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METHODS FOR STUDYING THE RAW MATERIAL OF POTTERY OF ANTIQUITY (ON THE EXAMPLE OF MATERIAL FROM OLBIA)

ABSTRACT

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The aim of this paper is to demonstrate the methodology of researching the potential pottery raw materials of excavated material from the antique polis using the example of Olbia in the North Western Black Sea region. The historiography of the issue is considered and the main methods are defined. It includes fieldwork, laboratory analyses and their interpretation, as well as an experimental component. The discussion is based on the description of the stages of fieldwork, the study of the macromorphological structure of the clay deposits, micromorphological and granulometric analysis of ancient ceramics and experimental products made of potential pottery raw materials. According to the obtained results, it can be said that the population of Olbia used local materials in pottery making, although their characteristics are specific for the preparation of the clay mass. A comprehensive study confirmed the ability to find out the raw material base of the ancient polis and the possibility of its application at other sites.

Keywords: antiquity, Northern Black Sea region, Olbia, pottery, methods, interdisciplinary research
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INTRODUCTION

The ancient centres of the North-Western Black Sea region belong to the ancient Greek *Oikumena*, that has specific features of material and spiritual culture. The founding of Borysthenes (a settlement on Berezan island) and Olbia are key events in the history of this region. The economic development of these settlement structures can be traced archaeologically through the remains of the craft production among which the pottery played an important role for obvious reasons. Ceramic products provided not only for the everyday life of the settlers, but also were goods used for distribution to the barbarian population of the Forest Steppe region north of the coastal regions where it shipped through the mediation of these centres.

The significant information in the source base of Olbia, accumulated over a hundred years of research, is represented, first of all, by the ceramics that consist of local products and imported items. Nevertheless, convincing evidence of the development of local ceramic production is poorly shown there, although archaeological materials give reasons to hypothesize that it definitely took place in Classical, Hellenistic and Roman periods. Taking into account some discovered pottery kilns. we should pay special attention not only to the products but also to the resource potential of Olbia in ancient times. Deposits of mineral raw materials were a basis of pottery making as one of the most important branches of the Hellenic economy: ceramics were used both as a container for trade products but also separate goods. Moreover, it probably was one of the factors in the colonisation process if we talk about the place of *poleis* establishment and is often considered in the context of urban processes (Kotenko *et al*. 2023, 140-142). Currently, we have a situation when the creation of an economic model of Olbia is impossible because there is an information gap related to the basic criterion for evaluating the raw material deposits as a guarantee of the development of the *polis*. The issue is relevant also considering the fact that the erosion of the coastline of the estuary of the River Buh in the territory of Olbia is active here. Theoretically, this process can destroy the traces of the ancient development of deposits.

The study of the raw material base of Olbia and its surrounding area will allow the determination of the resource potential of the sites and therefore to reconstruct the economic model of the *polis*. Through interdisciplinary research, it will be possible to separate out the local ceramics from imports, which has been a debatable issue in ancient historiography for a long time. Therefore, the paper is based on the hypothesis that Olbia had a developed local pottery making industry, and that the selection of local products is possible namely on the condition of obtaining data on local deposits of mineral raw materials that were fit for the making of pottery.

Therefore, to cover this topic, we set ourselves the following tasks:

1) To investigate the potential locations of raw materials for pottery near Olbia by sampling; 2) To obtain and interpret the results of palaeogeographical laboratory studies of clay deposits in the context of the study of ancient pottery in Olbia;

3) To study the micromorphological composition of ceramic samples for comparison with deposits of potential local pottery raw materials.

In general, the main task has been to determine whether Olbia has the resource potential to develop pottery manufacture on a larger scale.

HISTORY OF RESEARCH

Interdisciplinary research of pottery is becoming increasingly popular. Similar studies of local raw materials and their mineralogical composition are an integral part of a number of scientific projects. For example, the analysis of mineral deposits in the area of the North Ionian *poleis* allowed us to consider the issue of local ceramic production in the Archaic period (Nezih Aytaçlar 2007), while for the other centres such methods are actively being implemented for the sites of the Roman period (Geerts *et al.* 2016; Istenič *et al.* 2003).

In recent years there have been a number of petrographic studies on ceramics carried out on material of different periods (for example, Ownby *et al.* 2016; Miše *et al.* 2020; Quinn and Burton 2010; Ting and Taxel 2020). The aspect of the source of the raw material needs to be considered with the application of different research methodologies that on the one hand can be seen as universal for all archaeological material (including that from sites of classical antiquity), but on the other hand taking into account some regional specifics.

The development of the methodology for studying the raw material base of the pottery of Olbia is at a preliminary level. Some initial steps to the development of this topic were taken by the authors (Kotenko and Kushnir 2022, 44). The historiography of the study of pottery as a craft in ancient Borysthenes and Olbia is covered in a separate publication (Kotenko 2017, 126-133; Kotenko *et al.* 2021). Special attention should be paid to the papers that include interdisciplinary research even in the first half of the 20th century (Knipovich 1940). It is also worth mentioning attempts to study ceramics and building remains using geological data (Shevchenko 2017). However, this information, despite the perspective of the tasks, did not give a comprehensive answer to the question of the raw material base of Olbia in ancient times. Significant shifts in the development of the methodology of studying ancient pottery in the region were made due to instrumental researches. The method of Neutron Activation Analysis revealed the resemblance of the ceramics, proved the local pottery making in Borysthenes in the 6th century BCE and the presence of such products in Olbia (Krutilov *et al.* 2021).

