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Insights into the production technology of the Late Bronze Age pottery identified at Topolița (Neamț County)

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Abstract: *The aim of this paper is to identify the technological features of the Late Bronze Age ceramic assemblage discovered at Topolița (Neamț County). The archaeological site is located in the Subcarpathian area of the eastern Romania and was assigned based on the typological features of the ceramic artefacts to the Noua culture (second half of the 16th century to the 12th century BC). The dataset investigated in this study consists in 30 samples, selected to represent the stylistic and functional variability detected at the site. For assessing the various stages of the* chaîne opératoire *(raw materials selection, paste preparation, manufacturing procedures, surface finishing and firing conditions), the pottery samples were studied by means of an integrated analytical approach combining macroscopic observation with petrographical and mineralogical investigations performed by X-ray powder diffraction (XRPD). This study revealed various aspects of the pottery production and emphasized a rather conservative behaviour in terms of raw materials selection combined with a significant degree of variability in the processing and finishing sequences. Besides, the technological analysis of the ceramic assemblage discovered at Topolița in terms of* chaîne opératoire *provided qualitative data to reconstruct technological features that corresponds to networks of socially linked object-makers.*

Rezumat*: Scopul acestei lucrări este de a identifica caracteristicile tehnologice ale ansamblului ceramic din perioada târzie a Epocii Bronzului descoperit la Topolița (jud. Neamț). Situl arheologic este situat în zona subcarpatică din estul României și a fost atribuit, pe baza trăsăturilor tipologice ale artefactelor ceramice, culturii Noua (a doua jumătate a sec. XVI-sec. XII BC). Baza de date investigată în acest studiu constă în 30 de fragmente ceramice, selectate pentru a reprezenta variabilitatea stilistică și funcțională detectată în sit. Pentru identificarea diferitelor etape ale* chaîne opératoire *(selectarea materiilor prime, prepararea pastei, procedee de fabricație, finisarea suprafeței și condițiile de ardere), fragmentele ceramice au fost studiate printr-o abordare analitică integrată care combină observația macroscopică cu investigațiile petrografice și mineralogice efectuate prin difracție de raze X (XRPD). Acest studiu a reliefat diverse aspecte ale producției de ceramică și a evidențiat un comportament destul de conservator în ceea ce privește selecția materiilor prime, combinat cu un grad semnificativ de variabilitate în etapele de prelucrare și finisare. În plus, analiza tehnologică a ansamblului ceramic*

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descoperit la Topolița din perspectiva chaîne opératoire *a oferit date calitative pentru a reconstitui caracteristici tehnologice care corespund unor rețele de realizatori de obiecte între care există legături sociale.*
Keywords: *ceramic assemblage, Noua culture,* chaîne opératoire, *petrography, X-ray diffraction, networks of interaction*

Introduction

The Late Bronze Age period of eastern Romania corresponds to the development of the Noua culture (second half of the 16th century to the 12th century BC) characterized by the practice of mobile pastoralism as the core subsistence strategy, which most often yielded sparse material remains associated to various crafting activities[6]. The main cultural features corresponding to the Noua culture that covered a large area, mainly, between the North and North-Western Black Sea and Western Carpathians region, are the ash-heap settlements and the very large number of funerary contexts, especially when compared to other Late Bronze Age cultures[7]. The material repertoire (bone, metal, and ceramic artefacts) and the funerary customs are related to the Sabatinovka culture, which is spread towards northern part of the Black Sea region. Besides the settlements with so-called" ashmounds"[8], recently reinterpreted as collectively used places at the boundaries of the settlements[9], only open settlements of variable sizes are known. In the Subcarpathian area of the nowadays eastern part of Romania, there were not identified any fortified or ash-heap settlements which may be related to the subsistence pattern developed by the Noua culture[10].

More than 1000 settlements are currently known for the area between the Carpathians and the Prut, but systematic archaeological excavations investigated only less than 1%[11]. The main settlements inventory consists in ceramic artefacts and faunal remains, in addition to a diversified range of bone, antler, stone and metal tools. Metal items played a diversified role in the daily life of the Late Bronze Age communities from the eastern part of Romania, as can be inferred based on their presence in the settlements inventory, and in the hoards.

Although appear in large quantities, the pottery artefacts identified in the Noua settlements show a rather restricted typological diversity comprising jars, so-called "bag-type" vessels, two-handled jars, vessels with profiled body, bowls, small sized vessels, and two-handled cups, so-called *kantharos*[12]. Until now, archaeometric investigations of the Noua

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[6] SAVA 2002.
[7] MOTZOI-CHICIDEANU 2011, 564-599.
[8] KAISER, SAVA 2006.
[9] DIETRICH 2012; DIETRICH 2013.
[10] FLORESCU 1964; FLORESCU 1991; SAVA 1998; PETRESCU-DÎMBOVIȚA 2001.
[11] DIACONU 2014.
[12] For a recent typology of the Noua pottery see SAVA 2002.

pottery were performed on ceramics identified at Săvești (Neamț county)[13], Cumpărătura (Suceava county)[14] and Aroneanu (Iași county)[15] and were focused on identifying the type of the raw materials used for the pottery recipe, how the vessels were made or the firing temperature and atmosphere.

The primary aim of this study is to determine the *chaîne opératoire* of the Noua ware identified at Topolița by using an interdisciplinary approach. Further on, the data obtained by evaluating the various stages of the *chaîne opératoire* will be interrogated for assessing the *interaction networks* existing within the pottery production system, which offers a glimpse into the social complexity of the Late Bronze Age pastoralist communities.

Evaluating interaction networks within a site were no habitation structures were discovered, and the ceramic repertoire tends to be stylistically and technologically similar is challenging. In this study, for exploring the relationship between potters as a proxy for community interaction we base our approach on a *communities of practice* theoretical framework[16]. For determining how communities of practice acted within the pottery production chain, we focus on identifying ***high*** and ***low visibility attributes***[17] employing macroscopic observations followed by minero-petrographic investigations.

We start with the evaluation of the vessel form and colour and examine these attributes in association with paste recipe in order to detect if communities of practices acted in a highly visible way. Further, we target resource acquisition and raw materials processing, and consider them as composing the paste recipe because these attributes can by reliably estimated based on the identification of minero-petrographic groups. Besides, the results of long-established ethnoarchaeological projects prompts towards selection and processing of raw materials as important tasks highlighting complex engagement of the broader environment[18], while the minero-petrographic data allows us to estimate how the potters interacted with the landscape and with one another[19].

By emphasising the interaction networks that appears within the pottery manufacturing process based on a *chaîne opératoire* methodology, this paper uses archaeometric data to investigate the learning and cultural transmission processes that were practiced within the Late Bronze Age communities located in the present-day eastern Romania.

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[13] BENEA *et al*. 2015.

[14] MĂȚĂU 2015.

[15] BOLOHAN, DROB 2020.

[16] LAVE, WENGER 1991; WENGER 1998.

[17] CARR 1995.

[18] GOSSELAIN, LIVINGSTONE SMITH 2005; ARNOLD 2017.

[19] MONTANA 2020.

Archaeological context

The archaeological site of Topolița-*La nord-vest de sat* (Grumăzești commune, Neamț county) occupies a key-area in the Subcarpathian area of the Eastern Romania, in the north-eastern part of the Neamț County, at approximately 8 km south of Târgu Neamț City. The settlement, comprising several habitational layers, covers a part of the terrace-like interfluve formed by the Topolița River, to the south, and Valea Seacă stream, to the north.

The first material remains were identified in this area in 2003 and were attributed based on the typological similarities to the Chalcolithic and Bronze Age[20]. In 2017, with the support of the University of Erlangen-Nürnberg, a geo-physical investigation of the site was carried out and several anomalies were identified as the remains of intentionally fired house structures (Fig. 1)[21]. Thereafter, in 2019, archaeological excavations were conducted, for the first time, to verify the information provided by the geo-physical survey.

Fig. 1. Magnetic map of the Topolița-*La nord-vest de sat* archaeological site showing the site planimetry and the excavated area

The successive three archaeological excavations conducted between 2019-2021 have revealed the remains of four Chalcolithic dwellings and of several other occupational

[20] DIACONU 2007, 101-103.

[21] PREOTEASA *et al.* 2018, 237.

structures[22]. Although the site has an area of about 2.5 ha, so far only a limited surface (150 m^2) was excavated. The Chalcolithic layer (Precucuteni culture) represents the oldest and the most consistent part of the anthropic deposit, while the material remains specific to the Bronze Age (Noua culture), the Getic period (3rd-2nd centuries BC) and Late Antiquity (4th century AD – Sântana de Mureș culture) are rather sparse.

For the Late Bronze Age, no habitational structures were documented, the archaeological deposit consists mostly in pottery fragments that were found as small agglomerations, in the layer overlapping the Chalcolithic habitation. The relatively low density of the material remains specific to the Noua culture indicates that the area was probably used only for a short-term, which is not surprising for the Subcarpathian area, where most of the investigated sites have rather thin archaeological deposits.

At Topolița, along with pottery sherds, faunal remains and some bone and bronze tools were also found within the Late Bronze Age layer. The identified ceramic materials consist in approximately 130 pottery fragments, and even if the vessels were not preserved entirely, the main type of vessels used on the site can be asserted. Based on the technological features, as for other Noua sites, three main ware categories were identified: a coarse and a medium category, comprising nearly 90% of the pottery, and a fine one, consisting of approximately 10% of the sherds. Within the Noua ceramic assemblage, five main types of vessels were detected (Fig. 2): jars, so-called ”bag-type” vessel, decorated with single or notched straps (Type I), two handled jars (Type II), medium sized pots (Type III), bowls (Type IV) and two-handled cups, so-called *kantharos* (Type V). The quantitative distribution shows an increased number for the first two types of vessels, a situation similar to other Noua sites.

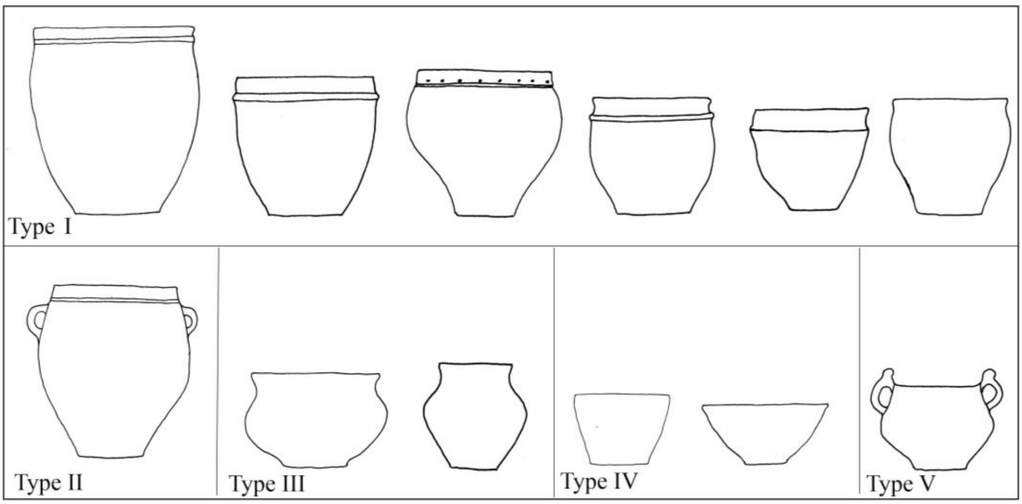

Fig. 2. The main types of Late Bronze Age vessels identified at Topolița-*La nord-vest de sat*

[22] DIACONU *et al.* 2020; DIACONU *et al.* 2021.

Locally available rock and clay resources

The archaeological site of Topolița-*La nord-vest de sat* (Grumăzești commune, Neamț county) is situated in the subsidence area of the Moldavian Platform (western edge of the Euro-Asian Platform), in the Pericarpathian/Subcarpathian Nappes which represent the molasse of the Eastern Carpathian (Fig. 3).

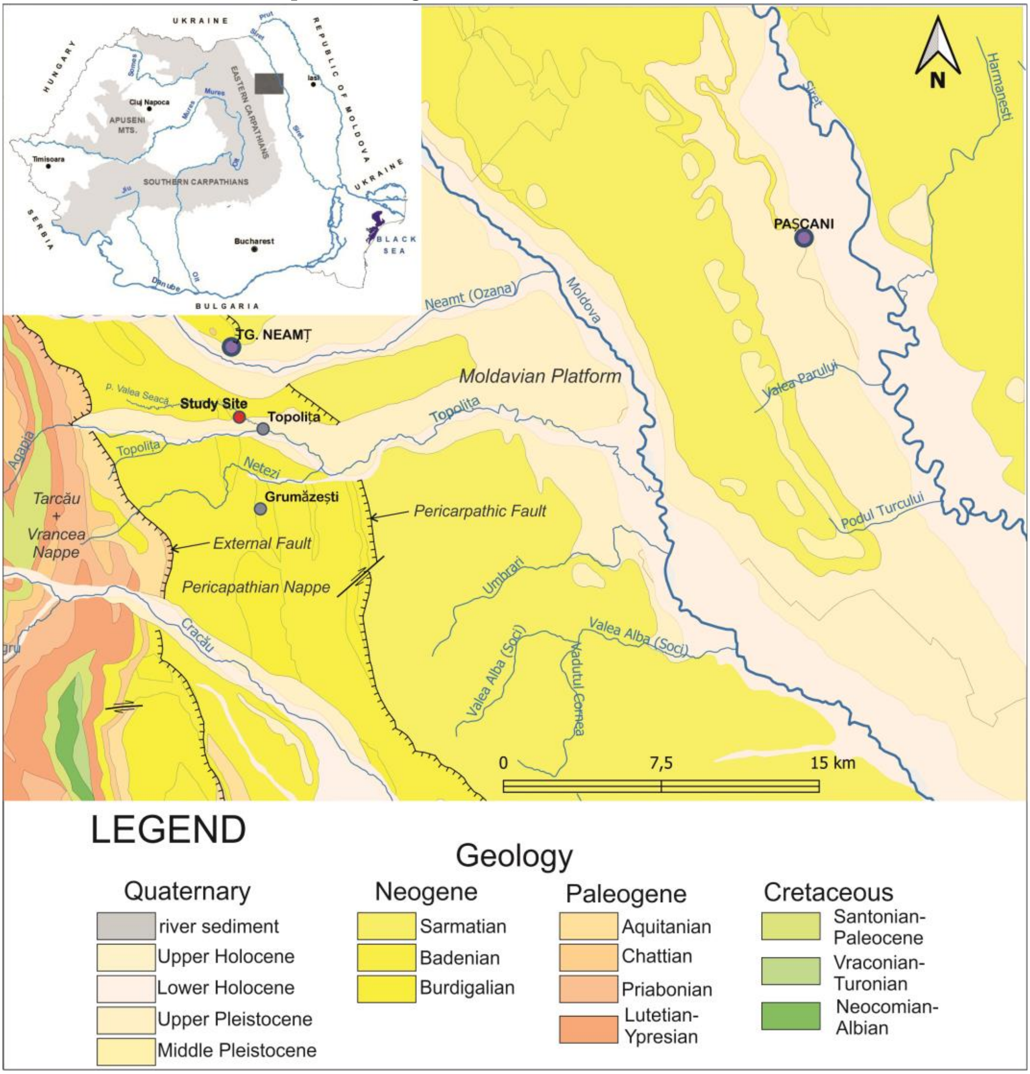

Fig. 3. Geological map of the area around Topolița- *La nord-vest de sat* (Joja *et al.* 1968)

The Eastern Carpathians are characterized by the presence of the nappes system, which are overtopped on each other (the older from the west – *Vrancea Nappe* cover the younger in the east - *Pericarpathian Nappe*) and overall, on the foredeep deposits of the Eastern European platform.

