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THE LOCAL PRODUCTION OF FINEWARE CERAMICS AT HISTRIA (DOBROGEA, ROMANIA) FROM THE PERSPECTIVE OF ARCHAEOMETRIC RESEARCH. A PRELIMINARY STUDY

Abstract: The article presents the results of petrographic, chemical (SEM-EDS), and isotopic (Sr-Nd) analyses of twelve ceramic samples from Histria. The samples were selected from vessels exhibiting comparable macroscopic characteristics to those observed in the ceramic fabric. The assemblage comprised vessels previously identified in the literature as potential local products, alongside additional examples displaying macroscopically comparable fabric features, which had not yet been recognised as products of the Histria workshops. The research aimed to ascertain whether the petrographic and chemical characteristics corroborate the standard features documented at the macroscopic level, and to evaluate how the archaeometric analyses may shed new light on the subject of local pottery production at Histria. The applied methods enabled the characterisation of the raw material and the distinction of two groups of ceramic fabric, designated as A and B, which suggests disparate sources of clay acquisition.

Keywords: pottery, clay, Black Sea, petrography, isotopes

1. Introduction

A representative group of twelve tableware ceramics covered with red, dark brown, and greyish-brown slip from the ancient city of Histria, a Greek colony on the Black Sea, was subjected to study. The ceramics come from archaeological research conducted in the 1970s in sector T by the Vasile Pârvan Institute of Archaeology, Romanian Academy of Science and from excavations on the Plateau (sector P) conducted by an archaeologist from the University of Texas at Austin with the cooperation of Vasile Pârvan Institute of Archaeology.[1] The ceramics are characterised by a significant chronological span, various vessel forms, and technological differences, revealed by the different colours of the coatings used as well as their application techniques. Concurrently, the pottery fabric exhibited similarities. Given that some of the selected specimens had already been identified in the literature as examples of local production, this hypothesis formed the basis for subsequent research. The objective of the study was to ascertain whether common macroscopic features translate into similarity in the mineral and chemical composition of the clay mass used

[1] The authors would like to thank Iulian Birzescu of the Vasile Pârvan Institute of Archaeology, Romanian Academy of Science and Adam Rabinowitz from the University of Texas at Austin for the opportunity to collect pottery samples from the former excavations in sector T and contemporary archaeological research in sector P (Plateau), Kiln Trench at Histria archaeological site (Romania).

to produce the vessels and, if so, whether it is possible to distinguish one or several petrographic groups based on the analyses conducted. The subsequent phase of the investigation entailed a comparison between the findings of the archaeometric analyses and the results of the typological and chronological studies of the ceramic vessels from which the samples were obtained. An essential aspect of this preliminary research was the evaluation of the production potential of Histria, the archaeological site from which the finds originated, in the context of the pottery workshops discovered within the city and the natural sources of the raw materials accessible in the vicinity of the *polis*. The obtained results complement the knowledge gained from the examination of pottery production undertaken at the site; they also constitute a proposal for a new research method that allows for the distinguishing of samples with shared macroscopically observed features.

2. Geological Setting

Histria is located at the eastern end of the Central Dobrogea tectonic unit, bounded by two major faults, Panacea-Camea to the north and Capidava-Ovidiu to the south [Fig. 1, dashed lines]. Structurally, it is an uplifted fragment of the crystalline basement of the Moesian Platform, locally exposed at the surface in the form of hills composed of Precambrian, slightly metamorphosed sedimentary rocks belonging to the Histria – Greenschist Formation.[2]

Most of the area is covered by extensive Quaternary sediments; starting from the Lower Pleistocene of the loess succession (*sensu stricto*), characterised by an alternation of several (less than seven) loess and palaeosol units of different thickness.[3] According to Ana Conea, followed by Dan C. Jipa, three main types of loess can be distinguished by grain size: sandy-silt loess with ca. 18% clay particles, typical loess, and fine-grained loess containing about 40% clay. The mineralogical composition of loess and palaeosols consists mainly of quartz, calcite, plagioclase-albite, K-feldspar, smectite, chlorite, and the mica group.[4] The Lower Danube River provided most of the loess detrital material; the Carpathian-Balkans is another source of loess and loess-like sediments, which is also indicated by the increased amount of sandy particles.[5]

Loess-like sediments (understood as sediments with loess characteristics but not of eolian origin) represent the fourth type of Dobrogea sediment cover. Compared to loess, they are richer in clay and sand fractions, and represent silty clay and silty clay sediments associated with coarse-grained clastics.[6] The loessoid clays are useful ceramic raw materials, still used for ceramic purposes, e.g. at Cobadin, 38 km west of the city of Constanța.[7] [Fig. 1a and Fig. 1b]

3. Histria. State of Research

3.1. Histria. The Archaeological Site

Histria is located on a peninsula flanked to the north and east by Lake Sinoe, a sea gulf in antiquity, to the west by Histria Lake, and to the south-west by Duingi Lake. The archaeological site is located near the village of Istria [Fig. 1]. Histria is considered a Milesian colony, and the founding

[2] For a detailed description of the geological situation, see Kräutner *et alii* 1988.

[3] Jipa 2013; Constantin *et alii* 2015; Tugulan *et alii* 2016.

[4] Tugulan *et alii* 2016.

[5] Jipa 2014.

[6] Jipa 2013; Jipa 2014.

[7] Marica, Ciornei, Cetean 2004; Radan *et alii* 2013.

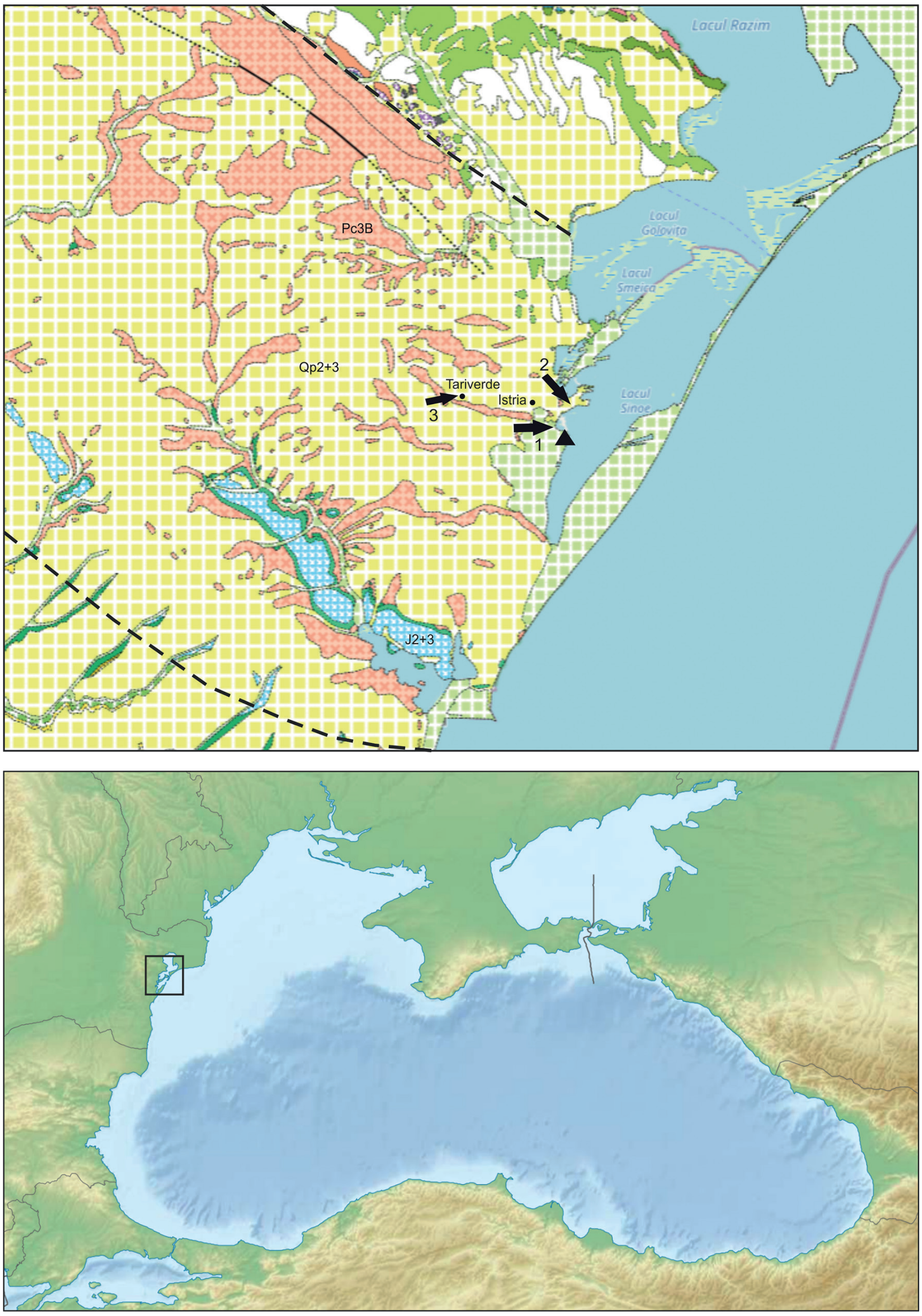


Fig. 1. The geological map of Central Dobrogea, showing the sampling locations of reference rocks and clays, as well as the location of the archaeological site of Histria (simplified after www.geoportal.igr.ro [accessed on 10.10.2025] and Săndulescu *et alii* 1978). Abbreviations: Pc3B – Neoproterosoic greenschists (Histria Formation); J2+3 – Jurrasic carbonates; Qp2+3 – Quaternary loess and loess-like sediments; ▲ – Histria archaeological site. The arrows indicate the locations where the clay and greenschist rock samples were taken: 1 (Histria Lake) – P1, P5; 2 (Sinoe Lake) – P2, P4, P6; 3 (Tariverde) – P8, P9, P10, P11, P12

of this settlement dates to the middle of the seventh century BC.[8] According to written sources, Histria was founded by Miletos[9] in 657 BC[10] or sometime later.[11]