Despite the fact that ceramics are a major source in the study of Olbian local pottery making, it is also worth mentioning the papers deal with the palaeoecological conditions in the Lower Buh region in antiquity. For example, the article by K. K. Shilik on the palaeogeography of Olbia (Shilik 1975) contains information about the geological structure of the bedrock of the bank of the Buh estuary near this *polis*, the geomorphology and geology of different sites of the settlement. However, this research was more related to the topography of the city than to its raw resources. The creation of the maps of minerals and the great geoarchaeological contribution of V. F. Petrun allowed a closer study of the geology and palaeogeography of the North-Western Black Sea region (Ostroverkhov and Smyrnov 2012). Episodic finds of pottery production traces and ceramics from Olbia brought to the foreground the topic of local pottery, but the comparison with local raw materials was postponed for a long time.

In this paper, an interdisciplinary approach to pottery studies is based on the comparison of ceramic products from the period of the site's functioning with potential pottery raw materials near the Olbia settlement, its *chora* and nearest territories. First of all, it can be represented by the comparison of petrographic, geochemical and mineralogical characteristics of ceramic products with deposits of different geological periods (*e.g.*, Matviishyna *et al.* 2021). The results of paleogeographic research of Olbia and other sites are represented separately (Kushnir and Leiberiuk 2022). Given the above, studying the raw material base of Olbia pottery is theoretically grounded and relevant for now.

IMPLEMENTATION OF RESEARCH METHODOLOGY AND METHODS

The proposed methodology for studying the raw material base of Olbian pottery consists of several consistent and interconnected stages. At the first stage, points with deposits of different geological periods were investigated in the field; their preliminary stratigraphic dissection and macromorphological description were made, along with aerial photography.

The study area is represented by deposits of the following geological eras:

1. Modern Holocene sediments (hl) are represented by soils, mainly chestnut, in particular dark chestnut residual-saline soils;

2. Upper Quaternary deposits (dIII+IV). Deluvial deposits of the slopes of river valleys and gullies. Loam, sandy loam, in places with the inclusion of crushed stone;

3. Upper Quaternary deposits (vd III). Aeolian-deluvial deposits. Loess loam with fossil soil.

4. Neogene deposits. Early Pliocene. Pontic layer (N_2pn). Sands, clays, limestones. Clays are grey and greenish-grey.

5. Neogene deposits. Late Miocene. Meoetic tier (N_1m). Clays with interlayers of limestones, sands, siltstones. Marine deposits. Clays are greenish-grey.

A detailed macromorphological description of the studied deposits is presented in Table 1.

Aerial photography, in turn, showed that we studied all available deposits within Olbia and its nearby chorus.

In the second stage, the selection of ceramic products, most typical for this site, took place. As a part of these two stages, catalogues with indexing of sediment samples and ceramic fragments were compiled.

All selected ceramic samples are presented in Table 2. The sample set is at the first stage of completion, but it allowed us to conduct analysis and relevant comparisons. In the future, we will plan to expand the selection and compile relevant catalogues.

The third stage involved laboratory studies, namely micromorphological and granulometric analyses. Micromorphology made it possible to study the structure of deposits of potential raw materials and ceramic products, to make their comparison. Along with this, based on the granulometric analysis of potential pottery raw materials, we found out its suitability for pottery making from physical and chemical points of view.

A comparison of the microstructure of deposits of different geological eras and ceramics of ancient times allows us to reveal similarities in certain mineral composition, aggregation of material, and concentration of individual mineral rocks (sand, clay, *etc*.). The granulometric composition of such components as, for example, physical clay and sand (Table 3) allows us to determine, based on previous studies (Matviishyna *et al*. 2021), the degree of suitability of raw materials for pottery making.

The last stage was represented by experimental research, i.e. reproducing pottery items in modern conditions from different combinations of selected raw materials. The micromorphological analysis of these products made it possible to make a background comparison of them with the microstructure of ancient ceramics and natural deposits.

At this stage, we combined different sediment samples that were collected in the field at the pottery production site (the workshop of a working potter). We made nine variants (Table 4) of mixtures. The most successful combinations were examined through a microscope and their micromorphological analysis was carried out.

Each stage is described in more detail below. At the same time, we note that this methodological approach was applied for the first time to the ancient ceramics of Olbia Pontica.

Macro- and micromorphological analysis

Selected monolith samples of potential pottery raw materials and fragments of ceramics were prepared in the laboratory of the Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the National Academy of Sciences of Ukraine). Thin sediment and ceramic sections (0.02-0.03 mm) were analysed through an Optika B-150POL-B 40×-640× polarising microscope at the Institute of Geography of the National Academy of Sciences of Ukraine. The interpretation of the micromorphological structure was made according to the methodology of M. F. Veklich and Z. M. Matviishina *etc*. (Veklich *et al*. 1979; Karmazynenko 2010). The analysis of ceramic samples was based on recent developments in ancient petrography and general works on the study of ceramic micromorphology (Ownby *et al*. 2016; Miše *et al*. 2020; Quinn and Burton 2010; *Soil Micromorphology*; Ting and Taxel 2020).

Granulometric analysis

Some samples were taken to determine the physical and chemical features of potential pottery raw materials, namely sand, dust and silt fractions. They were investigated at the Landscape ecology laboratory of Taras Shevchenko National University in Kyiv. The classification of the material according to the mechanical composition, which is based on the ratio of physical sand and physical clay, was made according to characteristics defined by N. A. Kachynskyi and those of the deposits according to the classification of M. M. Godlin (Tykhonenko *et al.* 2008, 88-104).