The Subcarpathian nappes, which were partially overlaid by the Carpathian thin-skinned nappes and exhumed by erosion, were formed by Oligocene and Miocene mollase type sediments interlayered by two evaporite levels[23]. The site nearby area corresponds to the Eastern Carpathian molasse nappe defined by the Middle Miocene Topolița Formation, which is the last area of sedimentation of generally weakly consolidated deposits represented by rudites, sandstones and arkoses, without obvious stratification[24]. The sedimentation process took place during the Eocene-Pleistocene period and consisted in two distinctive episodes separated by an interruption due to the Moldavian tectogenesis (Lower Sarmatian)[25].

The site is located, also, at the contact with the Quaternary sediments (Pleistocene and Holocene) represented by sands, gravels, boulders and loessoid deposits eroded by Topolița river from the formations it crosses (the external flysch from the Tarcău and Vrancea Nappes, but also from the Pericarpathian Nappe)[26].

Methodological framework for assessing interaction networks

In the recently published Topical Collection entitled ”Ceramics: Research questions and answers”[27] and aimed to guide researchers dealing with pottery analysis from excavation to study and preservation in museum collections, this ubiquitous category of material remains identified within the archaeological sites is perceived as a key-indicator for the study of cultural heritage[28]. Further on, it is proposed that research questions should contribute to the reconstruction of a "big picture" formed by significant and complex issues such as the circulation of a specific type of goods within large geographic areas and/or the diachronic evolution of production technology[29].

The main goal of this study is to identify *interaction networks* based on a combination of technological and stylistic attributes and to use these data to evaluate the production practice within the targeted Late Bronze Age site.

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[23] GRASU *et al.* 1999.

[24] IONESI 1994; GRASU *et al.* 1999.

[25] IONESI 1994.

[26] JOJA *et al.* 1968; IONESI 1994.

[27] GLIOZZO 2020a.

[28] E. Gliozzo (GLIOZZO 2020a) considers ceramics as a *technological indicator* because contributes to the advancement of pyrotechnology from the simple use of fire to the making of very complex installation for firing control and plays a significant role in cross-craft knowledge transmission based on firing control (eg. metal, glass), a *socio-economic indicator* because its use is not restricted to a specific social category, offers insights into various trade and exchange systems and is significantly influenced by the evolution of aesthetic taste and dietary practices and a *chronological indicator* providing relative dating by applying traditional archaeological methods in a comparative framework and absolute dates based on TL-OSL methods and contributing to the dating of other artefacts found in stratigraphic association.

[29] GLIOZZO 2020a.

The starting point for our approach is to consider ceramics as the result of a wide range of conscious choices the potters have made regarding the materials they select and process in various ways. Further on, we consider these choices as the result of a learning process that is acquired and passed on via social relationships. They express the potter`s enrolment in a *community of practice* that represents a group of participants acting in a similar learning environment and shared practice[30].

The *community of practice* defined as an analytical category was designed for examining shared practice in contemporary society. Initially, it was used for analysing the inter-connections between community and practice based on shared commitment, cooperative activity, and shared ways of doing[31].

Ethnoarchaeological observations revealed that "the gestures used in producing a vessel lie at the heart of the transmission process, while other types of knowledge and know-how are "easy" and already mastered when the actual learning begins"[32]. This preliminary participatory phase is not perceived as actual learning, even if the necessary skill is acquired in this stage. The information and the gestures that are passed on to the apprentices are not specific to a single person, but rather represent a *shared way of doing* practiced by a group[33]. When the group extends and become too heterogenous or too diffuse to be treated as a single community, it is considered as a *constellation of practice*[34].

In this study, for assessing the various attributes that are learned within a community of practice we rely a *chaîne opératoire* approach which allows us to investigate the multiple stages of the pottery manufacturing. In order to understand the various interactions taking place during the technological process we apply the theory of artefact design targeting various ceramic attributes[35].

Sampling and analytical protocols

The potsherds analysed in this study consists in 30 samples (Fig. 4; Table 1), which are representative for the ceramic assemblage identified at Topolița in terms of functional and stylistic features.

For documenting the various stages of the *chaîne opératoire*, the selected pottery samples were studied by means of an integrated analytical approach combining macroscopic observations with petrographical and mineralogical analysis.

[30] LAVE, WENGER 1991; WENGER 1998.

[31] LAVE, WENGER 1991, WENGER 1998.

[32] GOSSELAIN 2008, 160.

[33] GOSSELAIN 2008, 160.

[34] WENGER 1998.

[35] CARR 1995.

To obtain a preliminary insight into the firing parameters, the samples were first examined macroscopically by recording colour variability of the surface and of the cross sections within the individual sherds[36] (Table 1, Fig. 4, 5). The colour of the ceramic body was registered using Munsell Soil Colour Charts (Table 1). In addition, forming and finishing techniques were identified by examining macro-traces left by the potters[37].

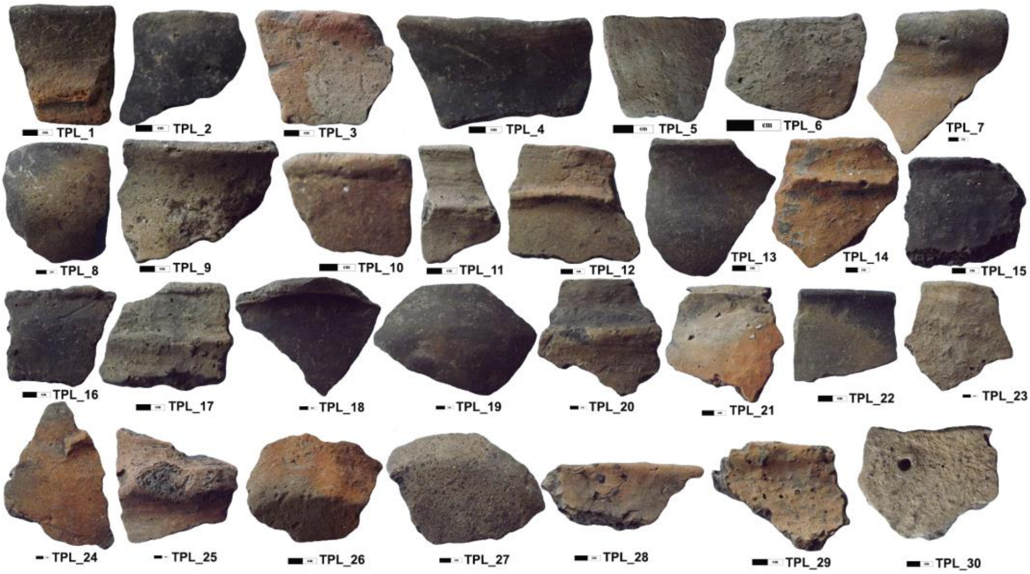

Fig. 4. Noua pottery samples from Topolița-*La nord-vest de sat* analysed in this study

The macroscopic observation of ceramic pastes is very useful for preliminary defining the technological and compositional features of the pottery identified within the site. This approach is very effective to document the various sequences of the *chaîne opératoire* such as paste preparation, firing conditions, manufacturing procedures and the surface finishing. Also, we have used macroscopic observations for approaching the firing atmosphere by analysing the chromatic transitions observed on the ceramic cross-sections.

Further, for preparing the thin sections a slice from the cross-section of each sherd was removed and pasted over a glass slide and then ground to approximately 30 μm thickness and subsequently analysed under a polarising microscope[38]. The analysis started with the identification of the clasts present within the pottery matrix and of the added temper which were then compared with the geological features of the region. The main objectives were to identify the matrix (clay) types and non-plastic inclusions, to determine the petro-fabrics and

[36] ERAMO, MANGONE 2019, 5.

[37] VUKOVIĆ 2014, 181-186; CÁMARA MANZANEDA *et al*. 2021, 23-26.

[38] For the analysis we have used the protocol advanced by WHITBREAD (2017 with his previous papers) and modified by QUINN (2013, 23-33).

to assess different sequences of the *chaîne opératoire* starting with the clay selection, processing, addition or removal of inclusions, surface finishing and firing.

Table 1: Details of the thirty samples from Topolița-*La nord-vest de sat* analysed in the present study
(The acronyms O (oxidized) and R (reduced) describe the firing atmosphere domains, E (external) placed at the end of the acronym ROE indicates asymmetric reduced-oxidized zoning on the outer surface, while M (marbled) refer to the patched reduced (MR) or oxidized structure (MO))

Sample ID	Vessel part	Typology	Texture	Ceramic body colour (in fresh cross section) (Munsell 2009)	Colour of the edges (Munsell 2009)	Outer surface colour (Munsell 2009)	Inner surface colour (Munsell 2009)	Firing atmosphere
TPL_1	rim	Type I	medium	7.5YR4/1	7.5YR4/2 7.5YR6/6	7.5YR4/2 7.5YR6/6	7.5YR4/3	ROE
TPL_2	rim	Type III	fine	5YR2.5/1	5YR2.5/1	5YR2.5/1	5YR2.5/1	R
TPL_3	rim	Type I	medium	7.5YR4/1	7.5YR6/3	7.5YR6/3 7.5YR6/6	7.5YR6/3	RO
TPL_4	rim	Type III	fine	7.5YR4/1	7.5YR6/3	7.5YR4/2	7.5YR5/2	ROE
TPL_5	rim	Type IV	medium	7.5YR5/1	7.5YR5/1	7.5YR5/1	7.5YR5/1	R
TPL_6	rim	Type IV	medium	7.5YR5/2	7.5YR6/4	7.5YR6/2 7.5YR6/4	7.5YR5/3	RO
TPL_7	rim	Type I	medium	7.5YR5/1	7.5YR6/1 7.5YR6/4	7.5YR6/4 7.5YR5/3	7.5YR5/3	ROE
TPL_8	rim	Type IV	medium	7.5YR4/1	7.5YR4/1	7.5YR4/2 7.5YR6/4	7.5YR4/1	ROE
TPL_9	rim	Type III	medium	7.5YR4/1	7.5YR6/3	7.5YR6/3	7.5YR4/1	ROE
TPL_10	rim	Type I	medium	7.5YR4/2	7.5YR5/4	7.5YR6/4	7.5YR4/2	ROE
TPL_11	rim	Type I	medium	10YR5/1	10YR5/1	10YR5/1	10YR5/1	R
TPL_12	rim	Type I	medium	7.5YR6/1 7.5YR6/4	10YR6/6	10YR6/6 10YR6/4	10YR6/4	MO
TPL_13	rim	Type V	fine	7.5YR3/1	7.5YR3/1	7.5YR3/1	7.5YR3/1	R
TPL_14	rim	Type I	medium	7.5YR6/6	7.5YR4/2 7.5YR6/8	7.5YR6/8	7.5YR6/8	MO
TPL_15	rim	Type I	coarse	7.5YR4/2	7.5YR4/2 7.5YR6/4	7.5YR4/2	7.5YR6/4	ROE
TPL_16	rim	Type I	medium	7.5YR4/1	7.5YR4/1	7.5YR4/1	7.5YR4/1	R
TPL_17	rim	Type I	medium	7.5YR4/1	7.5YR4/1	7.5YR4/1	7.5YR4/1	R
TPL_18	rim	Type III	coarse	7.5YR5/1	7.5YR5/2 7.5YR5/3	7.5YR5/2	7.5YR4/1	ROE
TPL_19	body	Type V	medium	7.5YR5/1	7.5YR5/1	7.5YR5/1	7.5YR5/1	R
TPL_20	rim	Type I	coarse	7.5YR4/1	7.5YR4/2	7.5YR4/2 7.5YR5/4	7.5YR5/4	ROE
TPL_21	rim	Type I	medium	7.5YR5/1	7.5YR5/1 7.5YR6/4	7.5YR6/4 7.5YR6/8	7.5YR6/4	ROE+MR
TPL_22	rim	Type III	fine	7.5YR5/1	7.5YR5/1	7.5YR4/1 7.5YR5/4	7.5YR4/1 7.5YR4/2	ROE
TPL_23	rim	Type IV	medium	7.5YR4/1	7.5YR6/4	7.5YR6/4	7.5YR6/4	RO
TPL_24	rim	Type I	medium	7.5YR5/1	7.5YR6/1	7.5YR6/6	7.5YR5.1	ROE
TPL_25	body	Type I	medium	7.5YR5/1	5YR6/6	5YR6/6	5YR5/1	ROE
TPL_26	base	Type I	medium	7.5YR4/1 7.5YR/5/1	7.5YR5/4 7.5YR6/6	7.5YR5/4 7.5YR6/6	7.5YR6/6	RO
TPL_27	base	Type I	medium	7.5YR4/1	7.5YR5/3	7.5YR5/3	7.5YR5/3	RO
TPL_28	rim	Type I	coarse	7.5YR5/1 7.5YR6/3	7.5YR6/4	7.5YR6/6	7.5YR5/4	RO
TPL_29	rim	Type I	coarse	7.5YR4/1	7.5YR4/1 7.5YR6/4	7.5YR6/6	7.5YR6/4	ROE
TPL_30	body	Type I	medium	7.5YR5/2	7.5YR5/3	7.5YR6/4	7.5YR6/2	ROE

The mineralogical composition was determined by X-ray Powder Diffraction (XRPD) analysis using a Shimadzu 6000 diffractometer using CuKα (λ=1.54059 Å) in reflection mode. A small quantity of the pottery samples (2 g) was powdered using an agate mortar and then side-pressed for minimizing the preferred orientation and analysed in the range of 2θ (2° - 80°) with a scan rate of 0.02° and 4 s/step. Phase compositions were automatically identified by comparison with the reference powder patterns included in the database (2006 PDF-4) created by the International Centre for Diffraction Data-Joint Committee of Powder Diffraction Standards (ICDD-JCPDS).

The mineralogical composition determined by XRPD analysis complimented the petrographic analysis by allowing the identification of the crystalline phase with small size, such as clay minerals and providing a more accurate identification of specific technological parameters such as maximum firing temperature range, redox conditions, or the firing process extension[39].

Results

a. Macroscopic analysis

The pottery sherds from Topolița-*La nord-vest de sat* included in this study consist of nineteen samples with typological features specific to Type I jars, five samples to the medium sized pots (Type III), four samples are bowls (Type IV), and two samples are from the so-called *kantharos* vessels (Type V) (Table 1, Fig. 2). Their fabric is relatively hard, fine to coarse in texture, and marked by the presence of brownish, blackish, grey, white, and more rarely shining inclusions (Fig. 4, 5; Table 1, 2). The textural features (Table 2) identified within the Type I jars fall into the medium (15 samples) to coarse (4 samples) category, the medium sized pots have mostly fine texture (3 samples), but a medium and even a coarser texture was also found. All the samples taken from bowls show a medium texture, whereas the *kantharos* samples display a fine and a medium texture. Most of the samples (11 samples) attributed to Type I have a rough feel, while three samples are harsh, and five samples are smooth at touch (Table 2). Type III samples are mostly smooth at touch (3 samples), but a rough and soapy one was, also, identified, the potsherds included in Type IV are rough at touch (3 samples), with one exception that have a smooth feel, while the *kantharos* samples included in Type V are smooth and soapy at touch (Table 2). The fracture appearance for most of the samples (18 samples) attributed to Type I is hackly, but a sample with a smooth fracture was, also, identified.

