About the building stones of the Eneolithic cromlech, sanctuary, and burial constructions near Shakhtar village (Dnipropetrovsk region, Ukraine)

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Abstract. The article presents the results of petrographic research of building stone that was used for the construction of a cromlech, sanctuary, and the ceiling of the Eneolithic burials No. 20 – 22 from the kurgan No. 29 near Shakhtar village, Nikopol rayon, Dnipropetrovsk oblast. The purpose of this work was to establish a probable place for mining the stone blocks and rubble used in the construction. As a result of petrographic and X-ray fluorescence analysis, it was determined that the studied rocks can be divided into two groups, namely granitoids and limestones. The group of granitoids included tonalites, plagiogranites (trondhjemites), altered granite gneiss, and feldspar crystal from pegmatite. All the limestones were represented by spherical layered aggregates, which most likely belong to oncoinds – carbonate structures that form as a result of cyanobacteria growth. The studied samples from the materials of the cromlech and the sanctuary of burial No. 22 were represented by plagiogranitoids, pegmatoid granite, and limestones. The first of them served as the main material for the construction of the cromlech. Carbonate aggregates together with the granites were also used as a backfilling when installing wooden pillars of the cult complex associated with the burial. The plates covering the burials No. 20 and 21 were made of tonalites. All the studied granitoids are typical rocks for the area where the excavations took place. In the Middle Dnipro Area, plagiogranitoids are represented by the rocks of the Dnipropetrovskyi, Surskyi, Saksahanskyi, and Inhuletskyi complexes of the Archaean. Plagiogranitoids of the Dnipropetrovskyi complex are the most common in the studied area. They occur in the middle and upper reaches of the Solona River and along the rivers of Bazavluk and Bazavluchok upstream of the Sholokhove Reservoir. The closest to the excavation site are the occurrences of plagiogranitoids, which are exposed on the right bank of the Solona River, opposite the village of Shakhtar. In this area, pegmatoid granites are found in the form of veins that intersect plagiogranitoids. In the area of excavations, carbonate oncoinds are found in the Sarmatian limestones of the Neogene. Most often they are found as the un cemented specimens that spilled out of the limestones. Today, such structures occur on both banks of the Kakhovskoe Reservoir, located south of the village Shakhtar. However, in ancient times there may have been closer outcrops of these rocks, as the Sarmatian limestone occurrences are common in the immediate vicinity of the excavation site, namely between the rivers Bazavluk and Solona, near their confluence, and the middle and upper reaches of the Chortomlyk River. As a result of the research, it is proved that in the valley of the river Solona during the Eneolithic, there began the active extraction of stone raw materials for mound construction, which was continued in later epochs, particularly, in the Scythian time.

Key words: petroarchaeology, building stone, cromlech, burial constructions, Eneolithic, Ukraine

Про будівельне каміння неолітичного кромлеху, святилища та поховальних споруд біля с. Шахтар (Дніпропетровська область, Україна)

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Анотація. Стаття присвячена питанню походження кам’яної сировини, що була використана для спорудження кромлеху та інших поховальних конструкцій доби енеоліту кургану № 29 біля с. Шахтар Нікопольського району Дніпропетровської області. Мегалітичні споруди на той час були найбільш виразними маркери, через які певні соціальні групи демонстрували свої пра ви на певну територію. Їх спорудження вимагало значної кількості будівельного каміння, що сприяло розвитку стародавнього гірництва. Метою роботи було визначення походження кам’яної сировини, що використовувалася для побудови зазначених
Introduction.

A petrographic analysis is one of the main methods of natural sciences used in archaeology in the study of stone artefacts. It can be used to determine the material of ancient stone monuments, as well as to establish its probable provenance. This, in turn, makes it possible to determine the location of ancient mining sites, where in ancient times the extraction of raw stone was carried out. The petrographic study of the megalithic constructions materials is especially important for the study of the history of ancient mining, as the production of large stone blocks necessarily presupposed the existence of mining sites and organized extraction with the use of certain mining techniques.