Experimental firings

This stage involved the reproduction of products from raw materials in the modern pottery workshop for the purpose of verifying the previous results of laboratory studies. Vessels were modelled on a potter's wheel with an electric drive. Clay samples were also made from seven different combinations of components to evaluate the physical properties of the mixture without technological influence on it. These samples (fired and unfired) were submitted for micromorphological analysis. Firing of samples and vessels was carried out in an electric muffle furnace in the mode of moderate temperature increase from 20°C to 1000°C for 8 hours (holding mode).

RESULTS AND DISCUSSION

Field research

The methodology included paleogeographic studies of Cenozoic sediments that came to the surface within the ancient city of Olbia and the settlements of the *chora* (Fig. 1).

According to the relief map, this is the territory of the Black Sea Lowland and Olbia with its area are located on the shore of the Buh estuary which led to a lowering of the territory and its dismemberment. It is worth noting that access to these deposits was also possible in ancient times, but probably in other places, as this was influenced by the water level of the sea and affected directly by coastal erosion. In order to investigate the degree of erosion of the coastline and its grassiness, aerial photography was also carried out using a UAV (DJI Mavic Pro). This method is effective for tracing the extent of natural deposits in places with difficult access. Today, the coastal line is represented mainly by the slopes of the right bank of the Buh estuary, which range from steep slopes with visible exposed deposits and gentle ones with grass-grown meadows covering any deposits. Therefore, panoramic images of the powerful stratigraphic layering on this large area are also informative (Fig. 2).

As a part of the fieldwork, the area of ancient sites was surveyed, a map of the researched sampling places and hypothetical places of potential pottery raw materials exploitation were made (Fig. 3). In total, nine points with deposits of various dates in natural outcrops were explored (Table 1), and samples were taken for the different analyses.

Fig. 1. Fieldwork: a – sampling at Point 3 (Kozyrka-1 settlement);
b – data recording at Point 4 (Voloska Kosa settlement)

Fig. 2. Aerial photography of the vicinity of Olbia: a – Katalyne; b – Parutyne

As a result of conducting fieldwork on potential pottery raw materials occurring within Olbia and the surrounding areas, it was established that the most common types of sediments are Neogene and Pleistocene deposits. Neogene sediments are mainly represented by Pontic (N_2pn) and Meoetic (N_1m) layers, stratigraphically determined at points 4 and 7. Pleistocene deposits are mainly represented by Buh (bg Q_3) and Vytachiv (vt Q_3) horizons, stratigraphically determined at points 1, 2, 6 and 8.

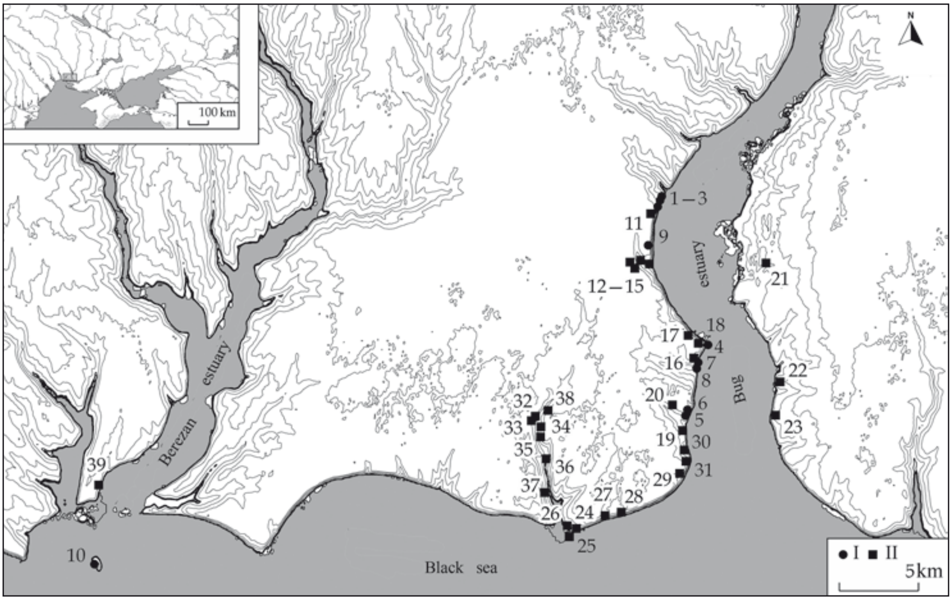

Fig. 3. Map of the of location of researched points (I) and archaeological sites (II): 1 – Point 1; 2 – Point 2; 3 – Point 3; 4 – Point 4; 5 – Point 5; 6 – Point 6; 7 – Point 7; 8 – Point 8; 9 – Point 9; 10 – Point 10; 11 – Kozyrka-1; 12 – Katalyne-1; 13 – Katalyne-3; 14 – Katalyne-4; 15 – Extra-urban sanctuary (ash heap) near Katalyne village; 16 – Voloska Kosa-1, 3; 17 – Voloska Kosa-2, 10, 13, 14; 18 – Voloska Kosa-5, 6; 19 – Shyroka Balka-1, 6; 20 – Shyroka Balka (necropolis of Olbia); 21 – Lisgosp-2; 22 – Lupareve-1; 23 – Lupareve-2; 24 – Adzhigol-1; 25 – Adzhigol-2; 26 – Adzhigol-3; 27 – Dniprovske-2; 28 – Dniprovske-3; 29 – Dniprovske-4; 30 – Zakysova Balka-1; 31 – Zakysova Balka-2; 32 – Adzhigolska Balka-2; 33 – Adzhigolska Balka-3; 34 – Adzhigolska Balka-5; 35 – Adzhigolska Balka-7; 36 – Adzhigolska Balka-8; 37 – Adzhigolska Balka-9; 38 – Adzhigolska Balka-10; 39 – Viktorivka-1

In the next step, samples of the ceramic products that chronologically belong to various stages of the existence of Olbia were selected (Fig. 4). These products are represented by tableware, ceramic slag, pieces of baked clay, *etc.*, which expands the spectrum of the researched issue. The samples were selected directly from the Olbia settlement. The main features of the materials, including macroscopic characteristics of pottery, will be presented below (Table 2).