Type III present a smooth (3 samples), but also a hackly (2 samples) fracture, the samples attributed to Type IV have a hackly (3 samples) and a smooth (1 sample) fracture, while the two *kantharos* samples have a smooth fracture (Table 2).

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[39] HEIMANN 2017.

Table 2: Details of the macroscopic observations performed on the inner, outer and on the cross-sections of the ceramic samples selected from Topolița-*La nord-vest de sat*

(Abbreviations: R=rock fragments, C=clay pellets, G=grog fragments, Q=quartz)

Sample ID	Hardness	Feel				Fracture		Inclusions frecquency				Inclusions sorting			Inclusions maximum size	Inclusions average size	Inclusions rounding		Inclusions composition		
	Hard	Harsh	Rough	Smooth	Soapy	Smooth	Hackly	Rare	Sparse	Moderate	Common	Well sorted	Moderately	Poorly sorted			Sub-angular	Sub-rounded	Predominant	Very few	Rare
TPL_1	*						*		*				*		2.4	0.9	*	*	R	C	G
TPL_2	*						*	*					*		1.5	0.3	*	*	Q	R	G
TPL_3	*			*			*	*					*		2.1	0.4	*	*	G	Q	C
TPL_4	*				*	*			*				*		0.7	0.4	*	*	Q	R	G
TPL_5	*		*				*		*				*		1.8	0.9	*	*	G	R	C
TPL_6	*		*				*	*					*		2.3	0.4	*		G	R	C
TPL_7	*			*		*	*			*			*		3.5	0.7	*	*	G	R	C
TPL_8	*			*		*				*			*		2.3	1	*	*	R	G	C
TPL_9	*		*				*				*			*	2.1	0.7	*	*	R	G	C
TPL_10	*			*			*		*				*		1.9	0.6	*	*	R	G	C
TPL_11	*			*			*			*			*		2.1	0.6	*	*	G	Q	C
TPL_12	*		*				*			*			*		2.2	0.6	*	*	R	G	C
TPL_13	*			*		*		*				*			0.7	0.2		*	G	Q	R
TPL_14	*		*				*			*				*	4.1	0.6	*	*	R	G	C
TPL_15	*		*				*			*				*	3.5	1	*	*	R	G	C
TPL_16	*			*			*			*			*		3.6	0.8	*	*	R	G	C
TPL_17	*		*				*			*			*		2	0.4	*	*	R	G	C
TPL_18	*			*		*				*			*		4.8	0.5	*	*	R	G	C
TPL_19	*				*	*				*			*		2.9	0.4	*	*	R	G	C
TPL_20	*	*					*			*				*	4.5	0.8	*	*	G	C	R
TPL_21	*		*				*		*				*		3.2	0.3	*	*	R	G	C
TPL_22	*			*		*				*		*			1.5	0.6	*	*	G	R	C
TPL_23	*		*				*			*				*	4	0.5	*	*	R	G	C
TPL_24	*		*				*				*			*	2.7	0.6	*	*	R	G	C
TPL_25	*		*				*				*		*		3	1.5	*	*	G	R	C
TPL_26	*	*					*				*			*	2.4	0.6	*	*	R	G	C
TPL_27	*		*				*				*		*		1.9	0.7	*	*	R	G	C
TPL_28	*		*				*			*			*		4.8	0.5	*	*	R	G	C
TPL_29	*		*				*			*				*	4.2	1.2	*	*	R	G	C
TPL_30	*	*					*				*		*		1.6	0.6	*	*	G	C	R

The inclusions frequency is mostly moderate with moderately sorting, predominant subrounded and subangular for all types of pottery identified at Topolița. Type I contains rock fragments (13 samples) and grog (6 samples) as predominant inclusions (maximum size varying between 1.6 - 4.8 mm and an average size between 0.4 – 1.5 mm), Type III have quartz (2 samples), rock (2 samples) and grog fragments (1 sample) as predominant inclusions (maximum size varying between 0.7 – 4.8 mm and an average size between 0.3 - 0.9 mm), while grog and rock fragments are the predominant inclusions identified in Type IV (maximum size varying between 1.8 – 4 mm and an average size between 0.5 -1 mm) and Type V (maximum size varying between 0.7 – 2.9 mm and an average size between 0.2 – 0.4 mm) (Table 2).

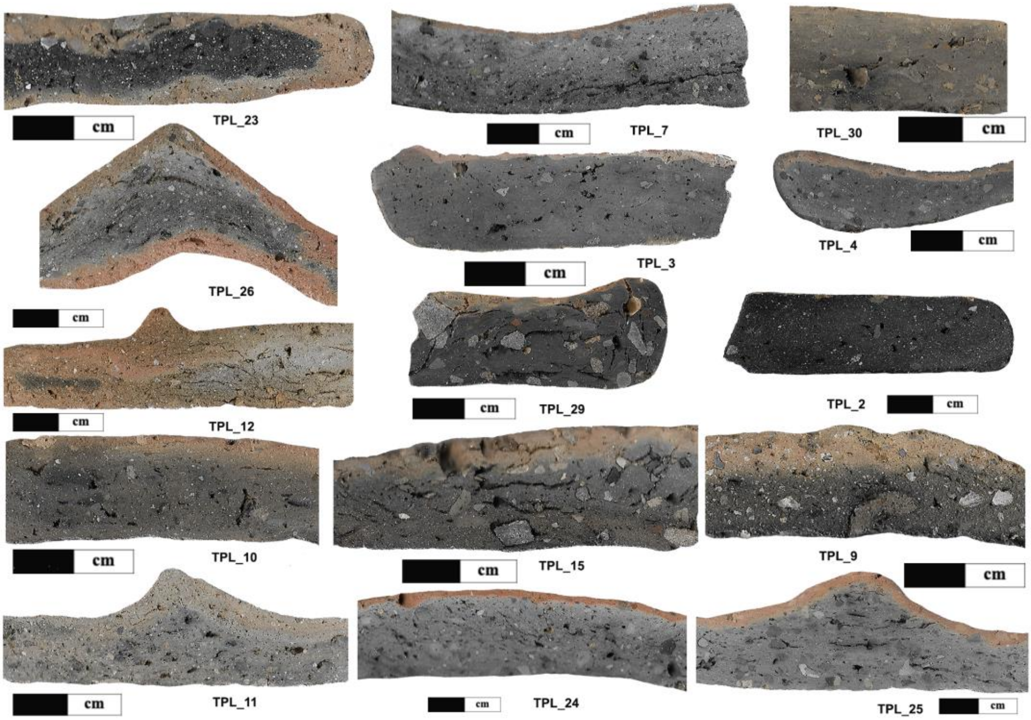

Fig. 5. Selected pottery samples from Topolița-*La nord-vest de sat* seen in cross-section

Most of the pottery fragments (Table 1, Fig. 4; 5) show non-homogeneous colour on the outer surface ranging from brown to reddish yellow hues and asymmetric zoning in cross-section extending from dark-gray and brown in the core to light brown and reddish yellow edges. Seven samples (TPL_2, 5, 11, 13, 16, 17, 19) display various shades of gray in the core and on the outer and inner surface that prompts towards a reduced atmosphere during the firing process (Table 1, Fig. 4, 5). Another group (TPL_3, 6, 23, 26, 27, 28, 30) exhibit a sandwich structure varying from dark gray and brown hues on the core to light brown and reddish yellow edges. Few samples (TPL_12, 14, 21) present patched reduced and oxidized domains ranging from gray to reddish yellow hues (Table 1, Fig. 4, 5).

The study of the macro-traces left by the potters (Table 3, Fig. 6) revealed that the primary forming technique identified within the Topolița ceramic assemblage was coiling.

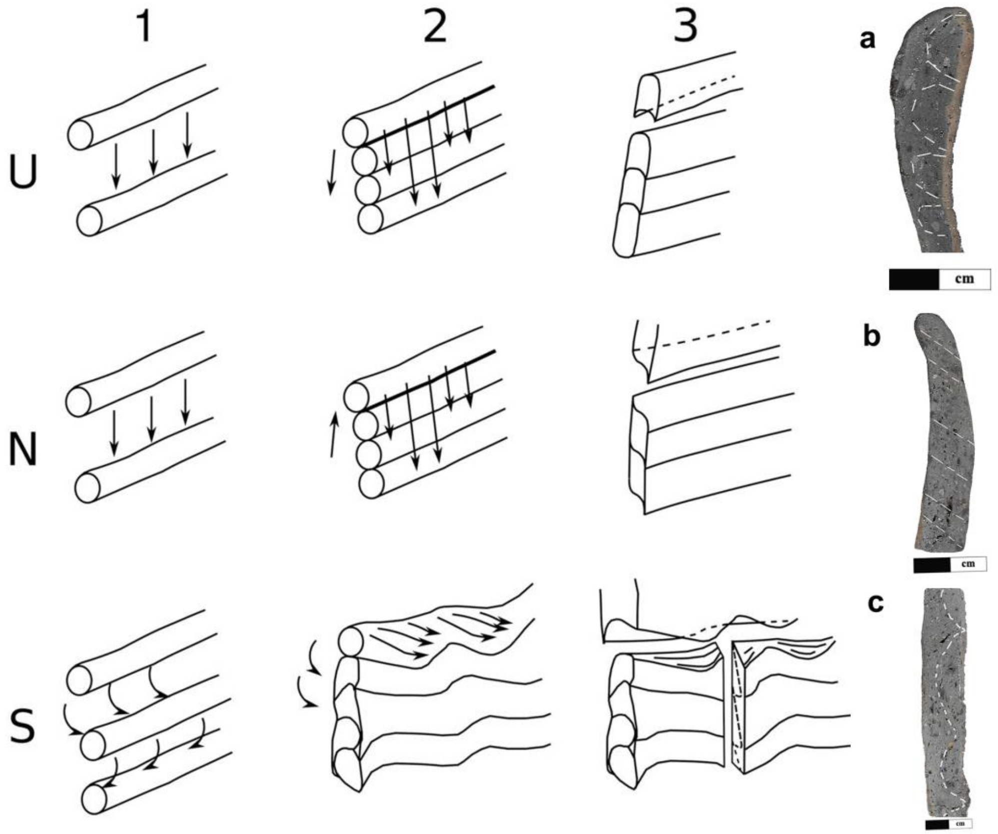

Fig. 6. Schematic representation of the forming techniques identified within the Topolița-*La nord-vest de sat* site (1-3): the position of the joining of the coils (first column), the mode of the joining (column 2) and the general characteristics of the fractures at the coils joining (third column) for the *U technique* (first row), *N technique* (second raw) and *S technique* (third raw) and of the representative pottery samples (a-TPL_4; b_TPL_22; c_TPL_5).
(The schematic representation is based on Neumannová *et al.* 2017)

Macro-traces suggestive for this technique are represented by points of connections between adjacent coils sometimes associated with fractures at the junction of coils (e.g. TPL_5). The distribution and the orientation of voids observed on the cut wall profile provided, also, strong indicators for the use of coiling technique. Individual coils were picked up by the varied quantities and texture of the coarse inclusions. The distribution of the non-plastics forms wavy, undulating, and spiral patterns in section.

The location of the coil joints can be identified based on the clusters of coarse non-plastics that create discontinuities at regular intervals in the fabric[40]. Although most of the samples were intensively dragged, smoothed, or burnished the ceramic walls still preserve the outline (however faint) of deformed coils, often marked by mm differences in wall thickness.

[40] ROSS, FOWLER 2021, 8-12.

Table 3: Details of the macro-traces related to the forming techniques determined on the outer, inner and on the cross-sections of the ceramic samples selected from Topolița-*La nord-vest de sat* (Abbreviations: v=vertical, h=horizontal, o=oblique)

Sample ID	Topographic variations/ Surface texture				Wall features				Internal structure - patterns of fracture			Internal structure orientation		Coiling			Scraping	Beating	Draging	Surface treatment		
	Burrs	Depressions	Edges	Ridges	Thickness (mm)	Vertical undulations	Horizontal undulation	Flattened areas	At coil limits	Around inclusions	Laminar fracture	Inclusions	Voids	U technique	S technique	N-technique				Slip	Smoothed	Burnished
TPL_1		*			11; 13		*					v+o+h	v+o		*						*	
TPL_2		*			8		*			*		v+o	v+h+o		*					*	*	
TPL_3	*	*			7.5		*			*		v	v+o	*			*			*		
TPL_4		*			3.5; 5		*			*		v+o	v+o	*								*
TPL_5		*			8; 9		*			*		v+o+h	v+h		*						*	
TPL_6	*	*			5.5							v+o	v+o		*					*	*	
TPL_7	*	*			6; 9		*		*	*		v+o	v+o		*					*	*	
TPL_8		*	*		6; 8		*		*	*		v+o	v+o		*						*	
TPL_9	*	*		*	7; 8					*		v	v		*						*	
TPL_10		*			8							v+o	v+o		*						*	
TPL_11	*	*			5; 10		*	*	*			v+o	v+o		*				*	*		
TPL_12	*	*			8	*		*	*			v+o	v		*				*	*	*	
TPL_13		*			4		*		*			v	v		*					*		*
TPL_14		*			8		*					v+h	v			*			*	*	*	
TPL_15	*	*			8; 11				*	*		v+h	v		*			*		*		
TPL_16		*			7; 7.5		*					v+h	v		*			*		*		
TPL_17	*	*			5; 8		*		*			v+h	v+o		*				*	*	*	
TPL_18		*			9		*		*	*	*	v+o	v+h+o		*					*		*
TPL_19		*			5; 6; 7		*		*			v+h	v+o		*			*		*		
TPL_20	*	*			9; 1.5		*		*	*		v+o	v+o		*				*	*		
TPL_21		*	*	*	12		*		*	*		v+o	v	*						*	*	
TPL_22		*			5.5				*	*		v+o	v+o			*				*	*	
TPL_23	*	*			10		*		*	*		v+o	v+h		*						*	
TPL_24	*	*	*	*	10; 11		*		*	*		v+h+o	v+o+h		*				*	*	*	
TPL_25	*	*	*	*	7; 1; 1.5		*		*	*		v+h	v+o		*				*	*	*	
TPL_26	*	*			7; 13		*		*	*		h+o+v	h+o+v		*						*	
TPL_27		*			8			*	*			v+o	v		*					*	*	
TPL_28		*			7; 9		*		*	*		v+o	v+o		*						*	
TPL_29		*	*		8; 9		*		*	*		v+h	v+h		*					*	*	
TPL_30		*			7	*			*			v+o	v		*					*	*	

The analysis of the manufacture traces of the Late Bronze Age ceramic assemblage has revealed three forming methods for building the vessels. All the analysed pottery fragments present the usual macro-traces related to coiling technique, with vertical undulations in the external and internal topography as well as horizontal fractures with U-inverted sections. The presence of small depressions in all the analysed samples (Table 3) indicates that discontinues pressure was used during the forming process[41].