3.2. Histria. Ceramic Production – Archaeometric Analysis – State of Research

During the initial stages of archaeological research at Histria, Vasile Pârvan identified a number of vessels that could have been produced in local pottery workshops. The primary distinguishing factor was the inferior quality of the craftsmanship.[12] In a later publication on Archaic pottery, Marcelle Lambrino excluded the possibility of producing tableware at Histria during this period. The potential for a local provenance was proposed solely in relation to grey ware pottery from the Hellenistic period.[13] Subsequent researchers have indicated the possibility of the production of grey ware pottery at Histria during the mid-fifth century BC[14] and the Hellenistic period.[15] In the following phase of research, Maria Coja presented the initial comprehensive study of ceramics produced on-site. She considered grey ware vessels, as well as vessels covered with black gloss and red slip, to be of local production, dated to the fifth century BC. The publication does not provide a detailed description of the fabrics used in the production of the aforementioned vessels, with the exception of one example where the researcher has indicated that the clay used was 'light pink and the ornamentation was created using red slip'.[16] Additionally, M. Coja proposed a potential regional distribution of vessels produced at Histria. In her following publication, M. Coja identified a series of grey ware pottery dating from the sixth to the first century BC as a set of local vessels.[17]

Petre Alexandrescu created the first definition for pottery produced locally at Histria based on the characteristics of the clay used. He formulated the hypothesis that the vessels made of pottery fabrics containing shell fragments was of local origin.[18] In his follow-up publication, he delineated two clay fabrics that were distinctive of vessels produced at Histria. The first fabric is distinguished by the presence of shells (*l'argile à coquillages*), while the second is characterised by whitish clay (*l'argile blanchâtre*). As a result of the reanalysis, a third distinguished group, described as chalk clays (*l'argile crayeuse*), was found to be a more basic variety of the shell clay fabric. As the author described it, the shell clay fabric is sandy and strongly micaceous, contains rare red-brown particles and calcareous concretions, and remains of white or grey shells can be seen, which lends support to the group's name. A total of 16 archaeometric analyses of ceramic examples dated from the sixth to the end of the fourth–beginning of the third century BC were conducted using the nuclear activation method at the Brookhaven National Laboratory in the USA.[19] The findings of these studies provided the initial geochemical characterisation of pottery believed to have been produced at Histria.

Subsequent research, including supposed examples of local vessels from Histria dating from the Archaic to the Byzantine period, was carried out by the researchers Maria Coja and Pierre Dupont. Typological and stylistic analyses were conducted in conjunction with archaeometric research. Furthermore, examples of raw materials from neighbouring archaeological sites in the area, including Sinoe-Zmeica (5 km north of the Histria site), Tariverde (18 km west), Jurilovca/Argamum (50 km north), and Constanta (60 km south), were selected for archaeometric research.[20]

[8] Avram, Hind, Tsetskhladze 2004; Alexandrescu 1978a; Alexandrescu 1978b; Alexandrescu 1990; Dupont *et alii* 1999.
[9] Hdt. 2.33; Ps.-Skymnos, fr. 6.
[10] Euseb. Chron. 95b.
[11] Ps.-Skymnos, fr. 6.
[12] Pârvan 1916; 1928; Coja, Dupont 1979.
[13] Lambrino 1938.
[14] Dimitriu, Zirra, Condurachi 1954.
[15] Dimitriu, Coja 1958.
[16] Coja 1962, p. 118.
[17] Coja 1968.
[18] Alexandrescu 1966.
[19] Alexandrescu 1972.
[20] Coja, Dupont 1979.

A series of 716 X-ray fluorescence analyses were performed at the Le laboratoire ArAr – Archéologie et Archéométrie (Le Laboratoire de Céramologie de Lyon), under the direction of Henri Metzger, Stéphanie Boucher, and Maurice Picon. The research yielded a group of ceramics that exhibited characteristics indicative of a local origin, among examples of high-quality Archaic vessels. Furthermore, it was determined that the two groups identified by P. Alexandrescu in 1972, primarily for pottery from later periods, constitute a single entity.[21] The observed colour difference can be attributed to the more intense firing of the clay. In his description, P. Dupont characterised the local pottery as a clay fabric with a porous structure and a sandy composition. The clay contained varying quantities of mica, small limestone concretions, and shell remnants.[22]

Subsequently, in 2013, archaeological analyses were conducted on selected ceramic samples representative of the West Slope Style. As part of an archaeological programme designed to ascertain the provenance of local pottery from Apollonia Pontica, Le laboratoire ArAr – Archéologie et Archéométrie conducted a comparative analyses of the regional variation between Apollonia Pontica and Histria vases. A total of thirty samples were subjected to analyses, sixteen of which exhibited West Slope style decoration. The results of the conducted research enabled the distinction of vessels belonging to the Histrian West Slope style.[23]

3.3. Histria. Pottery Kilns

The first archaeological evidence for pottery workshops at Histria emerged as a result of excavations carried out in the 1950s in Sector Z2 of the western part of the Plateau, where four pottery kilns and pits with post-production waste dating back to the fifth–fourth century BC and Hellenistic Period were discovered. Another four pottery kilns dated to the fifth and fourth centuries BC were uncovered during the campaigns in 1956 and 1957. A pit labelled as pit ε was discovered near one of these kilns, in which, among the other artefacts, ceramics considered examples of local products were found; no spatial, stratigraphic, or chronological analyses were performed that would have helped to explain the relationship between the discovered kilns and pits located nearby (pit γ). Exploration continued at the Plateau between 1963 and 1970, finding another seven pottery kilns in Sector Z2, all dated to the Classical Period. During the excavations in 1973 and 1975 at the western end of the Plateau, five kilns were unearthed: one is dated to the Archaic, two to the Classical and two to the Hellenistic Period.[24] Excavations conducted over the last decade led to the discovery of another kiln in the Plateau area, unearthed in the Kiln Trench (KT) in 2018.[25] The discovery of a Roman-period pottery kiln has also been reported in the literature. However, this find is mentioned in only a limited number of publications, which provide merely a generalised location and lack any detailed description or illustration of the kiln's form and dimensions.[26]

4. Materials and Methods

4.1. Materials

The assemblage analysed in this study consists of high-quality tableware recovered during excavations conducted in several areas of the site, namely Secret Zone (Sector T), Plateau (Sector P), the Pârvan Basilica, and Sector SG. Based on macroscopic analyses, fourteen groups sharing the similar

[21] Alexandrescu 1972.
[22] Coja, Dupont 1979.
[23] Lungu 2013.
[24] Coja, Dupont 1979, pp. 18–33.
[25] Iancu *et alii* 2020, pp. 205–210.
[26] Iliescu, Botis 2018.

fabric and slip characteristics were identified (macroscopic groups, MG). Among these, two groups —MG 1 and MG 8—exhibit features characteristic of local pottery as described in the literature.

4.2. Method

Each artefact was examined macroscopically. The assessment was conducted under daylight conditions through observation of both the surface and fresh fabric fractures, using conservation lenses providing 25× magnification. A preliminary macroscopic fabric classification was established based on fracture and surface characteristics, the shape and size of inclusions and pores, as well as hardness, brittleness, compactness, fabric texture, and surface treatment techniques.[27] The typological and chronological classification was undertaken on the basis of previous research conducted at Histria, together with established reference works that present tableware assemblages in a chronological framework from other sites in the Black Sea and Mediterranean regions.[28]

During the first stage of the petrographic analyses, the samples were examined microscopically and documented using an Olympus SZX-9 binocular microscope. Petrographic thin sections were made transversely to the coating slip layer. The study was performed in transmitted and reflected light using an Olympus AX70 Provis petrographic microscope. Chemical analyses of the clayey background were performed by scanning an area of approximately 0.5 mm², whereas the slip was analysed by spot analysis using a Hitachi S-370N scanning electron microscope (SEM) operated in backscattered electron (BSE) mode and coupled with an energy-dispersive X-ray spectrometer (EDS). The analyses were performed in the Institute of Geology, Adam Mickiewicz University in Poznań. Finally, five selected samples representing both fabric types were subjected to Sr-Nd isotopic analyses. They were performed in the Isotope Geochemistry Laboratory at the Institute of Geological Sciences, Polish Academy of Sciences, Kraków, according to procedures outlined by Aneta A. Anczkiewicz and Robert Anczkiewicz in 2016 to confirm the common or separate provenance of both fabric types.[29]

4.3. Studies of Local Clays and Crystalline Rocks

Samples of local clays collected from the shores of Lake Histria and Lake Sinoe, as well as from a stream flowing north-west of Tariverde, were used as reference material. The study was supplemented by three lithological varieties of greenstone rocks collected from the surface of the surrounding fields (Fig. 1). The clays were formed into bricks, from which thin sections were prepared, and subsequently subjected to petrographic investigation and SEM–EDS analyses to determine their chemical composition

5. Results

5.1. Archaeological Results

Macroscopic Characteristics
Macroscopic Group 1 (MG1) is characterised by a sandy fabric of a very pale brown to pinkish colour (Munsell 10YR 8/2–3; 10YR 7/3–4; 7.5YR 8/2, 8/4). The coating colour of MG1 ranges from

[27] Orton, Hughes 2013, pp. 71–80.
[28] Alexandrescu 1972; Sparkes, Tallcot 1970; Morel 1981; Hayes 1991; Elaigne 2007a; Buzoianu, Barbulescu 2008; Japp 2009; Kögler 2011.
[29] Anczkiewicz, Anczkiewicz 2016.

dark brown (His10/19), or brown (His06/19; His11/19; His30/19), to brown with a slight red tint (His01/22). The coating colour of MG1 ranges from dark brown (His10/19), or brown (His06/19; His11/19; His30/19) to brown with a slight red tint (His01/22). The slip was applied when dilute, with single brushstrokes noticeable at the surface, rather matt, and often covers the surface with one single layer.

Macroscopic Group 8 (MG 8) is characterised by a very pale brown to light brown, brown and reddish-yellow colour of fabric (Munsell 10YR 7/3; 5YR 7/4–3; 7.5YR 6/4, 6/6; 7.5YR 5/2). It is also sandy but displays lower porosity than MG1. The slip colour of MG8 vessels falls within a range from light red with an orange tint (His22/26) to dark orange with a red tint (His25/22), including orange (His28/22) and dark orange with a brownish tint (His27/22; His24/22). One vessel is characterised by a brown slip with a greyish tint (His28/19), and a single example displays a black-greyish tint (His25/19). The slip is of different thicknesses, so the individual layers, single brushstrokes, and the body surface showing through them are visible macroscopically, except for samples His25/19 and His28/19, which are covered with a thicker black slip.