As a result of the fieldwork, the main vectors of research and specific tasks were outlined with reference to the completed source base for data processing.

Laboratory studies

The next stage involves the implementation of a multidisciplinary approach in order to analyse the potential raw materials and compare them with ancient ceramic products. Ceramic fragments were selected for the study according to the catalogue presented in Table 2. In this paper, in order to demonstrate the application of the methods, we present only in-

Table 1. Description of the potential pottery raw material samples

No.	Point name	General description of the samples (potential pottery raw material)
1	Kozyrka-1	Deposits of light pale brown (8/3 – 7/3 10YR) material in the left side of the northern wall. Material with visible pieces of carbonates in the form of white granules and concretions. Light loess loam. Non-cohesive, lumpy and crumbly. Active reaction with 10% HCl. Visible stratigraphic layer in the slope – up to 3 m.
2	Kozyrka-1	Deposits of two layers: 1. Light (8/2 – 7/2 2.5Y) dusty loam, lumpy and crumbly. Clayed and ferrous material can be traced throughout the profile. Active reaction with 10% HCl. 2. Light brown to dark brown (5/8 2.5YR) light loam (to sandy loam). Easily crumbly. There are traces of carbonation in the form of a white spot. The brown material has not reaction with 10% HCl, and white material has active reaction with 10% HCl.
3	Kozyrka-1	Alternation of 2 types Neogene-Pliocene sediments, which indicate sharp changes in the alternation of shallow and deep sea. 1. Light (8/1 2.5Y) material. Deposits are sugar-white, sandy very crumbly. 2. Clayed and clay loam. It is pale-brown (7/3 2.5Y) and very dense. The thickness of alternation – 10-15 cm (each layer). Sand material is less thick. The clay deposits contain bright residues of molluscs.
4	Voloska Kosa	The deposits locate ashore of the Bug estuary, actively suffer to marine (estuary) abrasion. The total thickness of stratigraphy is about 4 m. Samples of 2 types were selected. 1. A material from the layer of 3.4-3.6 m is light pale (7/3 5Y), dusty, lumpy and crumbly light loam; it has an active reaction with 10% HCl. 2. A material from the layer 3.0-4.3 m is light greenish-dark-grey (7/2 5Y), medium to clay loam. The deposits are laminated, sticky in wet condition; lumpy and crumbly in dry condition. The material contains brownish interspersed (6/6 10YR), has an active reaction with 10% HCl.
5	Shyroka Balka	Shore wall. The total thickness of stratigraphy is from 2.5 to 1.5 m and below along the shore. In cross-section, it looks like a homogeneous light brown material, but three layers stand out in the morphological description. 1. The layer of 0.3-0.4 m represented by lumpy and crumbly medium loam (5/4 10YR); it has an active reaction with 10% HCl. 2. The layer of 0.45-0.95 m is represented by light loam to sandy loam. It is dusty, lumpy and crumbly (6/6-5/6 7.5YR). 3. This layer (0.95-1.35 m) is the sandiest material in the profile (6/6 10YR). Bright strips of crushed molluscs and minerals are observed.
6	Shyroka Balka (a road)	A heavy layer of homogeneous deposits with a total thickness of 2-4 m. It is a homogeneous light pale (7/3 2.5Y), dusty, medium-compacted, light to medium loam. Crumbly (lumpy and crumbly) sediment structure has an active reaction with 10% HCl.
7	Parutyne (a pier)	There are sediments along the estuary at a distance of 5 m from the water. A length is more than 100 m with a thickness of 15 m or more. Two samples were selected. 1. The densest horizon in section (10-11 m). It is light yellow to pale yellow (8/2 5Y). The structure is dusty; the material has an active reaction with 10% HCl. 2. Light green (7/2 5Y) sediments with dark orange (rusty) admixtures (11-15 m); the material has a weak reaction with 10% HCl.
8	Parutyne (a road)	A homogeneous light brown (6/66 7.5YR) deposits. The structure of medium to light loam is lumpy and crumbly; the material has an active reaction with 10% HCl. Visible micellar forms of carbonates and black veins of iron and/or manganese of the horizon are observed in the sediments.
9	Katalyne	The area is completely covered with grass, both at high hypsometric levels and at the estuary. Sediments and the general appearance of the territory (the right bank of the estuary) may indicate that the stratigraphy and nature of the sediments are correlated with section T.7. During the existence of the polis, the territory was probably not covered with grass, and these sediments could be used for the needs of the population.