The first method (25 samples) is characterized by *S-shaped configurations* in the cross-sections (Fig. 6/3; 6/c) with an alternated vertical and oblique orientation of the particles and pores or vertical-horizontal-oblique orientation. This observation indicates that the building procedure consisted in alternating oblique coils for building the vessels, the resulted wall-thickness varying between 4 and 13 mm. This method represents the most used one within the investigated ceramic assemblage, practiced for forming the rim (20 samples), but also the vessel body (3 samples) or the base (2 samples) for all pottery types.

The second method (3 samples) is represented by *U-shaped configurations* in the cross-sections (Fig. 6/1; 6/a) with coils regularly joined in the horizontal direction (wall-thickness varying between 3.5 and 12 mm). Coils assembled in the *U-technique* are superimposed one on top of the other, without any significant inner deformation during the joining[42]. One of the samples was further scraped (TPL_3), one was smoothed (TPL_21), and one was burnished what caused the vertical orientation of the aplastic inclusions near the edges (TPL_4).

The third method presents *N-shaped configurations* oriented towards the inner wall (Fig. 6/2; 6/b). This forming technique consists in superimposed coils (wall-thickness varying between 5.5 and 8 mm) as in the U-technique, but in the opposite directions from the inner to the outer surface of the wall[43]. In the investigated pottery assemblage this method was used for shaping two rims which were later deformed by smoothing (TPL_22) or dragging (TPL_14) the surface.

After being formed, the surface of the vessel was finished by smoothing (21 samples), burnishing (3 samples) or the addition of a slip (21 samples) (Table 3). Some of the samples were smoothed (13 samples) or burnished (2 samples) before adding the slip (Table 3).

Most of the selected pottery fragments were not decorated, except eight samples attributed to the so-called ”bag-type” vessel (Type I) that present a horizontal strap obtained by dragging (Fig. 4).

b. Petrographic analysis

In total, three groups and several subgroups were defined based on the nature of the inclusions, clay matrix, and textural features (Table 4). Most of the samples (17 samples) can

[41] CÁMARA MANZANEDA *et al*. 2021, 23.

[42] NEUMANNOVÁ 2017, 174-175.

[43] NEUMANNOVÁ 2017, 174; CÁMARA MANZANEDA *et al*. 2021, 27.

be assigned to fabric 1, marked by quartzite tempering. The other samples can be grouped in fabrics 2 (grog tempered, 10 samples) and 3 (chert tempered, 3 samples).

Samples attributed to fabric 1 (*quartzite tempered fabric*) form a variegated group (Table 4; Fig. 7/a), characterized by the predominance of quartzite tempering. The grain size distribution of the inclusions is bimodal, varying from poorly to moderately sorted. Apart from quartzite, grog appear in reduced quantity in some samples, quartz and muscovite are also dominant inclusions, feldspars (plagioclase) are frequent, while opaque minerals are sparse. Besides, clay pellets were identified based on their specific textural features[44]. Most of the identified clay pellets present well defined boundaries, but in some samples they have moderately (TPL_26) to poorly (TPL_4) defined boundaries and most of them show low optical density. In samples TPL_10 and TPL_24 the clay pellets also contain quartz fragments.

The clay matrix of fabric 1 is micaceous and ranges from orange to dark brown in XP. The heterogeneity of the matrix colour identified within most of the samples was caused by distinctive firing treatments. Only seven of the pottery samples attributed to this group are optically active, while the other samples show no optical activity (Table 4). The voids identified in the pottery samples specific to fabric 1 are mainly channels and vughs, while the planar and vesicle voids are rather sparse.

Based on the abundance and grain size distribution of the inclusions and the differences observed on the clay matrix, two sub-groups were proposed for fabric 1. Sub-group 1a (Table 4; Fig. 7/b) contains two samples (TPL_2; TPL_4) with a fine micaceous clay matrix and a low percentage of reduced size inclusions. Sub-group 1b (Table 4; Fig. 7/c) is represented by sample TPL_29 defined by very coarse inclusions embedded in a very fine humic clay matrix.

Fabric 2 is illustrated by ten samples (Table 4; Fig. 7/d) characterized by the presence of *grog* as the main tempering agent (Fig. 7/d; 8/a; 8/b). The grain size arrangement of the inclusions is bimodal ranging from heterogenous in most of the samples to moderately homogenous as identified in sample TPL_13. In addition to grog, quartz, muscovite, feldspars, opaque minerals, and medium grade metamorphic rock fragments were identified.

The matrix is also a micaceous clay, orange to dark brown, optically inactive for most of the samples, except samples TPL_22, TPL_25 and TPL_30 which exhibit birefringence. The voids detected within the samples attributed to fabric 2 are characterized as vughs and channels, but vesicle voids were also identified.

Two subgroups were advanced for fabric 2 (*grog tempered pottery)* in relation to the size and the quantity of the inclusions, and the specificities of the clay matrix. Sub-group 2a contains 5 samples (Table 4; Fig. 8/a) that show a similar clay matrix with the samples included in fabric 2 and differentiate from these due to the reduced size and quantity of the grog temper.

[44] WHITBREAD 1986.

Sample code	Aplastic inclusions					Goundmass	Secondary calcite	Microfabric
	Distribution	Sorting	Aplastic grain size distribution	Mineralogical phases	Rock fragments	Optical activity		
TPL_1	not homogenous	Bimodal	granules (r), very coarse sand (+), coarse sand (++), fine sand (+++), very fine sand (++)	Qz (+++), Ms (++), Fsp (++), Opq(r)	medium grade metamorphic rocks (++)	birefringence		1
TPL_2	not homogenous	Bimodal	very coarse sand (r), coarse sand (+), fine sand (++), very fine sand (+++)	Qz (+++), Ms (+++), Pl (+), Fsp (+), Opq (r)	medium grade metamorphic rocks (++)	birefringence		1a
TPL_3	not homogenous	Bimodal	granules (r), very coarse sand (+), coarse sand (++), fine sand (++), very fine sand (+++)	Qz (++), Ms (++), Fsp (+), Opq (+)	quartz-feldspathic rocks (+)	inactive		2
TPL_4	not homogenous	Bimodal	coarse sand (+), medium sand (++), fine sand (++), very fine sand (+++)	Qz (++), Ms (++), Fsp (+), Opq (+)	medium grade metamorphic rocks (++)	birefringence		1a
TPL_5	not homogenous	Bimodal	very coarse sand (+), coarse sand (+++), fine sand (++), very fine sand (++)	Qz (+++), Ms (++), Fsp (+), Opq (r)	medium grade metamorphic rocks (r)	inactive		2a
TPL_6	not homogenous	Bimodal	granules (r), very coarse sand (+), medium sand (+++), fine sand (+++), very fine sand (++)	Qz (+++), Ms (+), Fsp (+)	medium grade metamorphic rocks (++)	inactive		2a
TPL_7	not homogenous	Bimodal	granules (r), coarse sand (+++), fine sand (++), very fine sand (+)	Qz (+++), Ms (++), Fsp (+)	medium grade metamorphic rocks (+)	inactive		2a
TPL_8	not homogenous	Bimodal	granules (r), very coarse sand (+), coarse sand (+++), fine sand (++), very fine sand (+)	Qz (+++), Ms (++), Fsp (+)	medium grade metamorphic rocks (++)	inactive		1
TPL_9	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+++), fine sand (++), very fine sand (+)	Qz (+++), Ms (++), Fsp (+)	medium grade metamorphic rocks (++)	inactive		1
TPL_10	not homogenous	Bimodal	very coarse sand (r), coarse sand (+++), fine sand (++), very fine sand (+)	Qz (++), Ms (++), Fsp (++), Opq (+)	medium grade metamorphic rocks (+)	inactive	(r)	1
TPL_11	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+++), fine sand (+), very fine sand (+)	Qz (+++), Ms (++), Fsp (++), Pl (+), Opq (r)	medium grade metamorphic rocks (r)	inactive		2a
TPL_12	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+++), medium sand (++), fine sand (+), very fine sand (+)	Qz (+++), Ms (++), Fsp (++), Pl (++), Opq (r)	medium grade metamorphic rocks (+)	inactive		3a
TPL_13	moderately homogenous	Bimodal	coarse sand (r), medium sand (++), fine sand (+++)	Qz (+++), Ms (++), Fsp (++), Opq (r)	medium grade metamorphic rocks (r)	inactive		2b
TPL_14	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+++), medium sand (++), fine sand (+)	Qz (+++), Ms (++), Fsp (++), Opq (+)	medium grade metamorphic rocks (++)	inactive		1
TPL_15	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (++), medium sand (+++), fine sand (++), very fine sand (+)	Qz (+++), Ms (++), Pl (++), Fsp (++), Opq (r)	medium grade metamorphic rocks (++)	inactive		1
TPL_16	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (++), medium sand (+++), fine sand (+)	Qz (+++), Ms (++), Fsp (++), Opq (+)	medium grade metamorphic rocks (++)	birefringence	(r)	1
TPL17	not homogenous	Bimodal	very coarse sand (+), coarse sand (++), medium sand (+++), fine sand (+), very fine sand (++)	Qz (+++), Ms(++), Fsp (++), Opq (r)	medium grade metamorphic rocks (++)	inactive	(+)	1
TPL_18	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (++), medium sand (+++), fine sand (+)	Qz (+++), Ms (++), F s(++), Opq (+)	medium grade metamorphic rocks (++)	birefringence		1
TPL_19	not homogenous	Bimodal	granules (r), coarse sand (+), medium sand (++), fine sand (+++)	Qz (+++), Ms(++), Fsp(++), Opq (r)	medium grade metamorphic rocks (++)	inactive		1
TPL_20	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+), medium sand (++), fine sand (+++), very fine sand (+)	Qz (+++), Ms (++), Fsp(++), Opq (+)	medium grade metamorphic rocks (r)	inactive		2
TPL_21	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+), medium sand (+++), fine sand (++), very fine sand (+)	Qz (+++), Ms (++), Fsp (++), Opq (r)	medium grade metamorphic rocks (r), chert	inactive		3
TPL_22	not homogenous	Bimodal	very coarse sand (r), coarse sand (+), medium sand (+), fine sand (+++), very fine sand (+)	Qz (+++), Ms (++), Fsp (++), Opq (+)	medium grade metamorphic rocks (r)	birefringence		2b
TPL_23	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+), medium sand (+++), fine sand (++)	Qz (+++), Ms (+++), Fsp (+), Opq (r)	medium grade metamorphic rocks (++)	birefringence		1
TPL_24	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+), medium sand (+++), fine sand (++)	Qz (+++), Ms (++), Fsp (+), Opq (+)	medium grade metamorphic rocks (++)	inactive		1
TPL_25	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+), medium sand (+++), fine sand (++)	Qz (+++), Ms (++), Fsp (++), Opq (+)	medium grade metamorphic rocks (r)	birefringence		2a
TPL_26	not homogenous	Bimodal	granules (r), very coarse sand (r), coarse sand (+), medium sand (+++), fine sand (++)	Qz (+++), Ms (++), Fsp (++), Opq (r)	medium grade metamorphic rocks (+)	inactive		1
TPL_27	not homogenous	Bimodal	very coarse sand (r), coarse sand (r), medium sand (++), fine sand (+++)	Qz (+++), Ms (++), Fsp (+)	medium grade metamorphic rocks (++)	inactive		1
TPL_28	not homogenous	Bimodal	granules (r), coarse sand (+++), medium sand (++), fine sand (+)	Qz (+++), Ms (++), Fsp (++), Opq (+)	medium grade metamorphic (+), chert(+)	birefringence	(+)	3
TPL_29	homogenous	Bimodal	granules (+), very coarse sand (r), coarse sand (r), medium sand (+), fine sand (++)	Qz (++), Ms (+), Fsp (+), Opq (+)	medium grade metamorphic rocks (++)	birefringence	(++)	1b
TPL_30	not homogenous	Bimodal	very coarse sand (r), coarse sand (+), medium sand (++), fine sand (+++), very fine sand (++)	Qz (++), Ms (++), Fsp (++), Opq (+)	medium grade metamorphic rocks (r)	birefringence		2

Table 4: Description of matrix and fabric types of the pottery samples selected from Topolița-*La nord-vest de sat* analysed by polarised microscopy (Abbreviations: quantitative estimation: r=traces, +=scarse, ++=abundant, +++=very abundant; minerals: Qz=quartz, Ms=muscovite, Fsp=feldspar, Opq=opaque mineral, Pl=plagioclase) (Mineral abbreviations according to Whitney, Evans 2010)

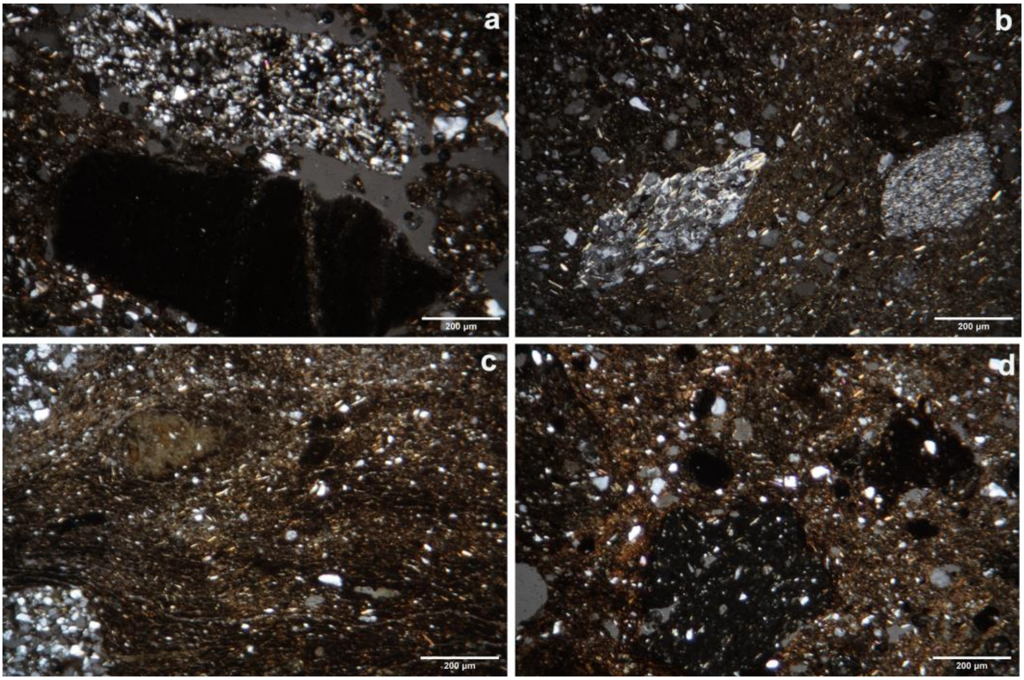

Fig. 7. Photomicrographs of ceramic thin sections of samples selected from Topolița-*La nord-vest de sat*: (a) TPL_19 (fabric 1) with coarse quartzite and grog temper in a micaceous clay matrix; (b) TPL_4 (fabric 1a) with quartzite and grog temper in a fine micaceous clay; (c) TPL_29 (fabric 1b) with quartzite and grog temper in a humic clay matrix; (d) TPL_3 (fabric 2) with abundant grog temper in a micaceous clay matrix (All images were taken with cross polarised light (XPL) at 4x)

Sub-group 2b (Table 4; Fig. 8/b) consists of two samples (TPL_13, TPL_22) separated from the samples subsumed to fabric 2 and sub-group 2a due to the matrix features which are typical to a very fine micaceous clay. Moreover, the grog temper identified in the pottery samples listed to sub-group 2b present similar quantitative distribution and type of processing as in the samples attributed to sub-group 2a.