The first megalithic constructions in the Northern Black Sea Region appeared in the Eneolithic Age (3900/3800 – 3500/3400 BCE). They are represented by cromlechs built from rough unhewn and partly hewn stone blocks or processed stone stelae, which, if possible, were given a more or less proper geometric shape, as well as burials in stone boxes, cysts, and pits with stone ceilings. Megalithic structures at that time were the most expressive markers through which certain social groups demonstrated their rights to an appropriate territory. Their great importance is confirmed by the amount of labor input required for the construction of these structures.

This article is devoted to the study of the building stone used in the construction of the Eneolithic burial structures of the Eneolithic-Bronze Age kurgan No 29 near the village Shakhtar, Nikopol rayon of the Dnipropetrovsk oblast. The first stage of kurgan construction is represented by burial No 22, around which a cromlech of rounded shape was built with a diameter of 6.60 – 6.56 m (Fig. 1). The cromlech consisted of two layers of rough stone represented by different rocks. There was also a cult complex connected with the same burial, from which 9 deep holes remained, which formed a quadrangular figure with the dimensions of the sides: 6.507 x 6.500 m. Quite thick pillars with a diameter of about 0.3 m were installed vertically in the holes. The lower parts of the pillars near the bottom part of the holes were solidly fixed at a height of 0.55 – 0.95 m with a stone backfill (Chernykh et al., 2014). The stone samples for the research were taken from the cromlech and the backfill of the sanctuary holes.

Fig. 1. General view of the cromlech during the excavations

The next stage of the kurgan construction is connected to the Eneolithic burials No 20 and 21, where stone blocks were used for the covering. Burial No 21 was covered with a stone ceiling based on two
massive plates: measuring 1.54 x 1.06, 0.1 – 0.3 m thick, and measuring 1.28 x 0.86, 0.1 – 0.24 m thick. Burial No 20 was covered by a plate from which a fragment 0.57 m long, 0.72 m wide and 0.2 m thick has remained (Chernykh et al., 2014). Plate material from both graves was taken for the study.

Petrographic methods are used in the study of ancient megalithic structures and stelae around the world. For example, today, the petrographic study of building stone of the world’s most famous such complex Stonehenge in the UK still continues, despite the long history of research. The provenance of the so-called bluestone (mostly altered porphyry dolerites), brought from the territory of modern Wales, is currently studied. There is performed an additional study of the material of the altar stone, located in the centre of the complex, made of mica sandstone with carbonate cement, which also has an imported origin. In particular, British researchers have verified all available fragments of this stone from museum collections and determined whether they are really its fragments. Also, at the modern scientific level, the study of sarsen stone was carried out – the main building material of the complex, represented by medium-fine-grained quartz sandstones with regenerated quartz cement. These sandstones, unlike other stones, are of local origin. Their nearest occurrences are 20 km north of Stonehenge, in the West Woods area, southwest of Marlborough in Wiltshire. Researchers have established the full mineral composition of both the debris and cement, as well as other properties of rocks, which in the future will let more accurate determination of the origin of the building material used to build the complex (Bevins et al., 2020; Ixter et al., 2019, Ixter et al., 2020; Nash et al., 2021). Anorthomorphic stelae common during the Eneolithic-Bronze Age are also being studied. Among recent major studies, we should mention the work of V. Rubinetto and co-authors, who have studied 47 stelae from the archaeological site of Saint-Martin-de-Corlean in Northern Italy. The analysis showed that their raw materials are represented by marbles and metabasites and come from various deposits, including remote ones from the territory of modern Switzerland (Rubinetto et al., 2014).

