsi artisans had a choice of various raw materials, hence the opportunity for experimentation to produce their pottery – *i.e.* they could have either adopted or adapted the received technology. The detailed study of Ilindentsi pottery, considered in the context of the individual settlement local geology, shows a wide variety of technical approaches and raw-material choices. This allows us to assess the interplay between tradition and innovation in pottery production, acknowledging that the real complexity would have even be greater. For example, we also consider the concept of 'quality' – whether this is defined by whiteness of the paint or its ability to stick. Equally, we could relate these material choices to distance, such as whether a special journey was necessary to acquire them.

Further complexity is introduced when the three different decorative styles are considered. There is no correspondence between the individual technological approaches and specific ornamental styles, and this refers to each of the three major components – body fabrics, red surfaces and white paints. No obvious correlation was established between the decorative styles and specific body types, nor with specific red-surface treatment or white-paint raw materials. Strict combinations between the various components or 'recipes' are missing, and no obvious correlation is registered between the raw materials used and the quality of the vessels (if we define this in terms of vessels' thickness or surface appearance).

In a broader archaeological context, the results correspond with the assumption that Ilindentsi is closely related to Kovachevo (the parent site), but is also widely open in all directions, despite the surrounding mountain ridges. The similarities with Kovachevo lay in the concept of shaping the settlement space (the system of ditches and the special organization of the households), the architecture, the white-painted style, and a series of technologies, including the prevailing mica-based white-paint recipe and the marble working. At the same time, various 'material culture' aspects (*Grębska-Kulow* et al. *forthcoming*) reveal that the site maintained active contacts in all directions – northern Greece to the south, the Thracian valley to the east and the Vardar River valley to the north-west. The latter, most probably, also relates to the presence of several decorative styles and a variety of technological approaches to make the Early Neolithic pottery at Ilindentsi.

The demonstrated variability of the white-on-red painted wares (traditionally considered as a technologically consistent group), and the high number of possible combinations between the three main components of the category, reveal the complexity of this early technology, characteristic for broad European areas. Exploring the tension between adoption and adaptation, which could be hidden in each of these three major components, has the potential to reveal technological transfer and inter-site relations within Early Neolithic context.

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