Fabric 3 comprises three samples (Table 4) characterized by the addition of *chert* as temper (Fig. 8/c; 8/d). All the samples are defined by a heterogenous distribution of the inclusions displaying bimodal sorting. Besides chert and grog fragments, quartz, muscovite, feldspars, opaque minerals, and medium grade metamorphic rock fragments were present in various amounts. The clay used for the matrix is also a micaceous one, with a colour varying from brown with orange spots to dark brown, optically inactive in samples TPL_12 and TPL_21 and showing birefringence in sample TPL_28.

The voids identified within the three samples attributed to fabric 3 are mainly vughs, but channels were also detected. Sample TPL_12 (Fig. 8/d) distinguishes from the other two samples attributed to fabric 3 based on the reduction in size of the chert and grog temper and was attributed to sub-group 3a.

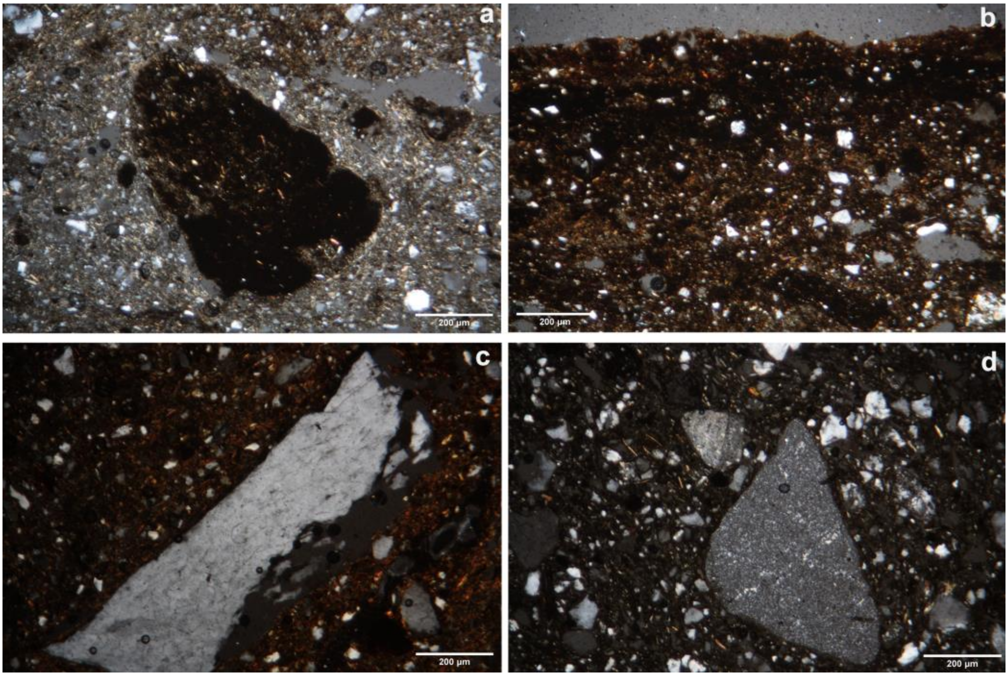

Fig. 8. Photomicrographs of ceramic thin sections of samples selected from Topolița-*La nord-vest de sat*.
(a) TPL_25 (fabric 2a) with grog temper in a micaceous clay matrix; (b) TPL_13 (fabric 2b) with fine grog temper in a very fine micaceous clay matrix; (c) TPL_21 (fabric 3) with chert temper in a micaceous clay matrix; (d) TPL_12 with fine chert temper in a micaceous clay matrix
(All images were taken with cross polarised light (XPL) at 4x)

c. XRPD analysis

XRPD investigations conducted on a selection of samples attributed to fabric 1 (Fig. 9), also, confirmed the presence of quartz and feldspars as the main mineral component, as identified based on the thin sections analysis. In sample TPL_2 the peak at approximately 10 Å d-spacing (8.845° 2θ) is common to both illite and muscovite and is referred in the literature as "illite/muscovite". Two types of feldspars were identified within sample TPL_2: albite, a member of the plagioclase group and microcline that is a potassium feldspar. Besides, the diffractogram have revealed the presence of magnetite confirming the macroscopic and petrographic observations prompting towards a reduced firing atmosphere. Sample TPL_14 displays only quartz and albite as initial minerals, and anorthite as a mineral formed due to the firing process. The diffractogram obtained for sample TPL_14 show no phases associated with the presence of iron minerals which may be linked to the duration and intensity of the firing process.

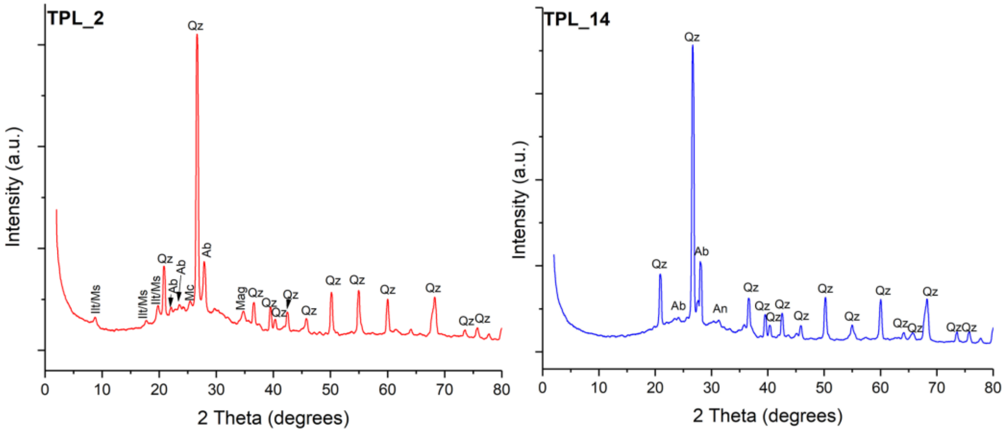

Fig. 9: X-ray diffractograms of the pottery selected from Topolița-*La nord-vest de sat* (Abbreviations according to Whitney, Evans 2010: minerals: Qz=quartz, Ill/Ms=illite/muscovite, Ab=albite, Mc=microcline, Mag=magnetite, An=anorthite)

Discussion

1. The chaîne opératoire

1.a. Clay procurement

All the analysed Late Bronze Age ceramics selected from the Topolița – *La nord-vest de sat* archaeological site were made with raw materials which are consistent with the local geology. The nearby Topolița river carry metamorphic and sedimentary rocks to the site, including, phyllite, schists, quartzite, and limestone. Besides, the Topolița River, located south to the site and Valea Seacă stream, situated north of the site transport a wide range of Quaternary sediments such as sands, gravels and boulders (Fig. 3). The great consistency between the local geology and the matrix and inclusions composition provides compelling arguments for a local production of the pots, reflecting the technological know-how of the local potters. Most of the samples were made with a micaceous clay, except sample TPL_29 for which a very fine humic clay was used. The results of the XRPD analysis suggest the use of an illitic clay that is locally available, although need to be taken with care due to the difficulty in separating illite and muscovite peaks. Illite represents one of the most common clay minerals used for pottery production throughout prehistory[45]. In the site's nearby area, clays with low calcium content ideal for firing under a reducing atmosphere without necessitating very sophisticated kiln structures are widely available[46]. The raw materials used to produce at least the ware attributed to fabric 1 were probably collected close to the river, as they contain a mixture of metamorphic and sedimentary rock fragments, and the

[45] PARK *et al.* 2019.

[46] MANIATIS, TITE 1981, 65-66.

naturally occurring inclusions varies from granules to very fine sand in different amounts (Table 4). The pottery fragment included in sub-group 1b (TPL_29) was made from a different type of raw material consisting in a very fine humic matrix, indicating that at the site the potters used different clay sources for producing the same type of vessels (Type I).

1.b. Raw material processing

The raw material processing involves, also, the removal and/or addition (tempering) of aplastic inclusions using varying procedures[47]. The fine micaceous clay matrix identified within sub-groups 1a and 2b demonstrates clay refinement by sieving or levigation, as some of the samples (TPL_2, TPL_4, TPL_13 and TPL_22) are very fine textured.

The addition of grog as temper represents the most compelling technological feature of the Late Bronze Age ceramic assemblage identified at Topolița. Although grog was present in all the analysed pottery fragments, it was processed based on a wide variety of pottery recipes and added in various amounts and combinations (Table 2, Fig. 10-13).

The long-lasting tradition of using grog as a temper is also confirmed by the presence of various ceramic lineages (*grog within grog*) observed in *grog type 1* (Fig. 10a-b) (TPL_1, TPL_3, TPL_14, TPL_15, TPL_20, TPL_27 and TPL_30), *grog type 7* (Fig. 10c-d) (TPL_3, TPL_21, TPL_22, TPL_TPL_25), *grog type 8* (TPL_4, TPL_7, TPL_12, TPL_16, TPL_22, TPL_25, TPL_30) and *grog type 9* (TPL_4, TPL_15, TPL_20, TPL_23, TPL_25). *Grog type 1* was added only in the coarse and medium paste of vessel type I, while *grog type 7* was selected for making the medium paste of vessel type I and IV, and the fine paste of vessel type III. A more restrictive behavior is associated with the use of *grog type 8* that was present only in the medium paste of vessels type I and the fine paste of vessels type III. Unlike the other *grog within grog* types, *grog type 9* was included in a wide range of paste categories used for making medium and coarse ware attributed to vessel type I, medium paste corresponding to vessels type IV and a fine paste used for shaping vessels type III.

Nine different types of grog were detected based on their matrices and inclusions features (Table 5). Seven of the identified grog types display a high degree of similarity with *fabric 1* (including sub-group 1a) and *fabric 2* (including sub-groups 2a and 2b) that were most likely locally produced and regularly recycled. The very fine and fine matrix specific to *grog type 5* and *grog type 9* (grog in grog) have no correspondence in the pottery fabrics observed on the site that may be linked to a change in the pottery technology or to the existence of various interaction networks.

Grog type 3 was extensively used at Topolița-*La nord vest de sat* (Fig. 14) being present in the matrices of twenty-nine of the investigated pottery fragments.

[47] SANTACREU 2014, 67-77; ERAMO, MANGONE, 2019; ERAMO 2020.

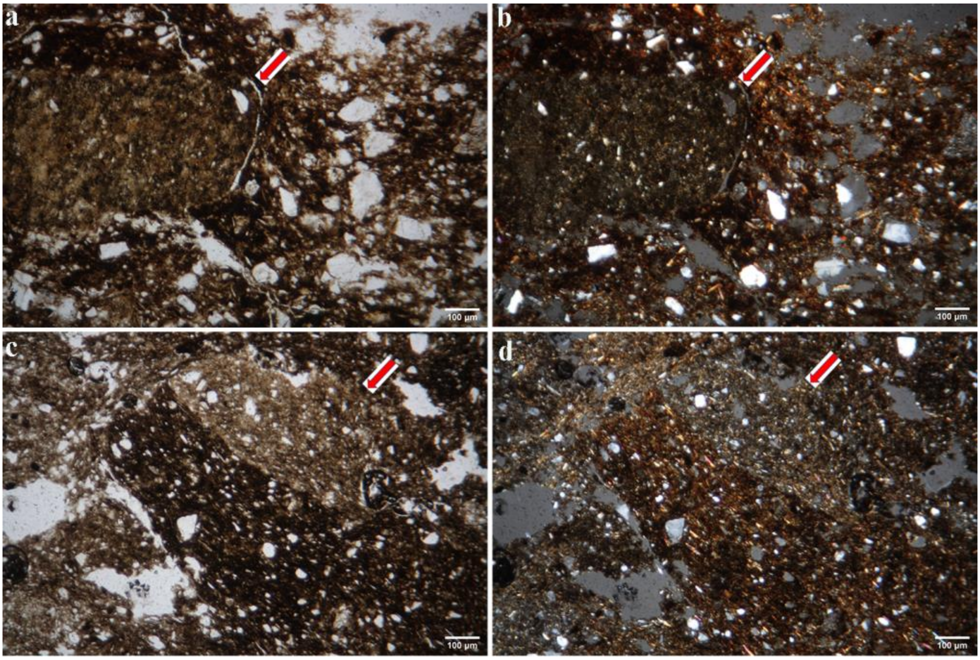

Fig. 10. Photomicrographs of ceramic thin sections showing grog types identified in the pottery samples from Topolița-*La nord-vest de sat:* a, b – *grog type 1* (TPL_1), c, d – *grog type 7* (TPL_3) (a, c - plain polarized light (PPL), 4x; b, d – cross polarized light (XPL), 4x)

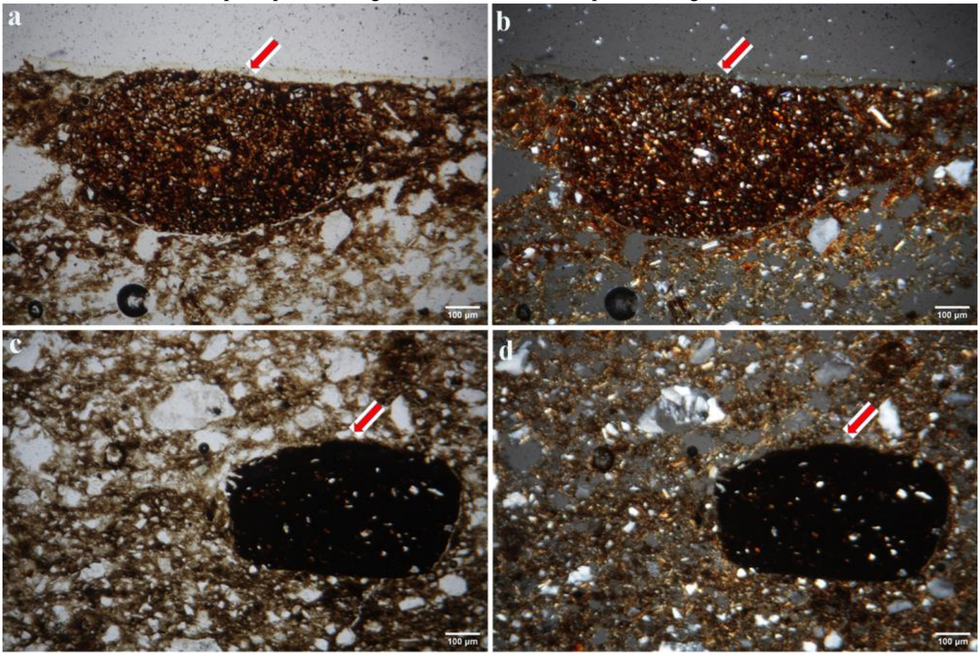

Fig. 11. Photomicrographs of ceramic thin sections showing grog types identified in the pottery samples from Topolița-*La nord-vest de sat:* a, b – *grog type 2* (TPL_1); c, d – *grog type 3* (TPL_1); (a, c - plain polarized light (PPL), 4x; b, d – cross polarized light (XPL), 4x)