The authors of this article conducted petrographic studies of the crepidoma and stone shield of the Aleksandropol Scythian barrow. It was determined that almost all studied rocks are of local origin. The main source of building stone was the nearest outcrops of granitoids and metabasites in the basins of Bazavluk and Mokra Sura rivers. It is also possible that some rocks originate from the Kryvyi Rih Area and the Dnipro valley, and some samples of pebbles may be of Crimean origin (Nikitenko et al., 2016a). Also, I.S. Nikitenko and S.V. Polin studied the building stones of the Polovtsian burial of the Mongol period, discovered near the city of Pokrov. It was determined that for the construction of the crepidoma and stone shield of the mound, in addition to the Neogene limestones that are common in the zone of former Dnipro floodplains, very rare local rocks, such as actinolitite and silicified ocher, were also used (Nikitenko et al., 2019). In addition, one of the authors studied Eneolithic-Bronze Age constructions and stelae from the collections of Dnipro-petrovsk National Historical Museum named after D.I. Yavornitsky (Nikitenko et al., 2015), Horishni Plavni Museum of History and Local Lore in Poltava region (Nikitenko et al., 2016b), and Poltava Museum of Local Lore named after Vasyl Krychevskyi (Nikitenko et al., 2018). In most cases, it was found that the stones were brought from nearby occurrences and deposits located in the area, where the monuments were discovered. In the Right Bank Area of the river Dnipro and in the zone of Dnipro Rapids, where numerous outcrops of the Ukrainian Shield rocks exist, plagioclase granitoids, two-feldspar as well as pegmatoid granites were used. In the Kryvyi Rih Area, meta-psammitic quartzites and metagravellites of the Kryvyi Rih Series were applied, and, in the area of Kakhovske Reservoir, the Neogene limestones were used. However, distant delivery also existed, especially in the areas, where the occurrences of stone materials are absent. Thus, granites were delivered to the Dnipro Left Bank Area from the right bank, and sandstone stelae were carried from the territory of the Donets coal basin rocks distribution area (Nikitenko et al., 2015; Nikitenko et al., 2016b; Nikitenko et al., 2018).

**Purpose of the study** is to establish the provenance of stone materials used in construction of the cromlech, sanctuary, and burial ceilings of the Eneolithic Age from the mound No29 near the village of Shakhtar, Nikopol rayon of Dnipro-petrovsk oblast, as well as localization of probable mining areas.

**Materials and methods.**

For petrographic research, nine samples of rocks were taken from the excavation materials of mound No 29. The study of the mineral composition of rocks in the thin sections was performed using a polarizing microscope LOMO POLAM R-312. The chemical composition of the rocks was studied using X-ray fluorescence analysis (XRF), which was performed
in the Analytical Research Laboratory of the Dnipro University of Technology using the device ElvaX Plus (analyst – Ye.V. Kosareva). The percentage of dolomite in limestone was determined by recalculating the chemical analysis using the appropriate coefficient. The origin of rocks was determined by comparing the petrographic features of the raw materials of the studied artefacts and rocks common in the Middle Dnipro Area. To locate possible sites of ancient mining, information from primary geological surveys and literary data were used, in particular, publications of the mid-twentieth century, which contain information on natural outcrops and quarries before man-made landscape changes (open cast mining of manganese ore) in the area of archaeological excavations.

Results.

As a result of petrographic analysis of building stone samples, their material was determined (Table 1). It was established that the studied rocks can be divided into two groups. The first comprises all the granitoids, including the feldspar crystal (1, 6 – 9). And all the samples of limestone identical in thin sections (2 – 5) can be united into the second group.

Table 1. Studied samples

<table>
<thead>
<tr>
<th>No.</th>
<th>Place of discovery</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shakhtar, kurgan 29, burial 20</td>
<td>Biotite tonalite</td>
</tr>
<tr>
<td>2</td>
<td>Shakhtar, kurgan 29, cromlech</td>
<td>Limestone (oncoid)</td>
</tr>
<tr>
<td>3</td>
<td>Shakhtar, kurgan 29, hole 5 (sanctuary)</td>
<td>Limestone (oncoid fragment)</td>
</tr>
<tr>
<td>4</td>
<td>Shakhtar, kurgan 29, cromlech</td>
<td>Limestone (oncoid fragment)</td>
</tr>
<tr>
<td>5</td>
<td>Shakhtar, kurgan 29, cromlech</td>
<td>Limestone (oncoid fragment)</td>
</tr>
<tr>
<td>6</td>
<td>Shakhtar, kurgan 29, cromlech</td>
<td>Plagiogranitoid, altered</td>
</tr>
<tr>
<td>7</td>
<td>Shakhtar, kurgan 29, cromlech</td>
<td>Plagiogranitoid, altered</td>
</tr>
<tr>
<td>8</td>
<td>Shakhtar, kurgan 29, burial 21</td>
<td>Biotite tonalite</td>
</tr>
<tr>
<td>9</td>
<td>Shakhtar, kurgan 29, cromlech</td>
<td>Feldspar crystal</td>
</tr>
</tbody>
</table>

Stone samples from cromlech and sanctuary.