Chronology

MG1 (His06/19; His10/19; His11/19; His30/19; His01/22), comprising colour-coated vessels, represents a wide chronological range. Among the bowls there is an example of a deep bowl with an incurving rim dated to the late third–second century BC (His06/19),[30] and an example of a bowl with out-turned rim is dated to the second half of the second century BC (His30/19).[31] The plate (His10/19)[32] can be dated to the second century BC, and a vessel of the Megarian bowl type (His11/19)[33] to the first half of the first century BC. The earliest chronological horizon, referring to the first century AD, is represented by a bowl or plate (His01/22),[34] coloured inside and reserved in clay colour on the outer surface (at least on the preserved fragment), which has a decorative motif in the form of a spiral made of individually impressed dots.

An extensive chronological range characterises MG8 (His28/19; His25/19; His24/22; His25/22; His26/22; His27/22; His28/22). The dating is based on the morphological characteristics of the vessels. The earliest examples appear to be mushroom jugs (inv. nos. His24/22;[35] His27/22).[36] The artefacts from Histria are comparable to the vessels produced in Athens, due to their characteristic shape, where they are classified as a variant of *oinochoe* and dated to the last quarter of the fifth century BC.[37] It should be emphasised that finds of vessels similar in form and decoration come from, among others, Apollonia Pontica, where they are dated to the fourth century BC; examples

[30] Buzoianu, Barbulescu 2008, pl. LXXV, C-119; Hayes 1991, figs. XL:24, XLIII:36, dated to the mid-second century BC; Kögler 2011, fig. 12:D.72, dated to the end of the second–first half of the first century BC; Rotroff, Oliver 2003, p. 26, pl. 7:34, dated to the second–first centuries BC.

[31] Wintermeyer 2004, p. 71, fig. 186, inv. no. 252, Type Te 4.14 – West Slope style dated to the third century BC; Elaigne 2007a, pp. 523–524, 542, fig. 7:2, dated to the end of the second–beginning of the first century BC; Elaigne 2007b, fig. 14. inv. no. 98–53, dated to the third quarter of the second century BC.

[32] Burkhalter 1987, p. 369, fig. 8:41, 42, dated to the second century BC.

[33] Japp 2009, pp. 110 and 244, dated to the first century BC–first century AD; Elaigne 2007a, p. 208, fig. 6:3 (Knidian example); Kögler 2011, fig. 63:Kn.284 (dated to the end of the second–first century BC), pl. 2:B29 (the third/second–beginning of the first century BC), pl. 12:E.44 (the last quarter of the second–beginning of the first century BC). The form from Histria is influenced by Knidian products dated to the beginning of the first century BC.

[34] Elaigne 2007a, pp. 534, 555, fig. 27:2272.

[35] Compare with the vessels: Alexandrescu 1966, fig. 7:1; Alexandrescu 1978a, pp. 96, 103–104, pls. 631, 677, 678; Sparkes, Tallcot 1970, p. 248, fig. 3:166, pl. 9:166, dated to 425–400 BC; Morel 1981, type F5111, dated to the end of the fourth century BC.

[36] Compare with: Sparkes, Tallcot 1970, p. 248, pl. 9:173, dated to 325–310 BC; the form is also known in this assemblage: Morel 1981, type F5114a, dated to the end of the fourth–third century BC.

[37] Alexandrescu 1978, pp.103–104, pl. 69:677, 678; Sparkes, Talcott 1970, pp. 66–68.

of undecorated vessels are also known from this site.[38] The presence of Athenian imports in the case of mushroom jugs has not been confirmed at any site. The next example, of a red slip closed-type vessel, is an oinochoe; because both sherds of this type are fragmentarily preserved, they can only be broadly dated to the fourth/third century BC (His28/19; His28/22).[39] Red slip pottery is also represented by two examples of bowls with incurving rim (His25/22; His26/22).[40] It should be remembered that further research is required to verify the chronology of the aforementioned red slip pottery, as the repertoire of shapes is not limited to these forms.[41]An example of a drinking vessel, His25/19, can be dated to the Hellenistic period.[42]

A detailed typological and chronological analyses of the vessels is presented in Table 1. [Tab. 1]

5.2. Petrographic Results

Twelve samples from two macroscopic groups (MG 1, MG 8), considered to represent local pottery production, were selected for archaeometric studies.

Under the microscope, the assemblage is not homogeneous, especially in terms of the composition of the sand-size components and the degree of sorting. Thus, we have distinguished two type of fabrics: A and B [Figs. 2, 3]. An overall summary of the petrographic features is provided in Table 2. [Tab. 2]

5.2.1. Fabric A

Fabric A (samples: His25/19; His28/19; His24/22; His25/22; His26/22; His27/22; His28/22) are sintered to varying degrees. Specimens His25/19 and His27/22 are highly sintered and amorphous. In contrast, samples His25/22, His26/22, and His28/22 are poorly fired and their background remains anisotropic. The non-plastic components are well sorted, and the amounts of silt-size quartz and fine red oxidised biotite lamellae ca. 30% vol. Sample His25/22 is more clayey, containing no more than 15% of silt-size, mostly angular admixture. Only a few sand-size grains are present (ca. 5% vol.), including sub-rounded quartz, quarzitic sandstone, well-preserved plagioclase and some quartz-biotite aggregates [Figs. 4, 5]. Among the heavy minerals, red oxidised hornblende and tourmaline are present.

[38] Hermary *et alii* 2010, pl. 105:a (CC 14, 26, 27), dated to 390–380 BC; Nadyalkov 2020, pl. 6:53, 55, 56.

[39] Sparkes, Talcott, 1970, p. 145, fig. 2:128, dated to 350–325 BC.

[40] His25/22: Rotroff 1997, p. 341, fig. 63:1006, dated to 225–175 BC; Elaigne 2007a, p. 547, fig. 15:812; His26/22: Rotroff 1997, p. 343, pl. 63:1021, dated to 250–200 BC; Hermary *et alii* 2010, pl. 74i (f7), dated to 280–260 BC.

[41] It is worthwhile mentioning that the forms of red slip vessels with distinctive fabric characteristics, which are discussed in this paper, represent only a portion of the vessels of this category known from Histria. Fish plates with a raised edge around a rectangular-shaped central depression, a ring foot, and an overhanded rim are particularly distinctive within this group. A multitude of variants of these fish plates have been unearthed at the site, and examples of such fish plates have also been found at Olbia Pontica (Buyskih 2011, pp. 242–264; Handberg *et alii* 2010, pl. 134:Dc-461) and Nikonion (the information presented here is based on the personal research of Inga Głuszek. It should be noted that the archaeological materials have not yet been published). Examples of this type in grey ware, covered with black gloss and with a plain surface, are known from Olbia Pontica and the Panskoe archaeological site (Stolba, Rogov 2012, pl. 33:B 122). It can be stated, therefore, that the shape of this vessel is not comparable to any example of a vessel produced in Athens or other Greek city in the Classical or Early Hellenistic periods. Furthermore, one-handled bowls represent another notable category of red-slip vessels unearthed at Histria and other Pontic sites. In this instance, the types are similar to those found in Athens.

[42] Petit 1995, fig. 7:4, dated to the first quarter of the third century BC.

Tab.1. Typological and chronological summary of Histria samples by their shape and decoration technique features

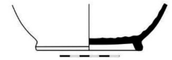
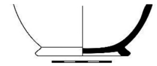
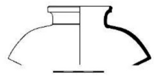
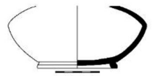
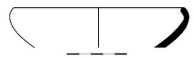
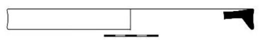
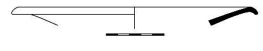
Sample no.	Macro-scopic group (MG)	Petrograph-ic group (PG)	Archaeological context	Shape		Fabric colour (in Munsell scale)	Chronology (century/-ies)
His25/19	8	A	HIS.1960_T21	cup		outside: 7.5YR 6/6 (reddish yellow) inside: 7.5YR 5/2 (brown)	first quarter of the third century BC
His28/19	8	A	HIS.1973_T50	oinochoe		10YR 7/3 (very pale brown)	second half of the fourth/ third century BC
His28/22	8	A	His19 Plat_KT031	oinochoe		5YR 7/4 (pink)	second half of the fourth century BC
His24/22	8	A	His19 Plat_KT031	maschroom jug		5YR 7/4 (pink)	end of the fifth – fourth century BC
His27/22	8	A	His19 Plat_KT031	maschroom jug		5YR 7/3 (pink)	fourth century BC
His25/22	8	A	His19 Plat_KT031	incurving rim bowl		out/in-side: 2.5YR 6/6 (light red) core: 7.5YR 6/4 (light brown)	end of the third – beginning of the second century BC
His26/22	8	A	His19 Plat_KT031	incurving rim bowl		out/in-side: 5YR 7/4 (pink) core: 2.5YR 6/4 (light reddish brown)	third century BC
His06/19	1	B	HIS.1972_T63	incurving rim bowl		10YR 7/3-4 (very pale brown)	second – first century BC
His10/19	1	B	HIS.1971_T66	plate		10YR 8/2-7/2 (very pale brown – light gray)	second century BC
His11/19	1	B	HIS.1971_T.66	Megarian type bowl		10YR 8/3 (very pale brown)	first half of the first century BC
His30/19	1	B	HIS.1971–1974_T	outturned rim deep bowl		7.5YR 8/2 – 10YR 8/3 (pinkish white – very pale brown)	second half of the second century BC
His01/22	1	B	His19 Plat_KT001	plate		7.5YR 6/4 (light brown)	first BC – first AD

Fig. 2. Fabric A, cross-section of specimen His25/19 under stereoscopic microscope (photo by J. Michniewicz)

Fig. 3. Fabric B, cross-section of specimen His30/19 under stereoscopic microscope (photo by J. Michniewicz)

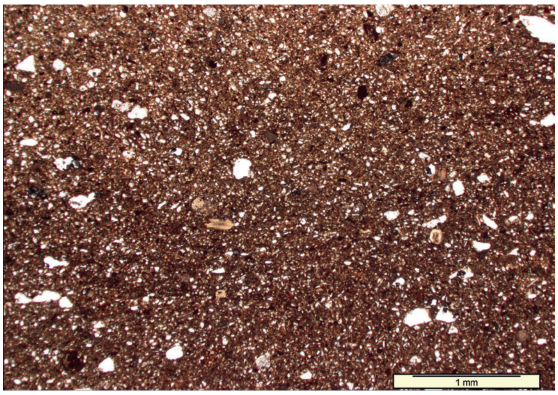


Fig. 4. Fabric A, sample His25/22. Microscopic view, plain polarised light (PPL). Width of scale 1 mm (photo by J. Michniewicz)