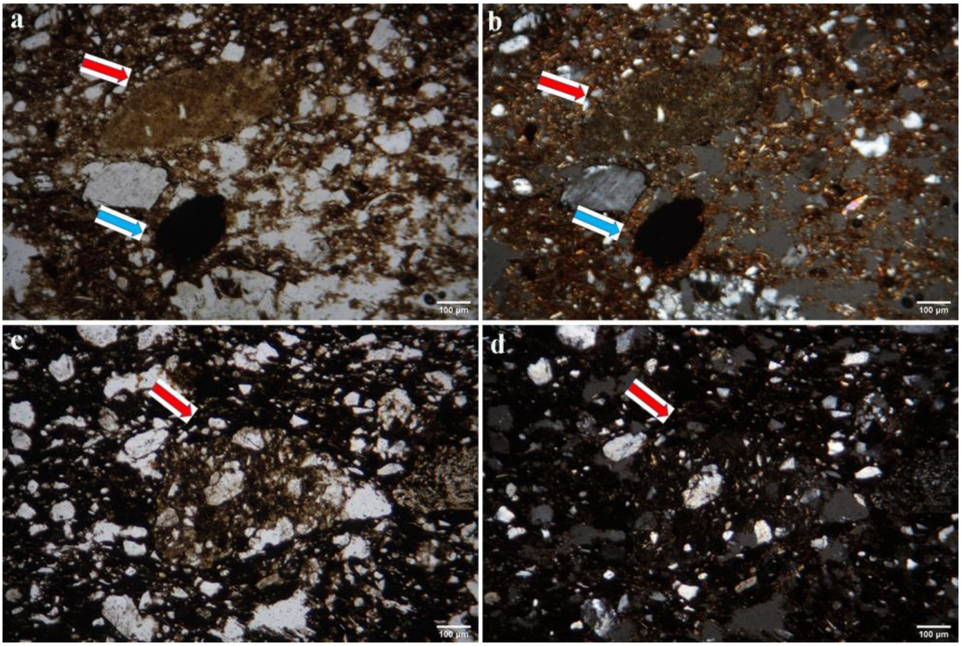

Fig. 12. Photomicrographs of ceramic thin sections showing grog types identified in the pottery samples from Topolița-*La nord-vest de sat:* a, b – *grog type 4* (blue arrow, TPL_1) and *grog type 5* (red arrow, TPL_1); c, d – *grog type 6* (TPL_8); (a, c - plain polarized light (PPL), 4x; b, d – cross polarized light (XPL), 4x)

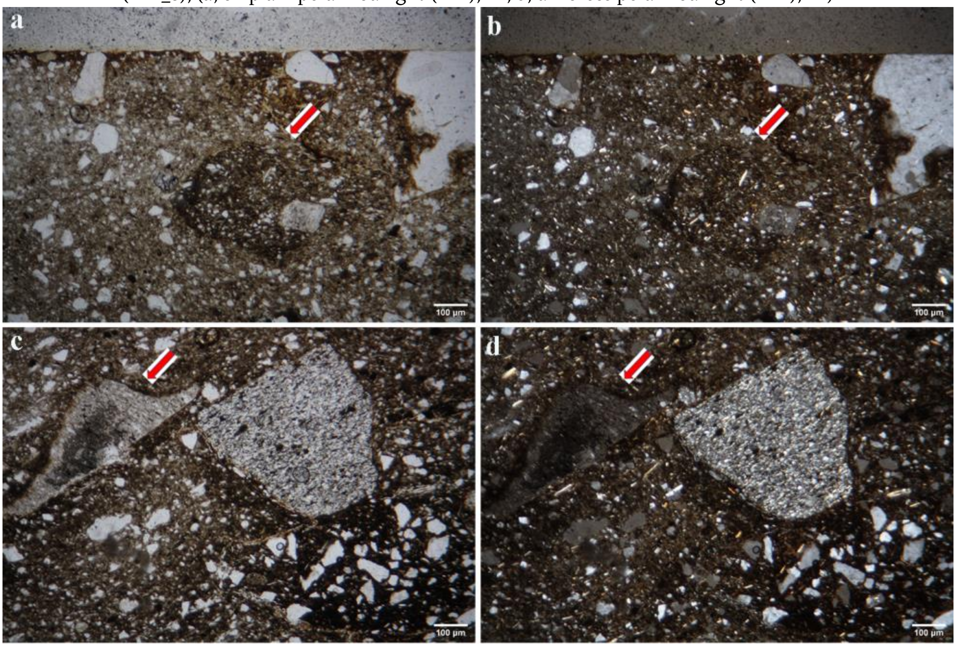

Fig. 13. Photomicrographs of ceramic thin sections showing grog types identified in the pottery samples from Topolița-*La nord-vest de sat:* a, b – *grog type 8* (blue arrow, TPL_4); c, d – *grog type 9* (TPL_4); (a, c - plain polarized light (PPL), 4x; b, d – cross polarized light (XPL), 4x)

Table 5: Characteristics of the grog types identified in the pottery samples from Topolița-*la nord vest de sat*

Inclusion type	Coarseness	Colour of matrix under XP	Main type of inclusions
Grog type 1	medium	dark brown	Qz, Ms, grog
Grog type 2	medium	reddish brown	Qz, Ms, metamorphic rock fragments
Grog type 3	fine	dark brown	Qz, Ms
Grog type 4	fine	yellowish brown	Qz, micrictic Cal, Ms
Grog type 5	very fine	dark brown	Very rare Qz inclusions
Grog type 6	coarse	dark brown	Qz, Ms, metamorphic rock inclusions
Grog type 7	medium coarse	orange brown/light brown	Qz, abundant Ms, grog
Grog type 8	medium coarse	brown	Qz, Ms, grog
Grog type 9	fine	light gray/dark brown	Qz, Ms, grog

There seems to be a systematic process of ware recycling process and a preference for the use of a combination of *grog type 3, grog type 4* and *grog type 6*. This *recycling pattern* (Fig. 14) was detected in twenty-two pottery fragments corresponding to the type I (1 coarse and 13 medium ceramic pastes), type III (1 coarse and 3 fine ceramic pastes), type IV (2 medium ceramic pastes) and type V (1 fine and 1 medium ceramic pastes).

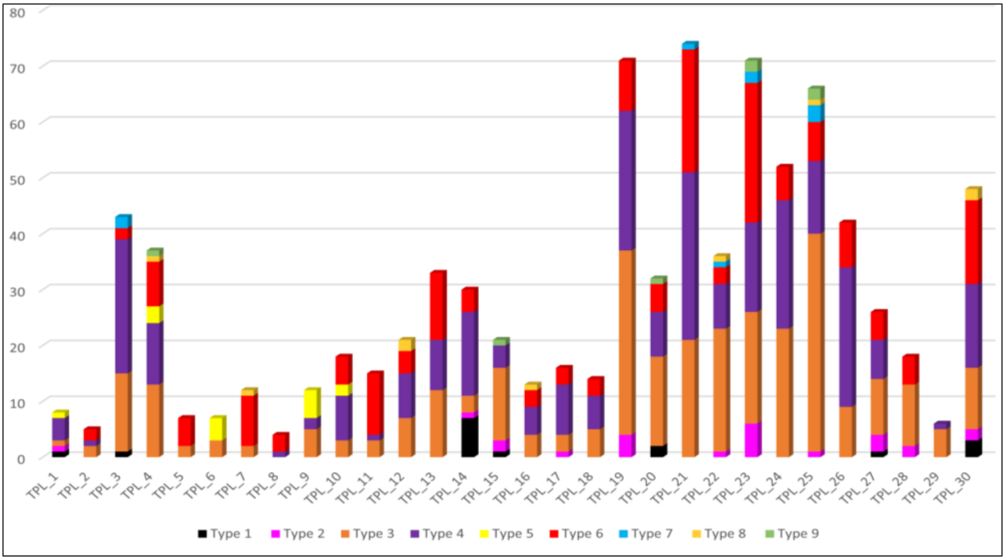

Fig. 14. Quantitative distribution of the grog types identified within the Topolița pottery samples

The complex process of ware recycling was practiced by potters throughout the world on a large scale starting with the onset of the Neolithic[48]. One possible reason for its wide use may be related to a functional motivation determined by the possibility to improve the mechanical and thermal properties of the vessel[49]. The addition of grog causes high

[48] SPATARO 2011; ZULUAGA *et al.* 2011; HOLMQVIST *et al.* 2018; KOUTOUVAKI *et al.* 2021; SPATARO *et* al. 2021.

[49] TITE *et al.* 2001.

strength loss, a situation somehow surprising if we look at the remarkably close values obtained for the thermal expansion coefficients. Experimental investigations performed on ceramic replicates proved that during firing the grog temper stays in close contact with the clay matrix and the mechanical properties of the grog and clay matrix remains similar. Hence, the cracks propagation goes through the grog temper instead of being deflected or bifurcated. Consequently, the propagation of the energy caused by the crack extension is very limited[50]. Due to the similar thermal expansion coefficient with the clay matrix, the grog temper has a limited influence on the thermal expansion of the matrix and causes no stress during heating[51].

The influence of the grog temper on the pottery microstructure is dependent on the firing temperature. The analysis performed on ceramic replicates fired under controlled conditions in a laboratory furnace between 500 and 900 °C showed that no significant changes affected the bulk density, diametral shrinkage, water absorption and mechanical strength. For a temperature range between 900 and 1100 °C, an abrupt decrease in the porosity resulted in a decrease in water absorption and an increase in mechanical strength[52].

The impact of the grog on the matrix properties is, also, strongly dependent on the chosen quantity. Therefore, the incorporation of 5% of grog practically has no effect on the properties of the ceramic. Increasing the grog amounts causes the decrease in the fired mechanical strength of the ceramic matrix[53]. The effect caused by the addition of grog on the fired properties of the ceramic matrix is, also, strongly influenced by the particle size of the grog. Consequently, by adding more than 5% of grog with a coarse particle size, will decrease the mechanical strength of both the dry body and the fired ceramic products. If the grog will have a finer particle size, the amount of temper may be increased up to 10% without causing any significant changes on the properties and the corresponding microstructure of the ceramic artefacts[54].

Ethnographic examples argue for the perception of the grog tempered ware in connection to very complex symbolic behaviours, acting as metaphors for rebirth and fertile soil and the vessel itself as a metaphor for food supplies[55]. In some communities the addition of grog is regarded as both a technical and a symbolic improvement of the raw materials, some potters considering that it is" good" to tie new vessels with the ones of the ancestors, because" they knew how to make strong pots"[56]. Therefore, the act of adding

[50] TITE *et al.* 2001, 316-317.

[51] TITE *et al.* 2001, 316.

[52] VIEIRA *et al.* 2009, 333-334.

[53] VIEIRA *et al.* 2009, 334-336.

[54] VIEIRA *et al.* 2006, 438-443.

[55] ERIKSSON 2013, 332 with references therein; 343.

[56] GOSSELAIN, LIVINGSTON SMITH 2005, 41.

grog to a new vessel is embedded with ritual and a symbolic meaning aimed to ensure continuity and rebirth[57].

It is difficult to identify if the selected clayey raw material used by the Late Bronze Age potters at Topolița was tempered for making it good enough to prepare the paste, or for other reasons (e.g., tradition, quality of the initial pots, symbolic perception). Among the Late Bronze Age pottery samples selected from Topolița, differences in the types of clay and temper allowed several ceramic fabrics to be expressed. The same pottery fabric was adopted for a wide variety of ceramic types within the site. For instance, fabric 1 (Fig. 7/a, Table4) was used to make most of Type I jars, but also medium sized pots (Type III), bowls (Type IV) and one of the *kantharos* vessels (TPL_19). The clay used to make the jars was very differently processed, ranging from the coarse (TPL_10, TPL_14) and medium sized fractions (TPL_15, TPL_16, TPL_17, TPL_24, TPL_26) to the fine sand clay used for the TPL_1 and TPL_27 jars. The fact that similar vessels were processed based on a wide variety of recipes might also suggest the existence of different potters on the site.

The vessels attributed to fabric 1 were also tempered with crushed quartzite (Fig. 7/a-c, Table 4), the most common rock identified in both medium and coarse sand matrix, but also in a fine one (TPL_1 and TPL_27). Quartzite is the second most-often used raw material for making a wide range of lithic implements since the Palaeolithic, with a genesis that can be metamorphic or sedimentary, which can obstruct provenance assumptions[58]. In the pottery fragments grouped in fabric 1, quartzite displays metamorphic features showing deformation and recrystallization in the quartz grains, and, consequently, in the general texture of the rock fragments[59]. The addition of quartzite increases the toughness of the pots, since it prevents the propagation of fractures resulting from differential stress in different points of the vessel. A strong relationship between the coarse fabrics and cooking pots was noticed worldwide, suggesting a certain universal perception of the *necessary physical qualities* of the raw materials[60]. On the other hand, the way of obtaining the *necessary physical qualities* varies widely, being socially embedded, and related to the organization of pottery production[61], but also to the potter skill level[62]. For instance, most of the Type I jars were made from a raw material with coarse sand and abundant inclusions, while the clay used for preparing TPL_1 and TPL_27 vessels was a fine one. The addition of coarse mineral temper improved the textural characteristics of the vessels and increased the toughness and thermal shock resistance of the products.

[57] ERIKSSON 2013, 343.

[58] PRIETO *et al.* 2018.

[59] PRIETO *et al.* 2018, 22.

[60] SANTACREU 2014, 153.

[61] COSTIN 1991.

[62] FORTE 2019.

The addition of chert temper identified in the pottery samples attributed to fabric 3 (TPL_12, TPL_21 and TPL_28) also represents the result of a behaviour influenced by the natural and cultural environment and the intended physical qualities of the final products. As one of the most important raw materials used in prehistory to produce chipped stone tools, it was identified in the pottery recipes since the Neolithic[63], although its processing for use as temper in the ceramic paste required complex operations.

The various fabrics identified within the site are only approximately related, if at all, to the final products. A wide variety of fabrics were used for making the jars attributed to Type I, which is the dominant vessel category identified within the site (Table 4), while the recipe used for making the bowls is restricted to two pottery fabrics (fabric 1 and fabric 2a).

1.c. Forming, finishing and decoration

The macroscopic and petrographic observations applied in this study allowed an estimation of the forming, finishing and decoration techniques adopted by the Late Bronze Age potters. A wide range of diagnostic attributes such as surface morphology and topography, variation in wall thickness, remnants of segmental joints, specific fractures, and the alignments of the vessel parts[64] confirmed that the primary technique for forming the analysed Late Bronze Age pottery was coiling with different joining methods. At Topolița, different vessel types were made using similar techniques, a "conservatism" that was recorded in the eastern part of Romania for the Middle Bronze Age pottery identified at Piatra Neamț-*Lutărie*, where the constant presence of the coiling technique combined with a wide variety of surface treatments were observed[65]. A wider variability was noticed for the pottery forming techniques used in the south-western part of Romania, at the Middle-Late Bronze Age Gârla Mare sites, the straight-sided bowls were made by coiling, urns by slab-building, and everted rim bowls with distorted and angular profiles were thumbed out[66].