This group comprises the samples represented by granitoids (6 – 7, 9) and limestones (2 – 5).

Granitoids. Two samples were determined as altered plagiogranitoids (6 – 7). Sample 7 has a high quartz content and is more altered than sample 6, due to which the petrographic features of the rocks differ. Both samples underwent cataclase processes.

Mineral composition of the sample 6 (vol.%): plagioclase – 61, quartz – 35, biotite – 3 (often in veins), muscovite – less than 1, ore mineral (pyrite) – single grains (has a rectangular shape in thin section), sericite – less than 1 (slightly replaces plagioclase), chlorite – less than 1 (slightly replaces biotite), epidote – less than 1 (in veins), goethite – dispersed impurity, calcite – less than 1 (in veins). The texture of the sample 6 is allotriomorphic (initial hypidiomorphic-granular), cataclastic, intersected by a net of veins. The rock contains elongated zones of fragmented main minerals. In the joints, the veins of biotite were formed, which also contain crystals and aggregates of epidote and cryptocrystalline calcite. Aggregates of tiny newly formed quartz crystals have a mortar texture. This indicates that the rock has undergone processes of grinding and recrystallization as a result of tectono-metasomatic processes (Fig. 2).

Sample 7 has the following mineral composition (vol.%): quartz – 55, plagioclase – 27, muscovite – 7 (replaces plagioclase), epidote – 5, microcline – 3 (including one large grain), biotite – 3, sericite – less than 1 (alters plagioclase). The texture of the granitoid is hypidiomorphic-granular, the quartz zone is lepidogranoblastic. The rock is a granitoid that is intersected by a quartz vein in the cataclase zone. This is evidenced, in particular, by the presence of
boundary zones of crushed and recrystallized main minerals. Quartz in the thin section makes up more than 50 % of the rock volume. Along with it, there are large crystals of minerals of the isomorphic epidote-clinozoisite series, and aggregates of biotite scales. Plagioclase in the central part of the thin section is almost completely replaced by large scales of muscovite. Further from the quartz zone, plagioclase is replaced by sericite. The microcline in the sample is represented by small antiperthites, as well as one large crystal.

Sample 9 is represented by a big white crystal. Judging by the nature of its extinction in the thin section, it underwent tectonic impact and has a cleavage. The refractive index is lower than that of Canadian balsam, thus, it most likely belongs to albite and possibly originates from a pegmatite vein.

Limestones. All the studied samples of limestone (2 – 5) were represented by spherical layered aggregates or their fragments. The color of the rocks is light grey, fawn. Microscopic examination revealed that the rock was composed of cryptocrystalline carbonate. The grains have an isometric shape and a high refractive index (Fig. 3). Scaly crystals with low birefringence and parallel extinction, which sometimes are present in the pores, are probably represented by a clay mineral. In the sample 4, some pores contain coarser carbonate. Sample 5, among all limestones, is the most porous. Carbonate aggregates in the pores are weakly colored with iron hydroxides. The texture of all samples is cryptocrystalline, the structure is banded (concentric-zonal) and porous.

To determine the composition of the rock more accurately, a chemical analysis of one sample was performed by XRF analysis (Tab. 2).

<table>
<thead>
<tr>
<th>Element</th>
<th>Intensity</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>8428518</td>
<td>91.294 ± 0.090%</td>
</tr>
<tr>
<td>MgO</td>
<td>11959</td>
<td>5.850 ± 0.284%</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>167033</td>
<td>1.010 ± 0.008%</td>
</tr>
<tr>
<td>SiO₂</td>
<td>17492</td>
<td>0.786 ± 0.025%</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>4544</td>
<td>0.536 ± 0.052%</td>
</tr>
<tr>
<td>MnO</td>
<td>69235</td>
<td>0.383 ± 0.006%</td>
</tr>
<tr>
<td>TiO₂</td>
<td>5346</td>
<td>0.070 ± 0.012%</td>
</tr>
<tr>
<td>ZnO</td>
<td>4431</td>
<td>0.033 ± 0.006%</td>
</tr>
<tr>
<td>S</td>
<td>16279</td>
<td>0.024 ± 0.010%</td>
</tr>
<tr>
<td>V₂O₅</td>
<td>1187</td>
<td>0.015 ± 0.012%</td>
</tr>
<tr>
<td>K₂O</td>
<td>0</td>
<td>&lt; 0.029%</td>
</tr>
</tbody>
</table>