Table 2. Description of the ceramic products *(reaction with HCI means that a small amount of HCI was added to the fresh chipping of each ceramic fragment in order to determine the presence of carbonates in the dry mass at the macromorphological level that reacted with acid. The intensity of boiling directly depends on the concentration of carbonates in the material. Designation: "+++" – intensive reaction; "++" – medium reaction; "+" – slight reaction; "-" – no reaction.)*

Code	Notes	Reaction with HCI
K/O-1	slags of ceramic production (?), O-2000, P-25, 5th cent. BCE (?). A coarse mix of homogeneous light-pale material with visible inclusions of carbonate rock grains and voids due to decomposition/burning of organic residues can be observed.	+++
K/O-2	a fragment of the wall of adobe amphora, P-25, 1st cent. CE, O-85. A light pale porous material, small inclusions of quartz and carbonate grains. Voids formed during the burning of organic matter can be seen.	+++
K/O-3	a fragment of louteria, O-2019/T-4, 828, 5th-4th cent. BCE. A light grey mass can be seen along the edges, that turns into a dark grey mass closer to the centre. The different colours were formed as a result of short firing/low temperatures. The mass shows voids formed during the burning of organic matter.	–
K/O-4	a wall of the greyware bowl (0,6-0,7 mm), T-4, backfill, 5th cent. BCE, (local production?). Homogeneous dark pale material with dark grey on the outer edge. Small single inclusions of quartz grains can be traced.	++
K/O-5	a wall of the greyware vessel (Cherniakhiv culture, 3rd-5th cent. CE), T-4, backfill 2021. Homogeneous dark grey material with isolated carbonate grains and voids formed by burning organic matter.	+
K/O-6	a wall of the red-glazed vessel (1st-2nd cent. CE, local production?), T-4, backfill 2021. Homogeneous light pale material. No visible inclusions of mineral grains.	++
K/O-7	cooking ware (bottom part), 5th-2nd cent. BCE, T-4, backfill 2021. Dark pale porous mass with inclusions of carbonate grains.	+++
K/O-8	a fragment (rim) of the greyware bowl (local imitation of the Attic product?), 4th cent. BCE, T-4, backfill 2021. Mixed grey-pale, layered and porous mass.	++
K/O-9	a wall of the red clay vessel (local production?), 5th cent. BCE, T-4, backfill 2021. A light pale mass. It contains voids formed during the burning of organic matter.	+
K/O-10	a fragment of the lamp, 5th cent. BCE, surface find, 2019, Lower city. Dark grey mass with inclusions of light quartz grains.	–
K/O-15	a fragment of a baked clay, Suburb, O-2021, 5th cent. BCE. Mixed dark-pale porous material, slightly fired, dusty. There are inclusions of carbonate grains and lighter-coloured quartz minerals.	+++

dividual samples that belong to different stages of the functioning of Olbia (Greek period – classical period, fragment K/O-9, 5th cent. BCE and the Roman period – K/O-6, 1st-2nd cent. CE). They are represented by "red clay" products. Ceramics of this type are widespread in Olbia so the issue of its production is important.

K/O-6 (Fig. 5) is a light brown densely packed mass. There is a proportionate amount of sand and clay in the raw material. There is a relatively drastic change in colour observed, in particular in images 'b' and 'd'. This can be evidence of some kind of mechanical influence on the vessel (in general use) after its manufacture and/or insufficient mixing of the clay mass before firing. Sporadic small grains of quartz and carbonates are present in the

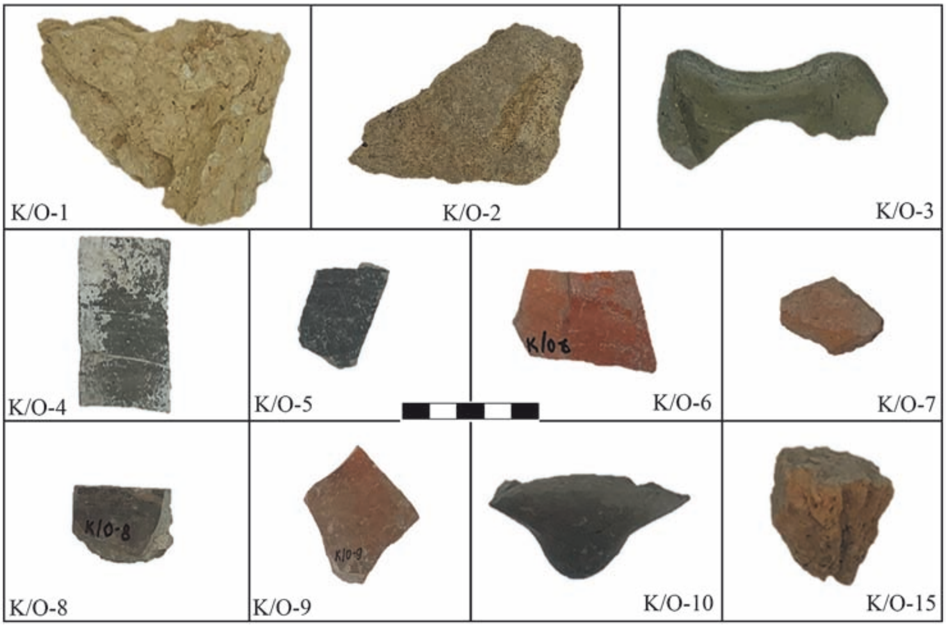

Fig. 4. Samples of ceramic products from Olbia

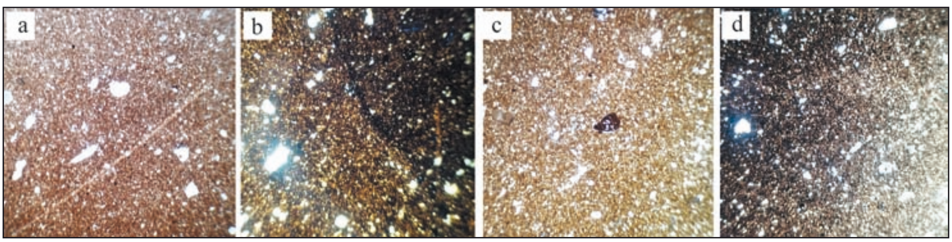

Fig. 5. Micromorphological structure of a ceramic fragment K/O-6. All images are magnified at 40x. Images a and c were taken in parallel nicols, images b and d were taken in crossed nicols