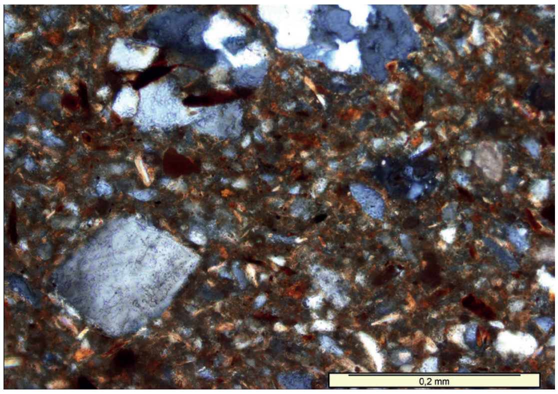


Fig. 5. Fabric A, sample His25/22, crossed polarised light (CPL). Sand-size components: mono- and polycrystalline quartz, quartz-biotite schist fragment. Width of scale 0.2 mm (photo by J. Michniewicz)

5.2.2. Fabric B

Fabric B (samples: His06/19; His10/19; His11/19; His30/19; His01/22) is petrographically different and richer in sand-size lithic fragments. Under the microscope, in plain polarised light (PPL), the matrix is reddish-grey and greenish-grey, with dispersed yellowish-gold secondary carbonates in crossed polarised light (CPL). Generally, the background is highly sintered, isotropic, and calcareous. Non-plastic silt-sized particles cover 20–25% of the area [Fig. 6:1]. Quartz predominates (>70%), fine thin sheets of oxidised red biotite are common (ca. 15%), a few (5%) usually single coarse laths of muscovite, and very few (2%) feldspars mainly plagioclase [Fig. 6:2]. In contrast to fabric A, there is a large petrographic spectrum of fine sand-size lithic fragments. Most common are biotite-rich metasandstone [Fig. 6:3], quartzite metamudstone [Fig. 6:4], crystalline quartz-feldspar gneiss or granitoid fragments, as well as quartz-biotite phyllite [Fig. 6:5].

Tab. 2. Petrographic dataset of the fabric A and B ceramics

Sample no.	Fabric	Groudmass				Temper																								
						Silt				Sand																				
		colour in PPL	colour in XPL	anisotrophy	raw clay type	silt frequency	Qz silt	carbonates/milky overcollors after CaCO3	opaque iron oxides	sand frequency %	size	roundness	fine biotite	fine muscovite	argillaceous red mudstones	quartz	Qz-Kf	Qz slates	feldspars	k feldspars	plagioclase	cherts	Qz-mica slates/shists	gneise	granitoide	metasandstone	large muscovite / biotite	volcanites	volc glass	Qzuartzite sandstone	limestone	pyroxene, amphibole
His25/19	A	gray	reddish-gray	0	marly silty clay	15	2	2	0.2	<5	fine	varied	1	1	0	1	0.2	1	1	1	1	0	**0**	0	0	0	1	0	0	0	0	0
His28/19	A	light reddish-gray with greenish tan	goldish-gray	0.5	marly silty clay (qz silt+ dispersed fine red biotite)	30	2	2	1	<2	fine	subangu-lar-ang	1	1	0	1	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0.2	0
His24/22	A	creamy-beige	greenish-gray	0	marly silty clay	30	2	0.5	0	<2	fine	varied	1	1	0	1	0.2	0	0.2	0	0	0	**0**	0.2	0	0	0	0	0	0	0.2	0
His25/22	A	beige	reddish-gray	1	marly silty clay	30	2	2	1	5	fine-med	varied	1	1	0	1	1	0.2	1	1	1	0	**1?**	0	0	0	1	0	0	0.2	1	0
His26/22	A	light orange-red	reddish-gray	1	marly silty clay	30	2	2	0	5	fine	varied	1	1	0	1	0	0	1	1	1	0	**?**	0	0	0	0	0	0	0	0	0
His27/22	A	reddish-gray	reddish-gray	0	marly silty clay	30	2	2	0	5	fine	varied	1	1	0	1	0.2	0.2	1	1	1	0	**1?**	0	0	0	0	0	0	1	0	0
His28/22	A	light brown	grayish-red	0.5	marly silty clay	30	2	1	0.5	5	fine-med	varied	1	0.5	0	1	0	0	1	0	0	0	**0**	0.2	0.2	0	0	0	0	0	0	0
His6/19	B	light green-ish-gray	reddish-green	0	marly silty clay (qz silt+ carbon-ates +dispersed fine red biotite)	25	2	2	1	5	medium	sub and ang	1	1	0	2	1	0	1	1	1	1	**1**	0	?	0	0.2	0	0	0	0	1?
His10/19	B	greenish-gray	goldish- green	0.5	marly silty clay (qz silt+ dispersed fine red biotite)	25	2	2	1	5	fine to coarse	angular and sub	1	1	1	2	0	0.2	1		1	0	**1**	1	?	1	1bi	0	0	0	0	0
His11/19	B	light gray with greenish tan	greenish-gray	0	marly silty clay (qz silt+ dispersed fine red biotite)	20	2	2	1	5	fine-med-coar	ang-subang	1	1	1	2	1	0.5	1	1	1	1	**1**	1	?	2	0	0	0	0	1	0.2
His30/19	B	light red	greenish gray	0	marly silty clay	25	2	2	1	20	medium	varied	1	1	1	1	1	1	1	1	1	1	**1**	1	?	2	1	0	0	1	0	1
His01/22	B	light brown	light red	0.5	marly silty clay	25	2	2	0	20	medium	varied	1	1	1	1	1	1	1	1	1	1	**1**	0	?	2	1	0	0	1	0	0

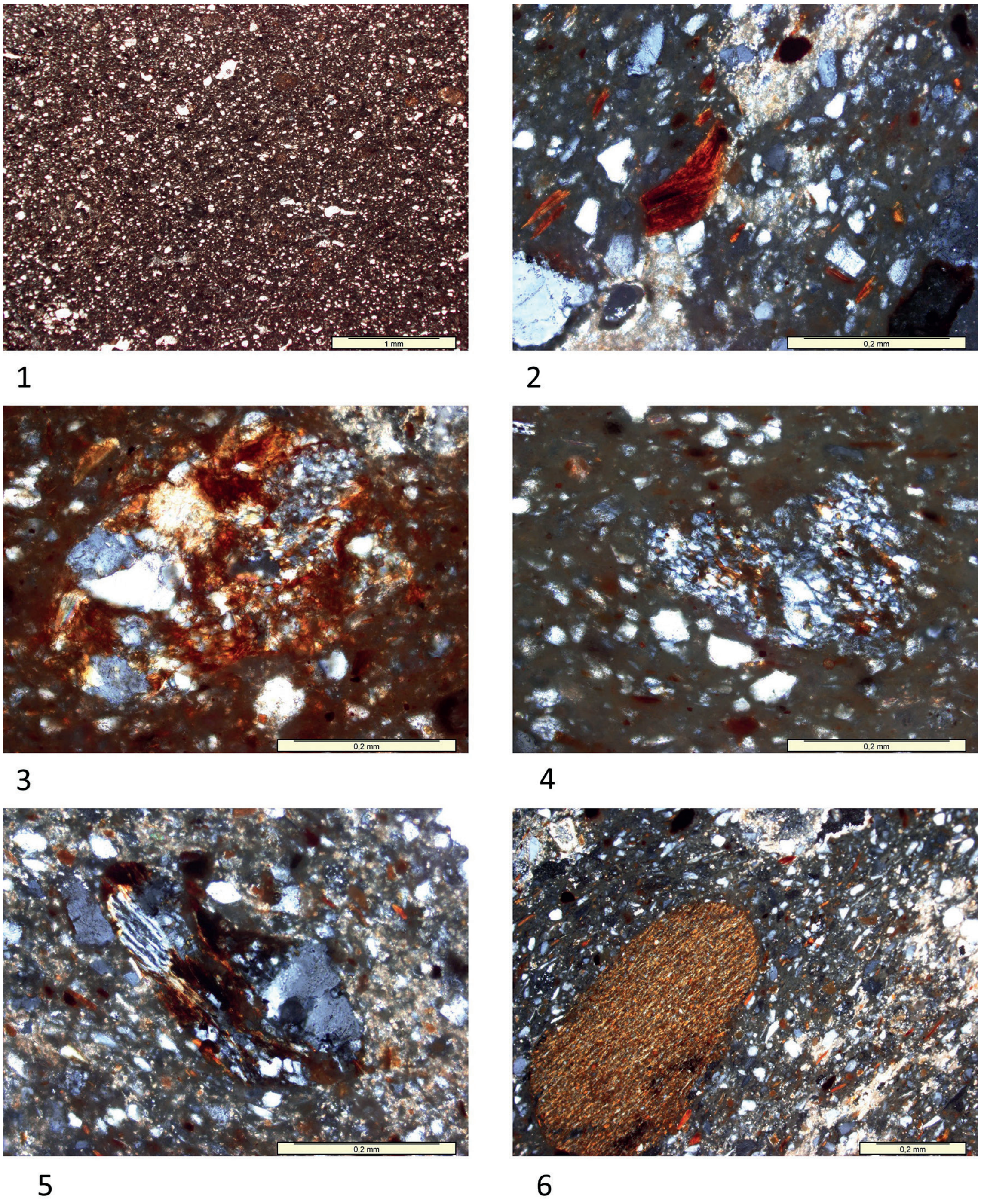


Fig. 6. Fabric B: microscopic views. 6.1 – Fabric B, sample His10/19. Scale bar: 1 mm, PPL. 6.2 – Fabric B, sample His10/19. Microscopic view of the matrix at higher magnification. Scale bar: 0.2 mm, CPL. 6.3 – Fabric B, sample His01/22. Metasandstone fragment. Scale bar: 0.2 mm, CPL. 6.4 – Fabric B, sample His11/19. Metamudstone fragment. Scale bar: 0.2 mm. 6.5 – Fabric B, sample His10/19. Quartz-biotite phyllite fragment. Scale bar: 0.2 mm, CPL. 6.6 – Fabric B, sample His10/19. Orange-fire metashale (greenschist) fragment. Scale bar: 0.2 mm, CPL (photo by J. Michniewicz)

Some coarse feldspars and mosaic chert are present. Especially diagnostic is the presence of fine orange-fired metashale fragments [Fig. 6:6]. The predominant heavy minerals are sphene and ilmenite.