The increased content of MgO in the rock indicates the presence of dolomite. Dolomite was not identified in the thin section due to the cryptocrystalline texture of the rock. To determine the dolomite content, magnesium oxide was multiplied by the appropriate coefficient:

Dol = 4.5739 x MgO = 4.5739 x 5.85 = 10.4239 %

Based on the chemical analysis of the sample 2, 10 % of carbonate is represented by dolomite, the rest is represented by calcite, respectively.

Stone samples from the ceilings of Eneolithic burials No 20 and 21. The studied samples of plates that covered the burials are represented by granitoids, namely, tonalites (1, 8). Both rocks are rather weathered. Macroscopically, they have grey color and a massive structure. As a result of microscopic study in thin sections, the mineral composition of both rocks turned out to be almost identical. The main minerals are represented by plagioclase, quartz, and biotite. Plagioclase accounts for more than 70 % of rock volume, quartz for about 20 %, and biotite for more than 5 %. Also, in both samples, there is potassium feldspar (microcline) – up to 2 %, as well as myrmekite – up to 1 %. Sample 8 also contains less than one percent of muscovite and epidote. Plagioclase in both samples is weakly and moderately sericitized, in sample 1 its saussuritization is also observed. Plagioclase crystals are more idiomorphic relative to quartz, which is why the rock texture was defined as hypidiomorphic-granular (Fig. 4).

The provenance of stone materials. The obtained data allowed to establish the most probable places of origin of the studied rocks.

Granitoids. Judging by the mineral composition of granitoid samples, all the studied rocks may belong to the plagiogranitoid (TTG) complexes of the Ukrainian Shield. First of all, these are tonalites and plagiogranites (trondhjemites) that were affected by
metasomatism and cataclase. The feldspar crystal (9) may originate from pegmatite veins that intersect these granitoids. In the Middle Dnipro Area, plagiogranitoids are represented by the rocks of the Dnipropetrovskyi complex, which forms the framework of the entire Middle Dnipro granite-greenstone area, as well as Surskyi, Saksahanskyi and Inhuletskyi complexes. In the area, where archaeological excavations took place, the most common are the plagiogranitoids of the Dnipropetrovskyi complex. The main minerals of the granitoids are plagioclase No 24 – 28 (early generation) and No16 – 20 (late generation), quartz, biotite. The rocks may contain hornblende and microcline (antiperthites). The most common accessory minerals are apatite, magnetite, zircon, ilmenite, sphene, orthite, rutile, and pyrite. The rocks of the Surskyi complex form comparably minor massifs in the vicinity of Nikopol city and to the north of Marganets city. Unlike the granitoids of the Dnipropetrovskyi complex, the mentioned rocks are the intrusives, which are genetically connected to the felsic volcanites of greenstone structures. In petrographic terms, the rocks of the Surskyi complex are represented by biotite and amphibole-biotite tonalites and plagiogranites. Quartz diorites, granodiorites and leucocratic plagiogranites are also noted. The rocks are massive, but, like the granitoids of the Dnipropetrovskyi complex, they often have a gneiss-like structure, which is usually less manifested. The rocks are medium-grained. The main minerals are plagioclase, quartz, biotite; secondary minerals are hornblende, microcline, chlorite, epidote, muscovite, and sericite. Accessory minerals are represented by apatite, zircon, sphene, and orthite.

Fig. 4. Biotite tonalite (sample 1). Pl – plagioclase, Qz – quartz, Bt – biotite, Fsp – potassium feldspar. Transmitted light, nicols (+), zoom 47x

(Shcherbakov, 2005; Yesypchuk et al. 2004; Sukach et al. 2016). Since the rocks of both complexes are not homogeneous, contain each other’s xenoliths, and have a massive or gneissose structure, it is difficult to distinguish them only by petrographic features. Therefore, we will rely on the distribution of all plagiogranitoids that form natural outcrops in the area of archaeological excavations and could be extracted in ancient times.