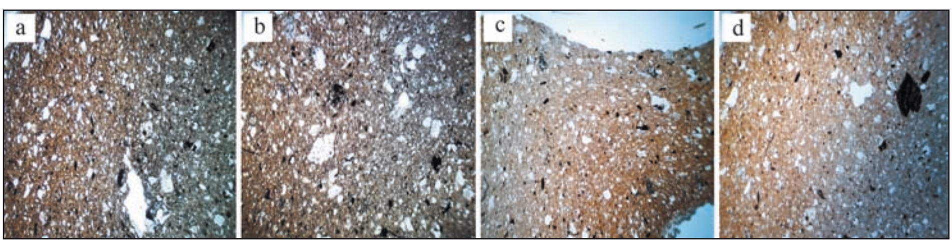

Fig. 6. Ceramic fragment K/O-9. All images are magnified at 40x. Images a to c were taken in crossed nicols, image d was taken in parallel nicols

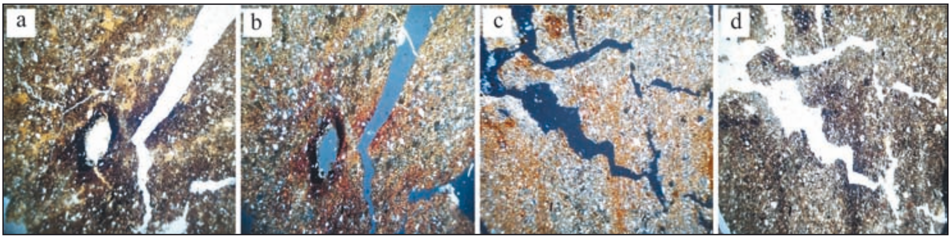

Fig. 7. Micromorphological structure of potential pottery raw material VK 1/21 (Voloska Kosa, sampling depth 3.4 – 3.6 m, 7/3 5Y, inclusions 6/6 10YR). All images are magnified at 40x. Images a and d were taken in parallel nicols, images b and c were taken with crossed nicols

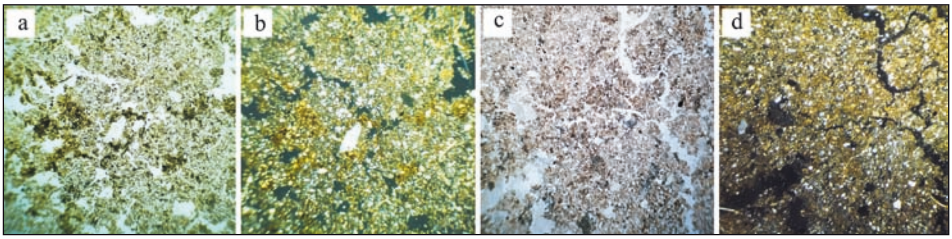

Fig. 8. Micromorphological structure of potential pottery raw materials ShB 2/21 (Shyroka Balka, deposits of Buh pleistocene, 7/3 2.5Y). All images are magnified at 40x. Images a and c were taken in parallel nicols, images b and d were taken with crossed nicols

clay matrix. We also note that the inclusion in microphoto 'c' is quite similar to basalt but is rather one of the types of carbonate inclusions.

K/O-9 (Fig. 6) has a light grey mass with a greenish tint, densely packed. There is a proportionate amount of sand and clay in the raw material. There is a relatively drastic change in colour observed, in particular in photos 'a' and 'd'. This can be evidence of some kind of mechanical influence on the vessel after its manufacture and/or insufficient mixing of the material before firing.

Figures 5 and 6 show photos taken in parallel and crossed nicols. We used the same approach to other types of ceramics and potential raw materials.

The next step involves conducting laboratory studies of natural deposits. There are represented the most typical sediments of this territory in the description of the micromorphological structure of potential pottery raw materials (Neogene sediments from point 4 (VK 1/21) and Buh Pleistocene sediments from point 5 (ShB 2/21). These deposits are found in the most complete of the investigated sections, namely at the point 7 Parutyne-pier, and singly in other investigated points. The micromorphological structure of deposits of potential pottery raw materials is as follows:

VK 1/21 (Fig. 7) – the material is heterogeneous, weakly aggregated, and cracked, but at the same time densely packed in blocks (c). The main mass is ferruginous with concentrations of iron deposits near the pores (b), organic matter and a relatively significant content of clay matter (a, d) can also be traced in the mass. The mineral skeleton consists mainly of small grains of carbonates and quartz.

ShB 2/21 (Fig. 8) – the material is well aggregated, a mass of spongy composition with carbonate and clay microaggregates separated by a system of winding pores. Carbonate and clay composition fills the structure of the sediment sample. The mass has a flat relief and uneven light brown colour. The rounded grains of quartz and silt prevail in the mineral skeleton (about 70% of the ground area).

We note that the description of the micromorphological structure of potential pottery raw materials and ceramic products is also briefly described when describing the corresponding photos. In the framework of this publication, we did not aim to provide detailed micromorphological characteristics of each section. The description of the micro photo was carried out in the context of the general approach of the proposed method of studying the pottery of Olbia. A separate publication will be devoted to the detailed micromorphological structure of all thin sections.