Both fabrics show almost identical chemical composition of the micromass [Fig. 7]. Fabric B is more homogeneous, which is reflected in the lower standard deviation values, especially in the Fe content cf. in Table 3. [Tab. 3]

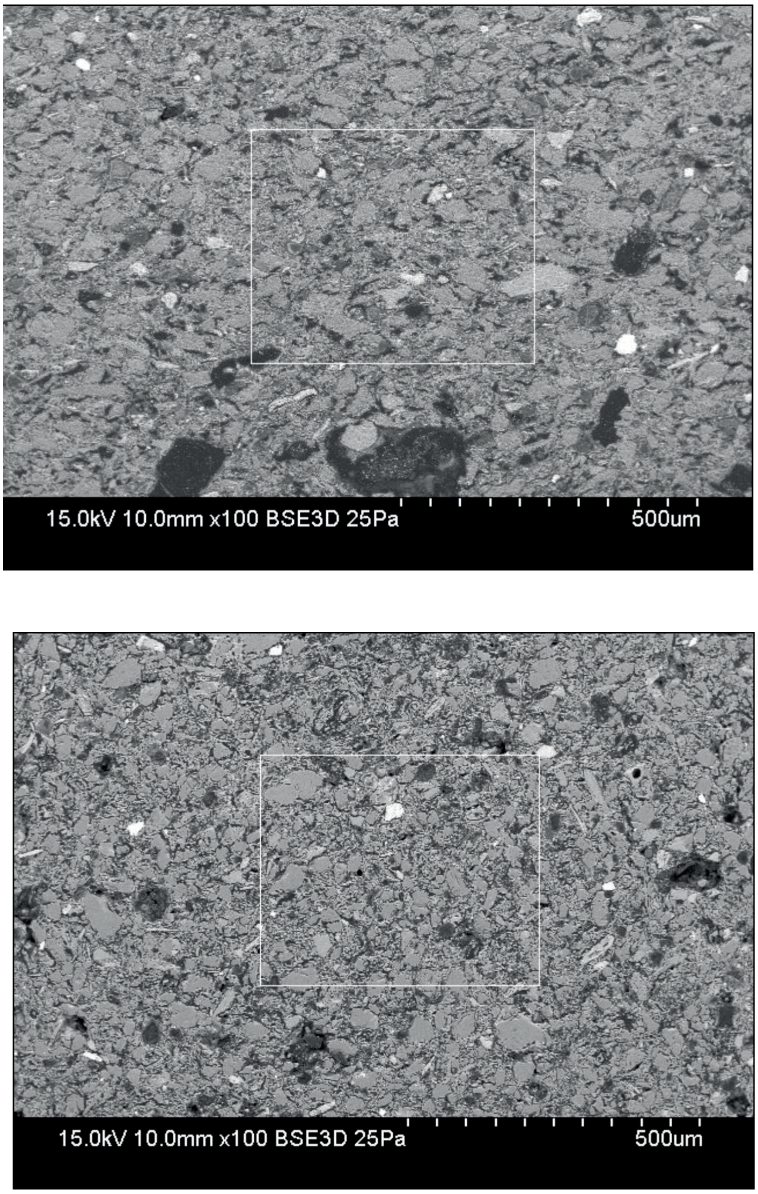


Fig. 7.Sample SEM–BSE images.
7.1 Sample His28/19—SEM–BSE image
showing a representative microtexture of the raw material for Fabric A.
7.2 Sample His06/19—SEM–BSE image
showing a representative microtexture of the raw material for Fabric B.
The white rectangle indicates the area of chemical analyses
(photo by J. Michniewicz).

Tab. 3. Semi-quantitative chemical composition obtained by SEM-EDS analyses of the micromass of samples assigned to fabrics A and B with comparison to average concentrations M of Dobrogea Late Quaternary loess deposits from the Constinesi-Dobrogea (after Tugulan *et alii* 2016)

	Fabric A [wt.%]									Fabric B [wt.%]							Costinesti samples (Tugulan *et alii* 2016)	
Element	His25/19	HIS28/19	His24/22	His25/22	His26/22	His27/22	His28/22	M	SD	HIS06/19	HIS10/19	HIS11/19	HIS30/19	His01/22	M	SD	M	SD
SiO2	59.7	62.48	63.11	63.01	64.83	66.7	65.77	**63.7**	2.3	63.7	61.75	62.46	62.14	63.7	**62.8**	0.8	62.83	2.73
TiO2	1.08	0	0	0.58	0.85	0	0	**0.4**	0.5	0		1.15	0.83	0.76	**0.7**	0.4	0.7	0.7
Al2O3	16.28	11.16	11.45	12.2	12.97	12.15	12.46	**12.7**	1.7	14.17	13.73	13.6	13.1	14.68	**13.9**	0.5	14.53	1.63
FeO	6.33	6.43	4.95	4.46	4.39	3.35	5.31	**5.0**	1.1	4.75	4.34	5.04	4.91	4.82	**4.8**	0.2	5.34	0.7
MgO	3.24	3.02	2.81	2.83	3.25	2.65	2.96	**3.0**	0.2	2.87	3.29	2.64	1.83	2.7	**2.7**	0.5	2.48	0.3
CaO	8.37	12.79	11.97	11.68	8.79	10.42	8.94	**10.4**	1.8	9.42	12.15	10.38	13.9	8.57	**10.9**	1.9	9.51	1.74
Na2O	1.2	1.65	2.01	2.35	2.07	2.46	2.1	**2.0**	0.4	1.8	2.39	1.57	0.95	1.81	**1.9**	0.3	2.51	0.31
K2O	2.76	2.52	2.06	2.88	2.86	2.27	2.47	**2.5**	0.3	2.2	1.84	1.85	2.3	2.05	**2.0**	0.2	1.99	0.17
MoO3	0	0	0	0	0	0	0	**0.0**	0.0	0	0	1.29	0	0	**0.3**	0.5	-	-
SO3	0	0	0	0	0	0	0	**0.0**	0.0	1.1	0.52	0	0	0.9	**0.5**	0.5	-	-

wt.% – weight percent

5.3. Isotopic Composition of Sr and Nd

The Sm-Nd and Sr isotopic data ratios of the five Histria samples (His01/22; His30/19; His28/19; His025/22; His27/22) are shown in Table 4. [Tab. 4] The four samples are very similar and only His01/22 is notably different, as far as Sr isotopes are concerned. The two groups can be differentiated only on the basis of Nd isotopes. Figure 8 shows the radiogenic differentiation of fabrics A and B. [Fig. 8]

Tab. 4. Results of Sm-Nd and Sr isotope analyses. Reproducibility of SRM 987 standard over the course of analyses yielded an $^{87}Sr/^{86}Sr$ ratio of 0.710274 ±12 (2SD, n=5). Reproducibility of JNd-1 standard over the course of analyses yielded an $^{143}Nd/^{144}Nd$ ratio of 0.512090 ±14 (2SD, n=8). The precision refers to the last significant digits. Errors reported for $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ are given as 2SE (standard error). The error for $^{147}Sm/^{144}Nd$ is estimated at 0.3%

Sample	Fabric	Weight (g)	Sm [ppm]	Nd [ppm]	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	2SE	εNd	$^{87}Sr/^{86}Sr$	2SE
His25/22	A	0.0910	5.579	28.269	0.1193	0.512108	0.000003	-10.3	0.712206	0.000013
His27/22	A	0.0917	6.788	34.106	0.1203	0.512119	0.000003	-10.1	0.712403	0.000012
His28/19	A	0.0976	6.498	31.069	0.1264	0.512110	0.000003	-10.3	0.712316	0.000015
His001/22	B	0.0923	7.150	35.732	0.1210	0.512200	0.000003	-8.5	0.712873	0.000009
His30/19	B	0.0930	6.187	30.687	0.1219	0.512180	0.000004	-8.9	0.712142	0.000014

The $^{143}Nd/^{144}Nd$ isotope ratios divide the samples according to the petrographic observations: fabric A shows a lower Nd radiogenity value of 0.512108–0.512119 (εNd of -10.1 ÷ -10.3) while fabric B Nd-isotope ratios are higher at 0.512180–0.512200(εNd = -8.5 ÷ -8.9).

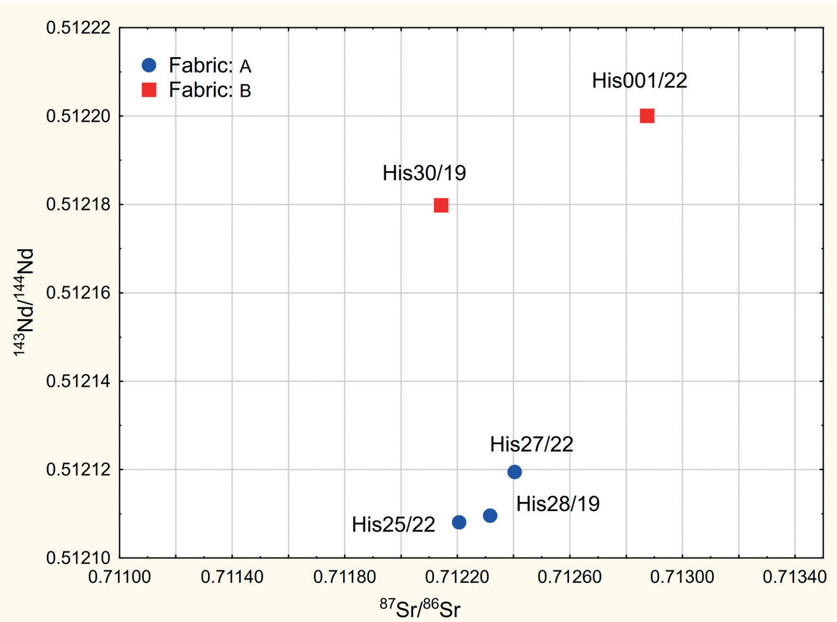


Fig. 8. Sr and Nd isotopic composition diagram of Histria samples.