1.d. Pyrotechnoloy

Firing is a key step of the *chaîne opératoire* characterizing pottery production, influencing greatly the microstructural and mineralogical features of the resulted products. The thermal profile of the ceramics can be inferred based on the maximum temperature, heating rate, soaking time, duration, and thermal homogeneity which greatly affect the

[63] It was reported as a widely present temper in the Neolithic ceramic assemblages from the western coast of the Adriatic, exhibiting local and regional variation in the pottery making recipes (SPATARO 2011). A recent study mentions the use of chert as temper in the earliest pottery (ca. 6500 BC) identified in Faynan, southern Jordan (BURTON *et al.* 2021).

[64] THÉR 2020.

[65] DROB *et al.* 2021.

[66] SOFAER 2018, 85.

visual appearance of the artefacts, as well as their microstructural and mineralogical characteristics[67].

The surface and cross-section colour of the ceramic artefacts selected from the analysed Late Bronze Age site prompt towards a wide range of firing conditions. Ethnographic studies mention colour as the most important parameter used for monitoring the temperature range. When the surface of the vessels had reached a homogenous colour, the potters remove the vessels from the firing structure[68]. The macroscopic inference of surface and core colour combined with the birefringence pattern of the matrix determined by petrographic analysis and the iron oxides identified by X-ray diffractograms offer valuable insights into the firing atmosphere and the temperature attained during the firing of the ceramics[69].

Among the pottery specimens selected from Topolița-*La nord-vest de sat*, six samples (TPL_2, TPL_4, TPL_13, TPL_15, TPL_16 and TPL_18) present uniform darker hues (Table 1, Fig. 4) on the surface caused by firing in a reduced atmosphere. Additionally, XRPD analysis (Fig. 9) suggest that the firing temperature attained for sample TPL_2 have not exceeded 750 °C, as can be inferred based on the identified mineralogical phases. The mineralogical changes affecting the non-calcareous iron-rich illitic ceramic artefacts fired in reduced atmosphere consist in the complete structural collapse of calcite near 680 °C[70], the breakdown of the illite content around 800 °C[71], together with the appearance of newly formed mineral phases at 750 °C[72]. Sample TPL_2 contains both albite and microcline, two feldspar mineral phases that do not show significant transformations when fired at temperatures below ~850 °C[73]. Besides their influence on the colour of the ceramic products, the iron-bearing minerals represent a strong indicator for the atmosphere attained during the firing process. The diffraction pattern of sample TPL_2 revealed the presence of magnetite, confirming that a constant reducing atmosphere was maintained during the pottery firing[74]. During firing under redox conditions, hematite converts into magnetite already below ~600 °C and in fired illitic clays magnetite is stable until 850-900 °C[75].

The reddish hues dominating the surface of sample TPL_14 strongly suggests that it was fired in an oxidizing atmosphere. The results of the XRPD analysis obtained for sample

[67] THÉR 2014, 78.

[68] RYE 1981, 105.

[69] ERAMO, MANGONE 2019, 5.

[70] MIRAS *et al.* 2018, 179.

[71] HEIMANN, MAGGETTI 2019, 247.

[72] HEIMANN, MAGGETTI 2019, 246.

[73] CULTRONE *et al.* 2001, 624; GLIOZZO 2020b, 10.

[74] GLIOZZO 2020b, 15.

[75] HEIMANN, MAGGETTI 2019, 248.

TPL_14 (Fig. 9) point towards a firing temperature in the range of 800-850 °C. The mineralogical transformations consisted in the disappearance of illite/muscovite diffraction peaks that appears when fired between 800-850 °C, in oxidizing conditions[76], and the appearance of anorthite, a calcium-aluminium silicate mineral formed at temperature ranging between ~750 °C – 1000 °C[77].

Twenty-three of the pottery samples selected from the investigated Late Bronze Age context show variable core hues when compared to the surface colour (Table 1, Fig. 5). The distinctive core effects appear in ceramic artefacts fired below about 1000 °C due to the removal of carbon by oxidation or deposition of carbon when fired in a reducing atmosphere[78]. All the mineralogical and microstructural transformations are strongly dependent on the thermal profile of ceramic production, while the variation in the core hues can be considered as reliable indicators of the firing temperature and atmosphere. Further on, the heating rate (i.e. the rate of temperature increase up to the maximum temperature) and the soaking time (i.e. time of maintenance at the maximum temperature) were considered as reliable firing parameters to distinguish between varying types of firing structures[79]. Fast heating rates and short soaking times are registered when the ceramic products are in direct contact with the fuel (pit firing or bonfire) and the firing temperature and colour shades varies greatly between the core and the margins of the ceramic wall[80], or between the various parts of the ceramic body[81]. When the firing implies that the fuel is separated from the vessels such as in complex two-chamber kilns, the heating rate grows slowly, and the soaking time is longer producing varying microstructural and mineralogical transformations in the ceramic artefacts[82]. Besides, there is a strong relationship between the type of fuel used during firing and the type of firing atmosphere[83]. The various types of fuels used by the potters produced a wide range of thermal/redox effects on the paste that were predominantly recorded by the matrix and can be inferred based on the macroscopic analysis of the ceramic cross-sections[84].

In Figure 15, a visual scheme of the thermal/redox effects documented within the ceramic assemblage identified at Topolița-*La nord-vest de sat* is resumed. The cross-section of uniform lighter hues (Fig. 15/O) produced by firing under fully oxidizing conditions and

[76] MARITAN *et al.* 2006, 7.
[77] TRAORÉ *et al.* 2000, 288-290; CULTRONE *et al.* 2001, 631.
[78] RYE 1981, 115.
[79] GOSSELAIN 1992; LIVINGSTONE SMITH 2001.
[80] GOSSELAIN 1992; LIVINGSTONE SMITH 2001.
[81] MAGGETTI *et al.* 2011.
[82] THÉR 2014, 79.
[83] ERAMO, MANGONE 2019, 5.
[84] RYE 1981, 114-118; ERAMO, MANGONE 2019, 5.

registered mainly for ceramic artefacts containing no organic materials[85] was not documented within the investigated ceramic samples, but it is listed here as a reference category. Some colour variation may be observed on some of the vessel's surface (Fig. 3), a situation caused when one part of the vessel was directly exposed to firing[86]. In this case the colour variation observed on the various parts of the ceramic body is caused by a variation in the firing temperature and not on the firing atmosphere[87].

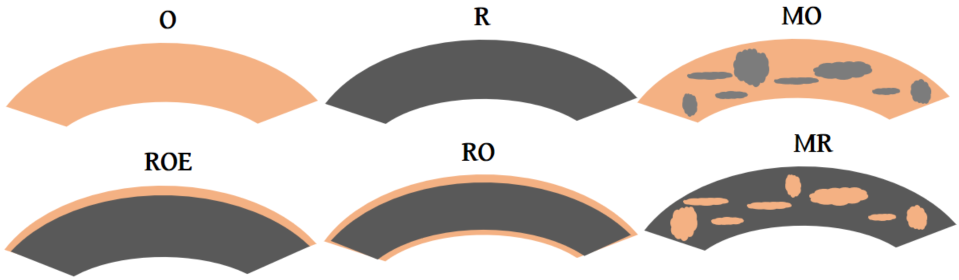

Fig. 15. Schematic representation of the colour variation identified within the Topolița-*La nord-vest de sat* ceramic assemblage as seen in cross-section
(Abbreviations: O=oxidized, R=reduced, MO= Marbled oxidized, ROE=reduced oxidized exterior, RO=reduced oxidized, MR=marbled reduced)
(Redrawn based on Eramo, Mangone 2019)

In the case of the examined Late Bronze Age ceramic assemblage, none of the selected ceramic shards present uniform lighter hues in cross-section. Two of the investigated ceramic artefacts (TPL_12 and TPL_14) exhibit a marbled oxidized cross-section (Fig. 15/MO) based on which we can assume that the potters were not able to maintain long enough a fully oxidized firing atmosphere.

The variable oxidized firing atmosphere causing the marbled structure of samples TPL_12 and TPL_14 is confirmed also by the XRPD results obtained for sample TPL_14, which showed no traces of hematite, a mineral formed when the ceramic is subjected to oxidizing conditions during firing[88].

A cross-section of uniform darker hues (Fig. 15/R) is formed when the access of air is completely prevented by covering the vessels, in the open firings and in the kilns, after the

[85] RYE 1981, 115; SANTACREU 2014, 102; ERAMO, MANGONE 2019, 5.

[86] SANTACREU 2014, 105.

[87] RYE 1981, 115; MAGGETTI *et al*. 2011.

[88] The hematite can form as nano-sized particles during firing in an oxidizing atmosphere in a temperature range between 750 – 850 °C (NODARI *et al*. 2007). As mentioned above, the XRPD results suggested a firing temperature range between 800-850 °C for samples TPL_14, but no diffraction peak specific to hematite was identified, which may relate to the variable firing atmosphere and insufficient soaking time.

vessels have reached the maximum temperature and are beginning to cool[89]. Within the targeted ceramic assemblage, seven samples (Table 1; Fig. 5) present uniform darker colours in cross-section, ranging from black (TPL_2) to gray (TPL_5, TPL_11 and TPL_19) hues, caused by the firing in a reducing atmosphere.

Five samples attributed to Type I and two samples assigned to Type IV vessels category (Table 1; Fig. 5) developed during the firing process a so-called *sandwich structure* consisting in a diffuse gray or black core, distinct from the colour of the surface or of the edges (Fig. 10/RO). The appearance of the so-called *sandwich structure* is influenced by a wide variety of factors such as: the type of clay used, the type of fuels, the firing structures, and the firing parameters (atmosphere, heating rate, soaking time). The complexity of the firing conditions related to the development of a *sandwich structure* during the firing process was revealed by the archaeometric investigations conducted on artefacts identified worldwide[90]. According to literature, the black core can be caused by the high proportion of Fe^{2+}/Fe^{3+}, consisting mainly in a high proportion of magnetite (Fe_3O_4) and wüstite (FeO) in the initial composition of the clay matrix[91], the presence of the carbon particles in the structure of pottery[92], firing of the pottery under reducing conditions leading to presence of the trivalent iron ions in the red surface and the reduced iron oxides such as FeO or Fe_3O_4 in the black core[93], firing of raw material rich in organic matter under oxidizing conditions[94] or a short firing duration and low temperatures hampering a complete oxidation within the ceramic body[95]. The analysis of ceramic replicates revealed the persistence of the blackish hues in the core up to a temperature range of 850 – 900 °C, in relation to shorter firing extent preventing hematite nucleation[96]. Additionally, a strong dependency on the temper amount was noticed, the increase of the temper reducing the black-core effect due to the porosity growth that furthered oxygen to reach the ceramic core[97].

Based on the composition and microstructural features of the ceramics selected from Topolița-*La nord-vest de sat*, we may conclude that the persistence of the black core was not determined by the addition of the organic matter (such as straw) to the clayey raw

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[89] RYE 1981, 115.

[90] MOLERA *et al.* 1998; NODARI *et al.* 2004; COLOMBAN *et al.* 2004; MARITAN *et al.* 2006; SZAKMÁNY, STARNINI 2007; BROEKMANS *et al.* 2006; BROEKMANS *et al.* 2008; BONG *et al.*, 2008; COLOMBAN *et al.* 2004; PALANIVEL, KUMAR 2011; NOGHANI, EMAMI 2014; De BONIS *et al.* 2017; XANTHOPOULOU *et al.* 2021; OUDBASHI *et al.* 2021.

[91] NODARI *et* al. 2004; COLOMBAN *et al.* 2004.

[92] NODARI *et al.* 2004; MARITAN *et al.* 2006; De BONIS *et al.* 2017.

[93] BROEKMANS *et al.* 2006; BROEKMANS *et al.* 2008; BONG *et al.* 2008; PALANIVEL, KUMAR 2011; NOGHANI, EMAMI 2014.

[94] MARITAN *et al.* 2006.

[95] SZAKMÁNY, STARNINI 2007.

[96] De BONIS *et al.* 2017, 8071.

[97] De BONIS *et al.* 2017, 8071.

materials as no specific features were determined by the petrographic analysis. Based on the persistence of birefringence for most of the samples, as well as the absence of iron minerals in the XRD patterns we may assume that an incomplete oxidizing atmosphere was attained during the firing process.

The uniform thin layer of lighter hues adjacent to the outer surface (Fig./ROE) notified within the investigated ceramic assemblage (Table 1, Fig. 5) may be the effect of the cooling methods. It is possible that this sharply defined oxidized zone adjacent to the surface was caused by open firing in a reduced atmosphere followed by very rapid cooling in air[98]. This feature could imply that pit firing was the type of installation used at this site. Without denying the possible use of more complex firing installations, the archaeological investigations did not reveal secured evidence of kilns at Noua sites[99]. For the Late Bronze Age period, fragments of clay grates asserting the existence of some possible kilns and the remains of more complex firing structures were identified in the southern part of Romania and attributed to the Coslogeni group[100].

2. Hands on action: Creativity embedded in the pottery making at Topolița

In approaching the creativity embedded in the pottery making, we considered it as a particular quality associated with the making of objects and the outcome of this process and with a particular type of entanglement between people and objects. Considered like this, the creative process involves ideas and knowledge consisting in experiences and experimentation as well as an active perception of the world around them explored[101].

The creativity embedded in the ceramic products identified within the investigated Late Bronze Age site was not expressed by the inventions of new vessel forms or the development of new design principles. It rather lied in the vessel forming and in the potters' responses to the challenges that the various types of paste identified within the ceramic assemblage pose. For instance, different recipes, with a variety of coarse to medium sand-sized inclusions, were used to make the so-called ”bag-type” jars which were then smoothed or slipped. Only 5 potsherds attributed to Type I were made of a coarse paste shaped using the S-coiling technique and further smoothed (2 samples) or covered with a slip (3 samples). Most of the so-called ”bag-type” jars were made of a medium paste (12 samples) further shaped applying mostly the S coiling technique. The final products were smoothed (12 samples) or smoothed and covered with a slip exhibiting mostly lighter

[98] RYE 1981, 118.
[99] TENCARIU 2015, 20.
[100] Fragments of clay grates were discovered at Lupșanu (Călărași County) among the remains of an ”ash-pan” (MORINTZ 1978, 137) and at Bugeac-*Ghețărie* (Constanța County) as part of the inventory of a possible household pit (IRIMIA 1981, 354-356). The remains of a complex firing structure were identified at Grădiștea-*Coslogeni* (Călărași County) (NEAGU, BASARAB 1986, 107-109).
[101] STIG SØRENSEN *et al*. 2018, 3.

hues (8 samples). Different creative possibilities were experienced through different hand movements as revealed by the variation in the shaping of the vessels defined as Type I. For example, two of the analysed ”bag-type” jars were made using the U shaping technique and then smoothed and covered with a slip, while another vessel was shaped using the N coiling technique and further smoothed and slipped. For obtaining the intended profile and thin and regularize the surface during the shaping sequence, in some cases (TPL_3) scrapers were used on wet clay. Further on, smoothing was practiced for removing many surface grains and deep striations most probably on the leather-hard paste as revealed by the persistence of the scraping marks on sample TPL_3.

For producing some of the medium sized pots, the potters applied a similar recipe with the one used for making the ”bag-type” jars, while other vessels were made with a fine paste used, also, for shaping the more exquisite *kantharos* type vessels. Moreover, some of the medium sized pots and of the *kantharos* vessels were burnished, obtaining additional compaction and orientation of the clay to obtain a shiny and compact appearance.