Comparing the micromorphological structure of ceramic samples and potential pottery raw materials, it is possible to make a conclusion about a certain similarity of the structure and filling of the mineral skeleton. We also note that there are organic remains in the form of clots and impregnations in the micromorphological structure of samples of potential pottery raw materials. At the same time, this feature is not noted in the microstructure of ceramic fragments (only isolated remains are present here) because the material was subjected to thermal effects and the organic matter burned out as a result of firing. At the same time, we record the compaction of the material in the ceramic samples, both in the structure and in the filling. The second case probably indicates a good mixing of the material and/or it is a consequence of the fact that the ceramics were made on a potter's wheel.

Analysing the physical and chemical properties of potential pottery raw materials according to the granulometric composition (Table 3), we note a significant content of physical

Table 3. Granulometric composition of the pottery raw material samples

Fraction name, size (mm)	**Quantitative, %**	
	VK 1/21	**ShB 2/21**
Coarse sand (1,0-0,25)	0.1795158	0.77453819
Fine sand (0,25-0,05)	6.5548042	29.64933741
Coarse dust (0,05-0,01)	43.53774	40.1416376
Medium dust (0,01-0,005)	0.660288	0.0814232
Fine dust (0,005-0,001)	13.288296	18.32022
Silt (<0,001)	35.779356	11.0328436
Clay (<0,01)	49.7279	29.4345
Attribution according to the classification of N. A. Kaczynskyi and M. M. Godlin (after Tykhonenko *et al.* 2008)	Heavy loamy deposits / sandy and heavy loamy deposits	Light loamy deposits / light sandy and loamy deposits

clay in the sample VK 1/21. This material could therefore have served as the basis for the manufacture of ceramic products in this region. At the same time, the main admixture could be the material from sample ShB 2/21. In particular, it has a significant quantity of fractions of fine sand, which helped in the formation of products.

Experimental studies of potential pottery raw materials

The last stage of the proposed methods is the verification of the obtained results based on the making of ceramic samples and products from the selected raw materials. For this, the materials that were taken from points 4 (Fig. 2), 7 and 8 (Table 2), plus sand from the coastline of the Buh estuary and water. That is, the necessary minimum components for the reproduction of a pottery product have been selected.

Through various combinations of components, the optimal clay mass suitable for pottery was found (when it does not deform and has specific product features). Firstly, with this purpose, samples were made from seven different combinations of components (Table 4, Fig. 9) in order to evaluate the physical properties of the obtained clay mass without technological influence on it. These samples (fired and unfired) were also analysed by comparing the micromorphological structure of ancient and modern products.

Table 4. Component combinations of the experimental samples

No.	Code	Components
1	1C/21 1B/21	Point 4 sample 2 (greyly green clay deposits), not crushed or sifted mass – 100% Water (30% from the total mass)
2	2C/21 2B/21	Point 4 sample 2 (greyly green clay deposits), crushed and sifted mass – 80% Point 7 („Bug loess”) 20% Water (30% from the total mass)
3	3C/21 3B/21	Point 4 sample 2 (greyly green clay deposits), crushed and sifted mass – 70% Point 7 («Bug loess») 10% Point 8 (red loam) 20% Water (30% from the total mass)
4	4C/21 4B/21	Point 4 sample 2 (greyly green clay deposits), crushed and sifted mass – 85% Sand – 15% Water (30% from the total mass)
5	5C/21 5B/21	Point 8 (red loam) – 60% Sand – 40% Water (30% from the total mass)
6	6C/21 6B/21	Point 7 («Bug loess») – 50% Sand – 50% Water (30% from the total mass)
7	7C/21 7B/21	Point 4 sample 2 (greyly green clay deposits), not crushed or sifted mass – 80% Sand – 20% Water (30% from the total mass)
8	1P/22	1st product (1st variant of the moulded mass) greyly green (T.4, sample 2, 100%) and water (30% from the total mass).
9	2P/22	8th product (2nd variant of the moulded mass) Point 8 (red loam – 80%), sand (20%) and water (30% from the total mass).

Fig. 9. Samples of pottery paste with different component composition

Fig. 10. Pottery making (a) and products from potential pottery raw materials (b)

Then there was an attempt to make pottery from authentic raw materials. Five test vessels were made on the potter's wheel (Fig. 10). The products were made from the best three types of pottery paste:

1) material from Point 4 (Sample 2) – grey-green mass (100%) and water (30% of the total mass) – three products (*e.g.*, Fig. 11).

2) material from Point 8 (red loam – 80%), sand (20%) and water (30% of the total mass) – one product. The mass showed good plasticity during making on the potter's wheel.

Fig. 11. An example of a product from the first type of pottery paste: 1 – before firing; 2 – after firing