5.4. Local Crystalline Rocks

The analysed local rocks are green (samples P6, P12) and light green (sample P5), and show variable, weakly developed schistosity, macroscopically aphanitic (P6, P12) and fine sandy (P5) with varied weathering. Under optical examination, these rocks reveal a broad spectrum of metamorphic alteration. They represent metamorphosed sediments of varying grain size, ranging from metapelite composed of fine-grained quartz and phyllosilicate minerals—mainly sericite and chlorite—to porphyroblastic phyllite composed of fine quartz, greenish sericite, and isolated chloritised amphibole porphyroblasts. Also present are metamudstones composed of fine, sand-sized quartz–feldspar grains set in a quartz–chlorite mosaic with laths of biotite–plagioclase–epidote and subordinate calcite, followed by medium-grained metaarcose (feldspar-rich sandstone) displaying a microgneissic to mylonitic texture and consisting of quartz and feldspars (mainly plagioclase) of the sandy fraction (Fig. 9). Equally abundant mosaic quartz (mylonitised?) co-occurs with lamellae of chloritised biotite, muscovite, numerous automorphic plagioclase, and chlorite, as well as multicoloured epidote. Diagnostic, irrespective of the degree of metamorphism, is the presence of euhedral to subhedral magnetite. Another diagnostic feature is the presence of brownish-red metashale fragments, with a texture and colour analogous to those observed in ceramics, as well as to experimentally fired, locally occurring greenschist [cf. Fig. 6:2; 9:1.9:2 and Fig. 17].

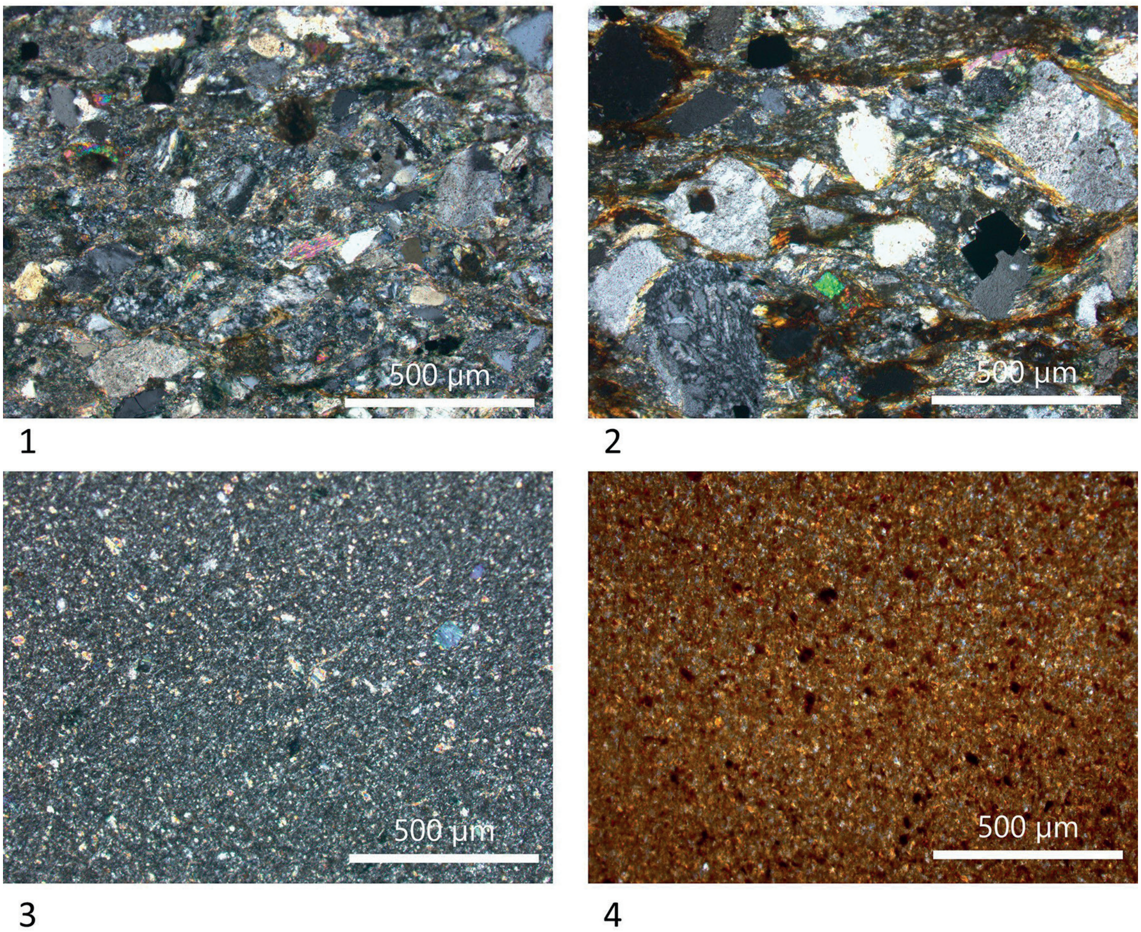


Fig. 9. Petrographic images of local rocks of the Histria formation.
9.1 – Sample P12 (CPL); 9.2 – Sample P12 fired at 750 °C (CPL) – note the change in the colour of the rock caused by firing; 9.3 – Sample P5 (CPL); 9.4 – Sample P6 (CPL); photo by J. Michniewicz.

5.5. Local Clays

The moulded bricks of the local clays were fired at 750 °C [Figs. 10, 11]. Following firing, samples from Lake Histria (P1 and P3) and sample P8 from the Taviverde area retained a light hue, while the remaining samples turned brick-red [see Fig. 10]. Petrographically (optically), all samples are dominated by silt-sized (pelitic) quartz, co-occurring with small lamellae of phyllosilicates, mainly biotite and muscovite; feldspars are also common. Similarly to the analysed vessels, samples P1, P3, and P8 represent pelitic-fraction sediments with a very good degree of sorting, containing only isolated grains of the fine sand fraction [Fig. 12]. The remaining samples (P4, P9, P10, P11) are less well sorted and therefore contain grains of the medium sand fraction within a predominantly silt-sized mineral matrix [Fig. 13].

Fig. 10. Clay samples before firing from Histria Lake (1 – sample P1; III – sample P3; IV – sample P4) and from the Taviverde vicinity (8 – sample P8; X – sample P10; 11 – sample P11); photo by J. Michniewicz.

Fig. 11. Clay samples shown in Fig. 10, after firing at 750 °C (photo by J. Michniewicz).

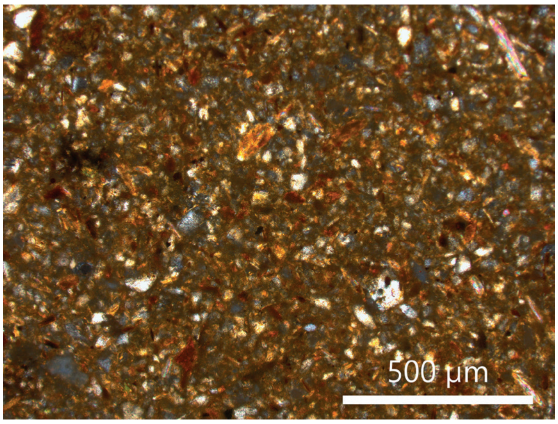


Fig. 12. Loess sample P3, microscopic view (CPL); photo by J. Michniewicz.

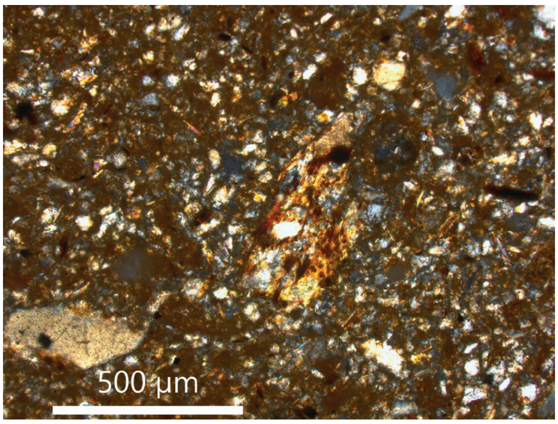


Fig. 13. Loess-like sample P9, microscopic view (CPL); photo by J. Michniewicz.

The mineral composition is similar in all samples, with predominantly silt-size quartz accompanying phyllosilicates, mainly muscovite and biotite. The coarse sand grains have the composition and texture of local greenschist rocks. These include, in particular, quartz-biotite grains [Fig. 14], plagioclase-epidote-biotite metashale fragments [Fig. 15], quartzite, metasandstone, [Fig. 16] and individual feldspars. Diagnostic is the presence of brownish-red metashale fragments, with a texture and colour analogous to those found in ceramics [cf. Fig. 6:2 and Fig. 17].

The chemical composition of reference local clays is presented in Table 5. Particularly noteworthy is the distinctiveness of the samples fired to a light hue due to their higher CaO content, which is comparable to that of the ceramics studied.

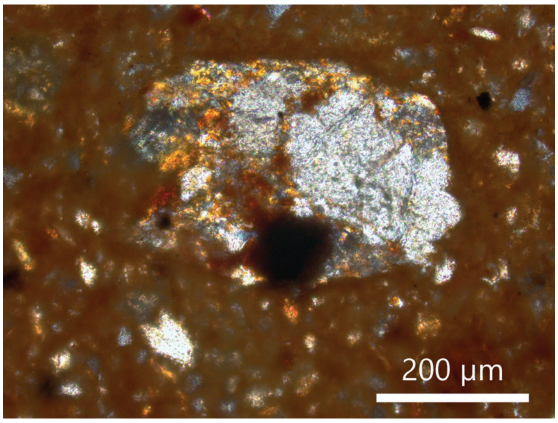


Fig. 14. Sample P4 – schist fragment (CPL); photo by J. Michniewicz.

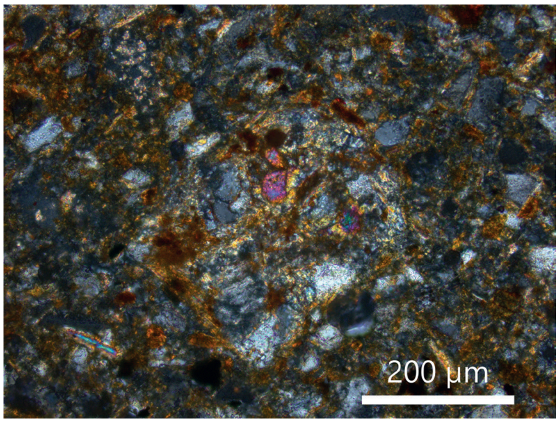


Fig. 15. Sample P11 – plagioclase-biotite-epidote metashale fragment (photo by J. Michniewicz).

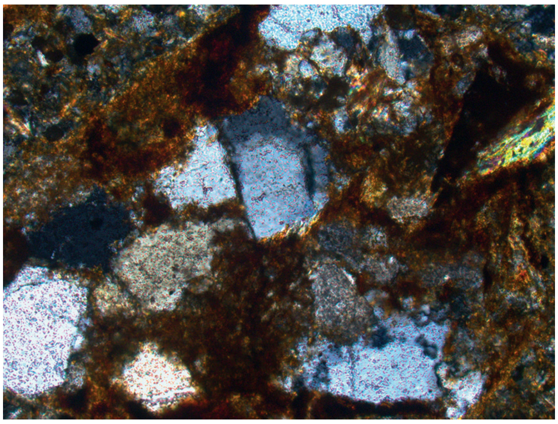


Fig. 16. Sample P11 – metasandstone fragment (photo by J. Michniewicz).