The persistence of a technological tradition of ceramic production at Topolița-*La nord-vest de sat* can be assumed based on the grog addition in all the paste recipes used at the site. A certain degree of ”conservatism” was noticed, also, for other sequences of the *chaîne opératoire* such as the extended use of S shaping technique.

3. Communities of practice. Evaluating interaction networks as revealed by pottery production

Although everyday activities hold a key-role in defining social interactions, in the archaeological record they are rather obscured. The evaluation of the interaction networks is based primarily on the material culture and spatial data. As ceramic artefacts are included in various everyday activities or in the more restricted ceremonial one, makes them suitable for evaluating various types of interaction networks. The use of a communities of practice approach allows to combine various analytical scales through an alternate unit of analysis that focuses on the history of learning.

Most approaches targeting interaction networks during the Late Bronze Age in the eastern part of Romania relies heavily on identifying the spatial distribution of *exotica* finds (e.g. metal, bone, antler or rare stone implements)[102]. More recently, additional insights were provided by more complex spatial analysis providing an in-depth evaluation of the environmental constraints[103].

Traditionally, the Late Bronze Age pottery studies concentrated on defining typological and stylistic features and the interaction networks were defined based on imported ceramic items[104]. Only recently, the social dimensions of the *kantharos* vessel type were

[102] DIACONU, KOVACS 2021; DIACONU, SÎRBU 2018; DIACONU *et al.* 2016; DIACONU 2012; BUZGAR *et al.* 2013.

[103] VIERU 2013; DIACONU 2014; GAFINCU 2014; GAFINCU 2015; NICULICĂ 2015, 366-372; BRAȘOVEANU 2021.

[104] SAVA 2002; DIACONU 2014.

investigated[105]. Although there is a strong connection between the Noua *kantharos* vessel type and the ones identified within Monteoru and Komariv contexts, the development of specific morphological features for the Noua *kantharos* vessels suggests connections with a more specific zoomorphic symbolism[106].

By investigating the various sequences that characterize the pottery production starting with the raw materials selection to the final product shape and decorative features we gain insights into an extended range of attributes that are learned and transmitted within a *community of practice*[107]. When trying to evaluate interaction based on the examination of all these attributes, we must consider their hierarchical distribution according to visibility, manufacturing decisions, and production sequence[108]. Those attributes that are not visible to the naked eye and are restricted to a limited geographic area are considered as *low visibility attributes*. They can be used as a proxy for tracing interpersonal relationships because are not easy to detect and to copy and must be learned based on a direct contact with another potter within a *community of practice*[109]. The ***low visibility attributes*** investigated in this study are the raw materials procurement and subsequent treatment. The ***high visibility attributes*** considered in our approach are the vessels form and decorative style which are easily detectable on the final product and have an extended geographic distribution. When considering the transmission mechanisms, we must take into account that the ***high visibility attributes*** can be easily copied by other potters via final product circulation. Their transmission chains do not necessary involve interpersonal relationships even though sometimes they can be learned through direct interaction. The ***high visibility attributes*** examined in our approach are vessel form and decorative pattern.

The constraints imposed by the theory of artifact design imply the existence of a relative uniformity of raw materials and a restricted artefact exchange to limit the influence of other factors that could induce variability in the ceramic assemblage[110]. Also, our approach infers that the knowledge about *low visibility attributes* is acquired in a system based on face-to-face relationships, although the potters can gain insights about the raw materials used by other potters by viewing broken pots[111].

The environmental constrains are met in this study, the clayey raw materials used for producing the vessels identified at Topolița-*La nord-vest de sat* is consistent with the local geology. The quartzite temper identified in *fabric 1* available within the nearby area of the

[105] DIETRICH 2011, 115-122.
[106] DIETRICH 2011, 121.
[107] JORDAN *et al.* 2020.
[108] CARR 1995, 173.
[109] JORDAN *et al.* 2020.
[110] CARR 1995, 179.
[111] JORDAN *et al.* 2020.

site was included in a wide variety of recipes used for making most of the jars attributed to Type I, medium sized pots (Type II), bowls (Type III) and one of the *kantharos* vessels.

At Topolița, for producing the three different pottery fabric groups and several sub-groups two distinctive clayey raw materials locally available were used. Most of the vessels were made based on a micaceous clay, while a humic fine clay was identified in one of the vessels attributed to Type I. The textural and compositional differences identified between the samples made from a micaceous clay may indicate that the clays were not selected from the same source. Although they are consistent with a similar depositional environment, they seem to be processed differently or selected from a variety of source locations. Further field survey and sampling for petrographical and geochemical analysis in the Topolița-*La nord-vest de sat* nearby area needs to be done to test the results obtained on ceramics.

The quartzite and chert minerals identified as the main added temper in *fabric 1* and *fabric 3* were available locally but were processed differently and used in combination with various types of grog temper. The use of quartzite in the Noua pottery recipe was previously mentioned for the ceramics identified at Săvești (Neamț County), located on the right bank of the Moldova River in a contact area between the Subcarpathians and the Suceava Plateau[112] and for various sites from the Suceava Plateau[113].

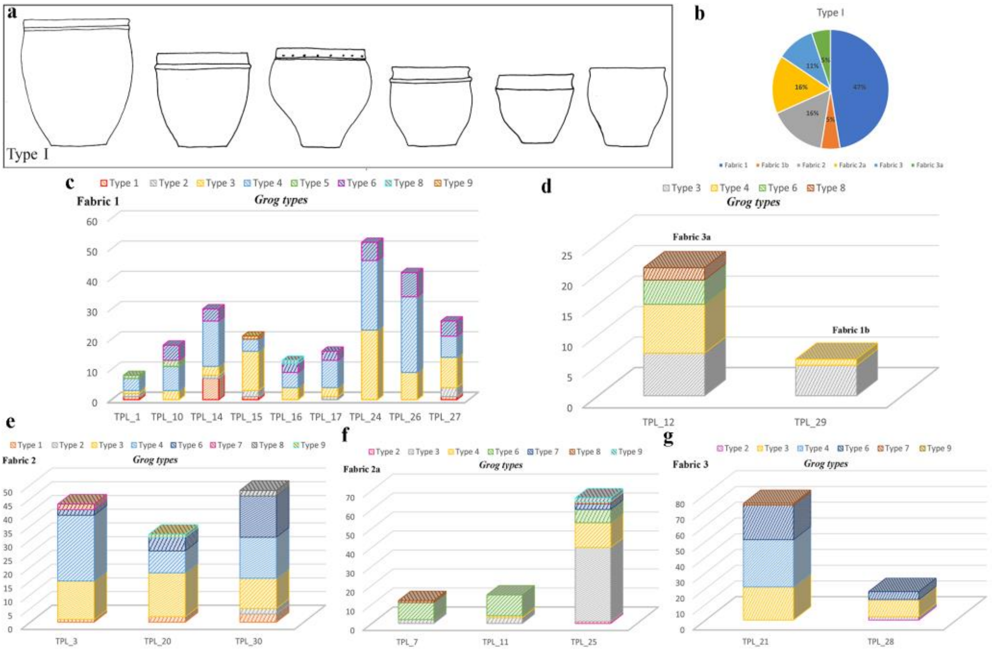

Fig. 16. Grog types identified in the vessels type I (a) according to quantitative distribution (b) and fabric types (c-g)

[112] BENEA *et al.* 2015, 90.

[113] NICULICĂ 2015, 385.

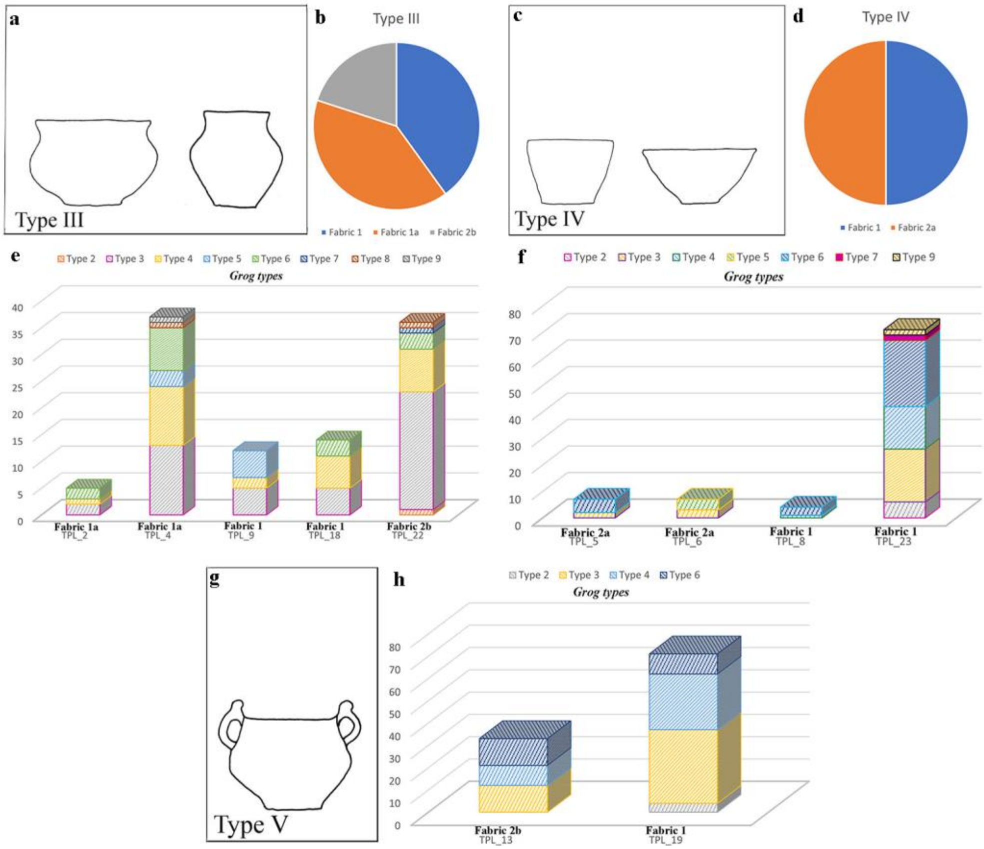

Fig. 17. Grog types identified in vessels type III (a) according to quantitative distribution (b) and fabric types (e); grog types identified in vessels type IV (c) according to quantitative distribution (d) and fabric type (f); grog types identified in vessels type V (g) according to fabric type (h)

The addition of chert and quartzite in the pottery recipe was also part of the technological know-how of the Middle Bronze Age communities[114]. The use of chert temper combined with various types of grog identified in other vessel types, including *grog-in-grog*, may suggest a tendency to integrate different raw materials available within the familiar taskscape within the already know-how to make paste recipe. At Topoliţa, the chert and quartzite temper were similarly processed, but their use was not restricted to a single vessel type. They were always combined with *grog type 4* that have no correspondence in the pottery fabrics identified at Topoliţa and *grog type 6* which present strong connections with *fabric 1* (Fig. 16c). The extended number of vessels attributed to *fabric 1* and the presence of *grog type 6* in all the samples investigated in this study shows the maintenance of pottery traditions that may be linked to a complex process of intergenerational knowledge transmission. The absence within the Late Bronze Age ceramic assemblage of a

[114] NICULICĂ 2015, 237-245

very fine fabric like the one identified in *grog type 4* may be related to a change in the ceramic consumption patterns or to interactions with other communities of practice. To distinguish if it is a product no longer produced locally by the potters or is an imported item further geochemical analyses need to be done.

The use of a wide variety of fabrics that contained beside the standard combination of *grog type 4-grog type 6* various other grog types, including *grog-in-*grog, for making the vessels type I (Fig. 16) may indicate the existence of a community of potters linked by a complex process of knowledge transmission to other communities of practice.

The more restricted range of fabric types used for making vessels type III and IV (Fig. 17a-f) combined with the tendency to diminish in size and quantity the grog addition may indicate a production made by a restricted number of more skilled potters. The addition of the same standard combination of *grog type 4-grog type 6* (Fig. 17e-f) prompts towards their production within the same community of practice.

Similar fabrics to the one used for making vessels type I and III containing the same standard combination of *grog type 4-grog type 6* were selected for making the *kantharos* vessels (Fig. 17g-h). The use of a fabric type (*fabric 2b*) that was prepared only for making vessels type III combined with the restricted number of grog types indicates a production within the same community of practice, while the absence of the *grog-in-grog* may suggest a recent integration within the ceramic repertoire made by the Late Bronze Age community identified at Topolița.

Vessels form and colour represent highly visible attributes that can be acquired and transmitted based on direct interactions or can be copied by the potters while observing the final product. However, the use of *fabric 1* for shaping jars (Type I), medium sized pots (Type III), bowls (Type IV) and one of the *kantharos* cups (Type V) may be connected to a very well-established knowledge transmission system. The learning environment show a rather conservative behaviour as can be inferred based on the quantitative distribution of grog types.

Besides, a certain degree of correlation between function and fabric group (i.e., finely crushed grog temper (*fabric 2b*) for thin-walled vessels (Type III and V) but the sample size is too limited for making general assumptions. The data did not reveal a strong relationship between all the identified fabric groups (or subgroups) and vessel form that would indicate that a distinct community of practice can be associated to the production of a specific vessel form.

The variability of the high and low visibility attributes encountered in the ceramic repertoire is not caused only by style and function, ”but results from people trying to solve the problems of everyday existence-conceptualized in terms of activity specific interaction and performance-in different behavioural, social, and natural environments”[115].

Conclusions

Our study, which combines macroscopical and archaeometrical analysis on ceramic artefacts from Topolița-*La nord-vest de sat*, allows us to tackle various aspects of Late Bronze Age pottery production.

Our approach shows the effectiveness of using *high* and *low visibility attributes* as a proxy for tracing knowledge transmission systems within a *community of practice* framework. The integration of a large dataset obtained from the analysis of pottery recycling process (grog processing and admixture) provided possible insights into the intergenerational social learning that affects various technological sequences. This type of investigation can be further extended with studies of childhood learning in potting communities[116].

This paper has focused on the evaluation of the vessel forms investigated these attributes in association with paste recipe to detect if communities of practices acted in a highly visible way. Our results evidenced the existence of a shared technological tradition as can be seen from the unrestricted use of *fabric 1* and the addition of a *standardized combination of grog types*. Most probably, this tradition is connected to a well-established knowledge transmission system in which the inhabitants of the microregion had deep knowledge on the natural resources available on the nearby area and knew the physical properties of the selected raw materials. Our data indicate that most of the potters selected similar raw materials which were further processed in more diverse ways sometimes linked to the intended vessel form. The lack of radiocarbon dates for the investigated site limits the possibility of tracing the temporal extension of the shared technological know-how.

The existence of shared technological traditions certainly argues for the maintenance of a well-established system of knowledge transmission within the same community of practice. In addition, the presence of large amounts of grog types that have no correspondence with the fabrics identified within the analysed ceramic assemblage may prompt towards the existence of various networks of goods exchange with other communities of practice. Further petrographic analysis conducted on ceramic samples selected from other Late Bronze Age sites across the region will allow us to trace the complexity of these interactions. Future analysis will focuson conducting geochemical analysis on the ceramic samples investigated in this study to understand the ceramic recycling process and the technological choices made by the Late Bronze Age communities.

[115] SCHIFFER, SKIBO 1997, 45.

[116] SMITH 2005, 68.

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