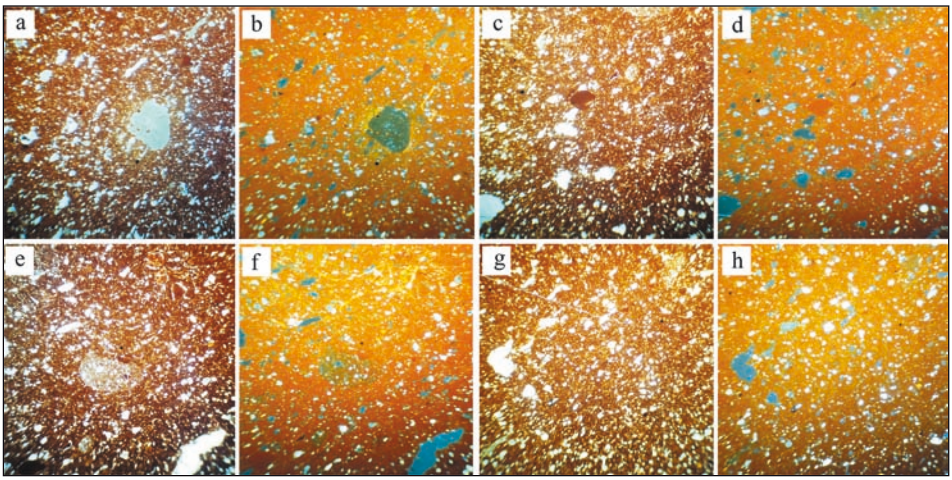

Fig. 12. Micromorphological structure of the experimental product (sample 1P/21).
All images are magnified at 40x. Images a, c, e, and g were taken with parallel nicols, pictures b, d, f, and h were taken with crossed nicols

3) material from Point 8 (red loam – 100%) and water (30% of the total mass) – one product. The mass showed low plasticity which indicates its unsuitability for pottery making.

In order to assess the methods, the results of the micromorphological structure (Fig. 12) from the most successful product (sample 1P/21) are presented (according to the potter's opinion). This mass of raw materials showed a good plasticity during making on the potter's wheel. The sample has a minimum number of components, because the determination of admixtures requires more extensive research. At the same time, these micromorphological data are the background for comparison with the micromorphological structure of ancient ceramics.

The sample 1P/21 (Fig. 12) is a homogeneous narrowed light-yellow mass with significant seepage, clumps of clay material (c-d) and proportional distribution of carbonates. There are also large (a-b) and fine (g-h) quartz grains in the matrix, as well as concentration of microcrystalline calcite (e-f).

Comparing the micromorphological structure of the presented samples of raw materials, fragments of ancient ceramics and experimental products, it is possible to conclude that they are similar. The micromorphological structure of the product made by the potter is quite similar to ancient ceramic fragments. They are similar in colour after thermal treatment, in the composition of the main mineral components (carbonates, clay, *etc.*), and in the general microstructure of the product. At the same time, we note that ancient ceramics were made with the addition of a certain fine sandy material which represented, for example, by deposits from sample ShB2/21 from the Buh. It is also likely that the firing temperature in the modern potter workshop was higher, as indicated by the colour of the product and the absence of an organic component in the microstructure. In this case, the sand saturation of the mass was sufficient. This may indicate that sand was not always added to the pottery as an admixture.

CONCLUSIONS

The study of the raw material base of Olbian pottery has produced the following results. During the implementation of the methodology, different kinds of components were covered. They include various aspects of the source base. In general, all stages can be divided into fieldwork, laboratory analyses and verification of results through experiment.

The proposed methods of studying the potential pottery raw materials of Olbia make it possible to talk about the characteristic features of ancient pottery in the Lower Buh region. Field paleogeographic studies showed that this region is characterized by the occurrence of geological deposits of different ages, composition and properties. Some of them are (and were in ancient times) suitable for making pottery. Laboratory studies demonstrated that Neogene and Pleistocene sediments with a significant component of physical clay and a small amount of sand could be used for the production of pottery paste in ancient times. They are quite suitable due to their physical and chemical properties. At the same time, the study of the micromorphology of ceramic fragments and these potential pottery raw materials proved a certain similarity of the materials. In addition to the discovering of pottery kilns, the raw material base confirms the existence of local pottery production in Olbia.

On the one hand, the results of the research show that ancient ceramics and raw materials are generally similar. But on the other hand, the forms of carbonates and quartz that we find in ancient ceramics can also be traced in the sediments. Therefore, our study demonstrates the general composition of Olbian ceramics and raw materials, which should be taken into account in further researches.

The properties of the studied raw material showed that it is quite specific and difficult for use in pottery manufacture, at least in the combinations that we have been able to investigate. Therefore, it is possible that this clay mass was suitable for production of other ceramics such as roof tiles, water pipes, building materials. These are known from the excavations of Olbia in the Roman period (Vetshtein 1975, 173-180). The production of tableware also developed here, but it seems to have been mainly for domestic use. For example, the so-called greyware (Late Archaic – Early Classical periods) (Krapivina and Lejpunskaja 2009, 67, 68), as well as ceramics with green tint (Late Hellenistic and Early Roman period) are now considered to be of local production. But these groups of material have not yet been specifically studied in terms of the raw materials base required to make them. In this paper, we did not aim to investigate the entire raw material base of ancient Olbia pottery. First of all, we wanted to demonstrate the methodology of researching this issue and focus on an interdisciplinary approach, due to the fact that such studies have not been carried out for this *polis* before. We have shown that the proposed methodology may be useful in the future for the study of different types of ceramics.

In addition, the stratigraphic study of local deposits in the Olbia settlement and its surroundings gave an opportunity to talk about the use of the lower layers as a local building material. This concerns mainly the so-called Pontic limestone with remains of small molluscs. It is quite a durable material and its discovery is associated with a number of archaeological objects in Olbia and settlements of the *chora*.

In general, speaking about the methodology of studying ancient pottery, it can be stated that it is necessary to take into account all the elements of the source base for the objectivity of the results: natural deposits, ceramic products and the remains of workshops. The proposed stages and methods can be applied to the study of pottery of different regions and periods.

It is also worth noting that at this stage, we have only limited ourselves to general observations within the framework of our proposed methodology for studying the ancient pottery of Olbia. Our further research will be aimed at expanding the laboratory data and specifying the results for individual groups of ceramics.

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