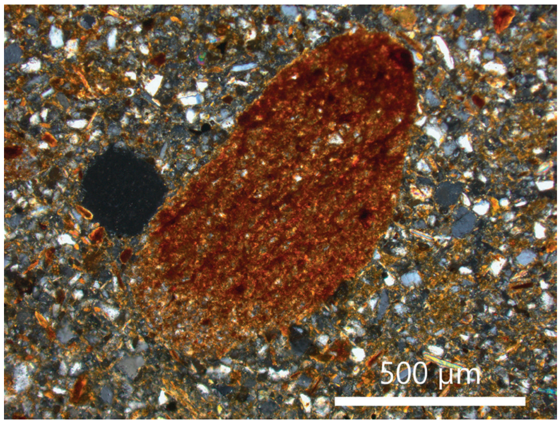


Fig. 17. Sample P11 – metashale fragment (CPL); photo by J. Michniewicz.

Tab. 5. Semi-quantitative chemical composition of reference clays

	P1	P3	P4	P8	P9	P10	P11
Na2O	1.96	2.06	1.91	2.18	2.05	1.97	1.94
MgO	3.11	4.17	2.96	3.71	2.00	1.94	1.78
Al2O3	12.29	12.57	11.90	12.25	12.00	11.62	11.53
SiO2	61.76	64.60	67.45	64.50	72.64	71.20	73.52
K2O	1.81	1.90	2.18	1.91	2.08	2.05	1.89
CaO	12.86	9.65	8.34	10.27	4.09	4.32	4.24
TiO2	0.95	0.63	0.73	0.70	0.82	0.84	0.71
Fe2O3	5.25	4.42	4.53	4.48	4.33	4.47	4.40

5.6. The Slip

There is a consensus that the coatings of 'varnished ceramics' were produced by applying clay paints (clay soil) rich in iron compounds and then firing the vessel in variable redox conditions: oxidation, reduction, and then oxidation again. Under oxidising conditions, Fe assumes the function of a red dye in the form of hematite (α-$Fe_2^{3+}O_3$) or maghemite (γ-$Fe_2^{+3}O_3$). Under reducing conditions, Fe acts as a black dye in the form of magnetite— $Fe_3(Fe^{2+}Fe^{3+})O_4$—hercynite ($Fe^{3+}Al_2O_4$), or wustite ($Fe^{+2}O$).[43]

In all analysed samples, the slip layer differs from the ceramic body in terms of structure, chemistry, and mineral composition [Fig. 18].

In the case of the samples His25/22, His27/22, His28/22, and His30/19, the anisotropy of clay minerals was preserved, and traces of clay domains are also visible in the SEM-BSE image in the case of a higher degree of sintering leading to their optical isotropy. The slip on fabric A is light red (His25/22), red (His24/22; His28/22), dark red (His26/22; His27/22), and black (His25/19; His28/19). They are of different thicknesses, usually less than five microns. Sample His25/19 is covered with a more dense coating of a constant thickness of twenty microns. The macroscopically black slip of His28/19 is unusually thick (30–50 microns). In optical studies of cross-sections in reflected polarised light with parallel polarisers, the iron compounds that underwent reduction are steel grey (His25/19; His28/19), those that were oxidised are bright red (His25/22) and red (His27/22; His28/22). In reflected cross-polarised light (CPL), the Fe(II) compounds are black, while oxidised Fe(III) are red. Thus, in the thin section, in reflected light, the black slip of His25/19 is evenly grey in plain polarised light (PPL) and black in CPL. The black slip of His28/19 in CPL is still black on the top and reddish-black inside. The red slip of His25/22, His 27/22, and His28/22 remains red, both in the plain and crossed polarisers. The slip on fabric B coatings, in most cases, is thin. Only on His10/19 is it unusually thick. The colour is generally similar, a greyish-brown of varied sheen: greyish-brown (His10/19), brown (His06/19; His11/19; His30/19), and in one case, brown with a slight red tint (His01/22).

In a thin section under polarising reflected light, we observe the co-presence of red oxidised Fe-phases with grey reduced ones. Just the presence of domains subject to reduction is responsible for the darker shade of the coating.

[43] Maggettti *et alii* 1981; Tite *et alii* 1982; Gliozzo *et alii* 2004; Aloupi-Siotis 2008; Aloupi-Siotis 2020; Balachandran 2019.

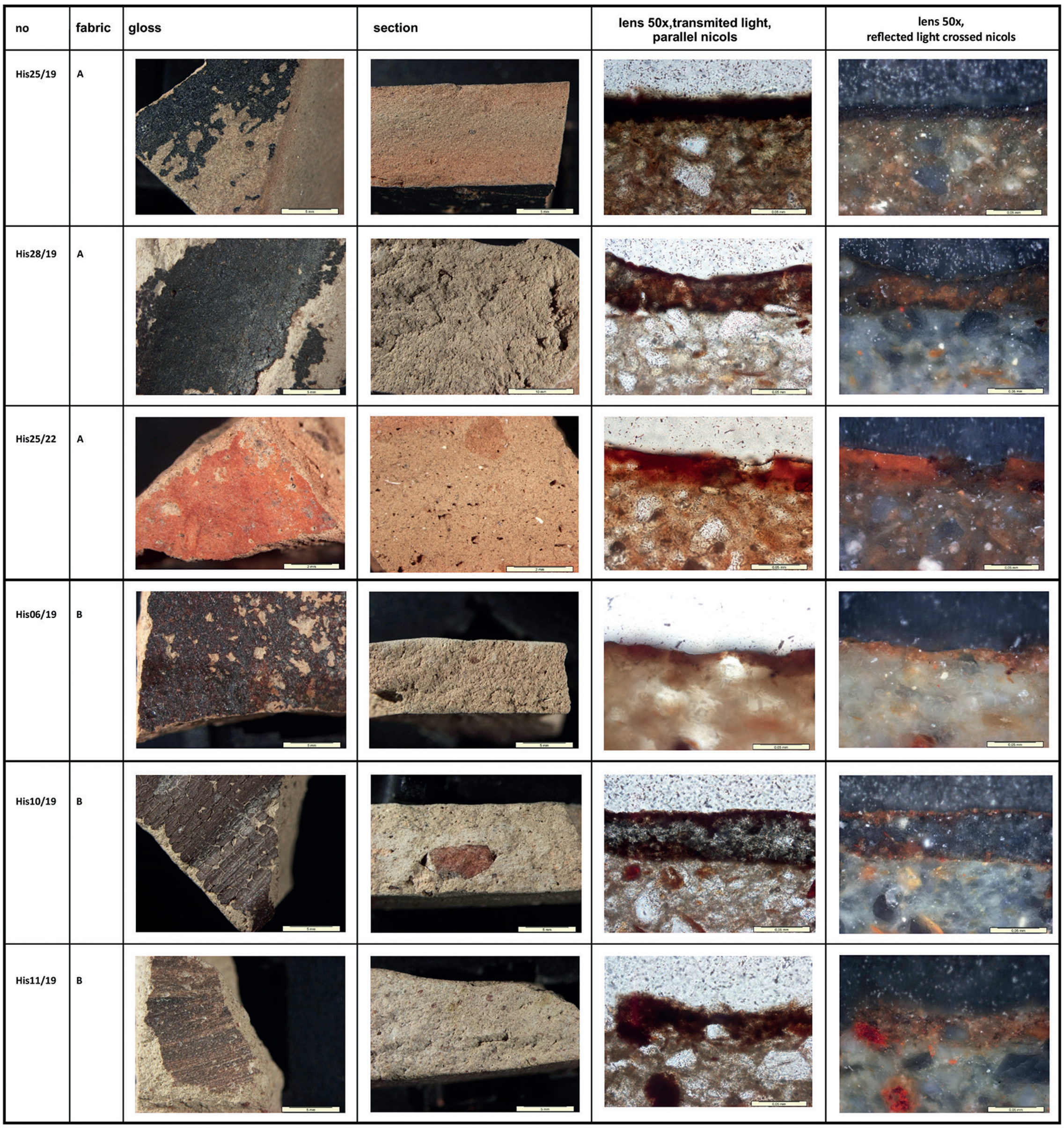


Fig. 18. Optical images of the cross-sections of fabric A and B coatings (photo by J. Michniewicz).

The chemical composition of the slip layers is presented in Table 6. The more significant chemical differentiation between the macroscopically similar coatings on fabric B in comparison to the colour-variable coatings on fabric A is surprising. Generally, the coatings on fabric A relative to fabric B show a lower content of SiO_2 and a higher content of FeO and Al_2O_3. Variable CaO content may come from secondary, post-burial carbonates or contamination of the slip with a high carbonate ceramic body. At the same time, the chemical similarity of the black slip and red slip on Fabric A is noteworthy.

Tab. 6. The chemical composition of the slip, mean (M) and standard deviation (SD) of the varied slip colours.

Fabric	A										B					
Colour	black slip [wt.%]				red slip [wt.%]						brown slip [wt.%]					
Sample	His25/19	His28/19	M	STD	His24/22	His25/22	His26/22	His27/22	M	STD	His6/19	His10/19	His11/19	His30/19	M	SD
SiO2	51.1	49.3	50.2	1.2	45.2	50.4	57.0	44.7	49.3	5.7	48.0	52.5	69.1	73.0	60.6	12.3
TiO2	0.0	0.8	0.4	0.6	0.6	0.0	1.3	0.0	0.5	0.6	0.0	4.6	0.0	0.0	1.1	2.3
Al2O3	26.1	30.0	28.1	2.7	22.4	25.7	21.4	23.5	23.3	1.9	28.2	23.5	12.9	15.8	20.1	7.0
FeO	10.8	10.2	10.5	0.4	10.0	6.6	11.6	10.9	9.8	2.2	7.2	12.7	3.7	5.3	7.2	3.9
MgO	4.2	2.0	3.1	1.6	2.8	2.9	1.9	2.9	2.6	0.5	1.6	1.9	2.7	1.6	1.9	0.5
CaO	1.7	0.0	0.8	1.2	8.7	2.3	0.8	5.3	4.3	3.5	2.0	1.4	8.0	0.0	2.9	3.5
Na2O	2.1	1.3	1.7	0.5	4.0	4.4	1.9	4.6	3.7	1.2	3.6	0.0	1.8	0.5	1.5	1.6
K2O	4.0	6.4	5.2	1.7	6.3	7.6	4.2	8.1	6.5	1.7	9.5	3.4	1.9	3.8	4.7	3.3

wt.% – weight percent

6. Discussion

6.1. Archaeometric Data

The analyses of a tableware group with black, red, and brown coatings indicated that they were likely produced using local raw materials. The clay is a creamy-beige, silty material containing approximately 30% quartz, with a calcareous component of 15–20% CaCO3, and exhibits petrographic heterogeneity. This heterogeneity leads to the distinction of two petrographic variants, referred to as petrographic group A (PGA) and petrographic group B (PGB). PGA is characterised by good sorting of non-plastic components and a predominance of silt-sized quartz, which is likely of aeolian origin. The sorting of PGB is inferior, with the very fine-sorted silt-sized quartz occurring alongside polymineral sand. This includes single fragments of red-fired, slightly metamorphosed shales and crystalline quartz-feldspar-biotite schist fragments that are diagnostic for this group.

The major element content of both fabric types is similar, including a high CaO content. They also exhibit similarities to the average composition of local clays and Late Quaternary loess deposits of Dobrogea, as documented by Luminița-Carmen Tugulan, Octavian D. Duliu, Anna-Voica Bojar, Delia Dumitras, Inga Zinicovskaia, Otilia A. Culicov, and Marina V. Frontasyeva in 2016.[44] The good sorting of the non-plastic components and the petrographic homogeneity of PGA are similar to loess in the strict sense of geology In contrast, the worse sorting and polygenetic petrography of PGB are more similar to the loess-like deposits described by D. C. Jipa in 2014.[45]

The distinct Nd isotope ratios observed in both subgroups provide compelling evidence for their petrographic and potentially workshop-related separation. The differing radioactivity suggests that the raw material may have originated from different sources, with PGB exhibiting a rejuvenated composition due to the presence of Neoproterozoic rock fragments within the sand fraction.

[44] Tugulan *et alii* 2016.
[45] Jipa 2014.

6.2. Archaeological Data

The results of the analyses enabled the identification of two petrographic groups (PGA, PGB). These groups, when considered in the context of the archaeological analyses, can be seen to fall within distinct stylistic and partially chronological categories.

Samples of red slip pottery were assigned to PGA. The artefacts represent a larger group of vessels with various shapes, including fish plates, bowls with one handle, jugs, and *oinochoai*. This category of Histrian pottery fineware requires further detailed research, particularly with regard to the dating of vessels. These issues are of great importance for the determination of the chronology of the finds themselves, and for a comprehensive assessment of the chronology of production and distribution of ceramics around the Black Sea.

A further issue for consideration is the relationship between the ceramics and the production of decorated tableware at the site. The results of the archaeometric studies have led to the hypothesis that these are ceramics produced on-site at Histria using raw materials obtained from locations in proximity to the Greek city. The production of pottery at Histria is corroborated by the discovery of pottery kilns in Sector P. The presence of pottery kilns, raw materials suitable for pottery production, and products of possible local origin provides a solid foundation for further investigation beyond the hypothetical probability of red slip vessel production at Histria. It is essential to determine whether the aforementioned pottery type, characterised by comparable macroscopic features, including vessel form and red slip decoration, can be identified within the archaeological record of other poleis along the north-western Black Sea coast, such as Apollonia Pontica and Olbia. As an illustration, mushroom jugs are known from Apollonia Pontica, while red slip fish plates were published among finds from Olbia. However, in both cases, no information is available regarding the features of the ceramic fabric, which has not been characterised in any publications, with the exception of some details regarding finds from the Lower City of Olbia.

With regard to Olbia, the archaeological record includes examples of fish plates discovered in both the Upper City and the Lower City. Some of the published Olbian examples exhibit a shape that is analogous with those documented from Histria. At this stage of research, the only basis for comparison between the finds from both sites is the morphological similarity of the shapes.[46] However, the finds from Olbia present the same interpretive problem in terms of chronology as at Histria. The artefacts from the Upper City are dated to the Late Classical period (late fifth and fourth century BC).[47] In contrast, the items from the Lower Terrace date to the Hellenistic period (second half of the second century BC).[48]

Single finds from Nikonion can also be dated to the Late Hellenistic period; in this case, there are examples of fish plates, which can be classified as MG 8.[49]

A further significant point is that the pottery found at ancient Tomis (present-day Constanța) also exhibits characteristics comparable to those observed in the artefacts from Histria. These similarities are evident in the features of the slip and clay in the assemblage of vessels from Constanța, retrieved during the rescue excavations conducted in the city in 2018 (in 2023, the fineware pottery

[46] Archaeometric analyses have yet to be conducted on fish plates from Histria. Furthermore, the artefacts from Olbia are only known from published sources. With regard to the finds from the Lower City, a preliminary account of the clay has been provided, which has led to the suggestion that the fabric might be similar to that of the finds from Histria.

[47] Buyskih 2011, pp. 242–264.

[48] Handberg *et alii* 2010, pl. 134:Dc-461.

[49] The classification made by the author of the article, Inga Głuszek, who analysed the ceramics, including the characteristics of the ceramic fabric, during archaeological excavations conducted in 2009–2011.

was studied by Inga Głuszek[50]). The assemblage of red slip includes vessels of the one-handled type, *oinochoai*, and other forms of jugs, which can be classified as MG8. Further archaeometric analyses is required to confirm or reject the hypothesis that these vessels are of the PGA type. In terms of the chronology of the vessels from the rescue excavations in Constanța, it can be stated that these artefacts originate from an archaeological context dated based on the presence of fineware pottery, which suggests a date not earlier than the turn of the first/second quarter of the fourth century BC. It should be additionally observed that examples of red slip amphora and feeding bottle displayed at the museum in Constanța as artefacts from ancient Tomis might also be considered representatives of MG8.

The results of the archaeometric analyses enabled us to determine the local provenance of the raw material used to produce at least some of analysed pottery examples from Histria. Nevertheless, it is not possible to exclude other production centres with certainty, not only because of the lack of direct archaeological evidence, but also because of the issues concerning the unspecified chronology of these vessels. Further studies are required on a larger group of samples to provide more comparative data on this subject.

In light of the comprehensive analyses of petrographic group A (PGA), the assemblage encompasses both finds with a relatively early chronology, namely those belonging to the Classical period (mushroom jugs and one-handled bowls), which can be interpreted as vessels produced as a result of inspiration from imported vessels, most likely from Athens. However, it would be erroneous to refer to such an early chronological horizon as the fifth century BC (as suggested by Alexandrescu), given that vessels of similar shapes from neighbouring Apollonia Pontica are dated at the earliest to the fourth century BC. The same significant chronological questions can be posed with regard to fish plates that are widely distributed in the cities of the north-western coast of the Black Sea (Histria, Tomis, Nikonion, Olbia). In the case of other forms, the morphological features of the vessels (such as incurving bowls and *oinochoe*) should be related to the repertoire of early Hellenistic and later vessels. The broad chronological range may indicate the existence of a long-term tradition of this type of ceramic production. Nevertheless, it is not implausible that this ceramic was also produced (during the same period) in other Greek centres neighbouring Histria. Due to their geographical location, these centres could have utilised raw materials from neighbouring outcrops with similar geological characteristics. The presence of black slip and colour-coated vessels in PGA also indicates the differentiation and continuity of production of a specific category of vessels, namely decorated fine tableware vessels. This is another factor that must be taken into account when assessing the possibilities for production and the characteristics of the production process, assuming that it is linked to a single centre of production. This also raises the question of territorial differentiation in line with the existing urban centres at a given time in an area that could use clay outcrops with the same or similar geological features.

The vessels included in PG2 exhibit distinctly younger forms, with due consideration given to the morphological and stylistic attributes of these vessels. The chronology of the group of vessels is consistent with a date range of the third century BC to the first half of the first century AD. Additionally, the group demonstrates notable diversity in terms of both the quality and technique of the applied slip and their chronology, as based on the vessel shape. At this research stage, it can be stated that the assemblage of PGB exhibits common raw material features, but is distrib-

[50] The authors of the article would like to thank the Directorate of History and Archaeology Museum in Constanța and researcher Laurențiu Cliante for giving their consent and making the ceramic collection available for research.

uted according to chronological and qualitative criteria. In light of the aforementioned research, it seems reasonable to suggest that single or dispersed centres of long or episodical character of production, including Histria, but also other locations of pottery production development, should be considered.

7. Conclusions

The applied petrographic and geochemical research methods proved the diagnostic features of the pottery fabric used for the production of selected vessels and, at the same time, indicated subgroups that translate into chronological differences. The results provides evidence for the continuity of pottery production using a defined (recognised) raw material. This suggestion is proven by similar petrographical results: loess and loess-like deposits, especially by the petrography of coarse inclusions similar to local Dobrogea Precambrian Greenschist (Histra) Formation. It is considered diagnostic for ceramics produced in the area of Central Dobrogea. Histria, in particular, can be regarded as a clayey, highly quartzose loess-like zone characterised by fragments of metamorphic schists (coarse and mosaic quartz or plagioclase plus biotite +/- epidote, especially clinozoisite) and the presence of orange slightly metamorphosed shale fragments. The hypothesis for local Histria ceramic production is justified in light of the presence of pottery kilns at the site. However, the lack of solid archaeological data connecting the aforementioned pottery with the pottery kilns leaves the discussion open. The results (archaeological and archaeometric) should be treated as preliminary, setting out further research directions to fully recognise the repertoire of vessels offering the fabric features defined above. In this case, one should also consider the possibility of a broader range of deposits, and their use by potters from neighbouring Pontic colonies.

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Abbreviations

Euseb. *Chron.*	*Eusebius' Chronicle*, translated by R. Bedrosian, Long Branch, NJ, 2008.
Hdt.	*Herodotus. The Persian Wars*, vol. I: *Books 1–2*, translated by A. D. Godley (= *Loeb Classical Library* 117), Cambridge, MA, 1920.
Ps.-Skymnos	*La Chronique d'Apollodore et le Pseudo-Skymnos: érudition antiquaire et littérature géographique dans la seconde moitié du II^{e} siècle av. J.-C.* (= *Studia Hellenistica* 46), ed. B. Bravo, Leuven 2009.

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