The place of archaeological excavations, the village Shakhtar of the Nikopol raion, Dnipropetrovsk region, is located to the northeast of the city of Pokrov. In this area, there are numerous outcrops of crystalline rocks. To the west of the excavation site, on the Bazavluk River, including the lower reaches of the river Solona, there occur the rocks of Chortomlytska greenstone structure, which are mainly represented by amphibolites. Earlier, they were exposed in the lower reaches of the Chortomlyk River (Usenko, 1953), south of the village Shakhtar. West of the village Sholohivske pink two-feldspar granites of the Tokivskyi complex begin to crop out. Plagiogranites in the area of the excavation site location were found in the middle and upper reaches of the Solona River and along the Bazavluk and Bazavluchoch rivers upstream of the Sholokhivske Reservoir. Also, north of Nikopol city, there is a large Novopavlivske granite deposit, but before its development, the minimum overburden thickness was 2.5 m, reaching 20 m in some places. So, most likely, plagiomigmatites of this deposit were not used in ancient times. The closest to the excavation site are the occurrences of plagiogranitoids, which crop out in the valley of the Solona River. In particular, the occurrence of crystalline rocks was recorded in the area of the village Oleksandrivka of Nikopol district, Dnipropetrovsk region (Vidergauz et al., 1964), located on the right bank of the Solona River, opposite the village of Shakhtar (Fig. 5). Thus, the granitoids of the studied monument were most likely of local origin.

Limestones. The studied samples are represented by rounded carbonate concretions with concentric structure or their fragments – the layers that broke away from a larger nodule. Oncoids (bioherms) have a similar shape, resulting from the activity of cyanobacteria, due to which the thin layers of cryptocrystalline carbonate grow overlaying each other. The most probable is the origin of this collection from the deposits of carbonate rocks of Neogene age, common in the area of excavations (Fig. 5). Carbonate rocks found in this area belong to the Sarmatian, Meotian and Pontic stages. They are represented by shell limestones, oolite limestones, marls, and clays.
The rocks occur in the form of beds, less often form lenses, contain layers of marl, sand, and clay. Limestones of the Upper and Middle Sarmatian are the most common. These are white to greyish white oolite, shell or marl rocks. They are usually exposed on the slopes of river valleys, in gullies and ravines. The thickness of the strata is from 0.5 to 8 m, less often – up to 20 m (Vidergauz et al., 1964). Most often, oncoids in the studied area are found as the uncremented specimens that spilled out of the limestones. They are recorded along the northern and southern banks of the Kakhovske Reservoir. In the primary deposits in limestones, they were noted by V.V. Maniuk near the village of Vyshchetarasivka, Nikopol rayon, Dnipropetrovsk oblast. The scientist dates oncoids containing limestones to the Middle Sarmatian and identifies them as stromatolite bioherms, as well as notes that they consist of calcite and dolomite (Manyuk, 2009), which is quite correlated with the data of our analysis.

In the middle of the last century, L.S. Bilokrys studied similar collections on the right and left banks of the Kakhovske Reservoir. In particular, the nodules sampled near the village of Velyka Lepetykha, were defined by him as oncolites and referred to the Kherson horizon of the Upper Sarmatian. The closest to the excavation site published occurrence of oncoids is the accumulation of oncolites washed out from the riverside outcrop of limestones near the village of Novovorontsovka, Kherson Oblast, studied by L.S. Bilokry (Dmitrieva et al., 1969), located 40 km from the excavation site. However, it can be assumed that such outcrops could exist much closer to the monument, as the occurrences of Sarmatian limestones are very common in the immediate vicinity of the excavation site (Fig. 5). Sarmatian limestones were found in the studied area between the rivers of Bazavluk and Solona in the zone of their confluence, as well as in the middle and upper reaches of the river Chortomlyk. Determining the affiliation of the studied oncoids to the Upper or Lower Sarmatian is quite problematic, but it should be noted that often rocks of different horizons of the Sarmatian stage are found in the same deposits, forming different layers in the strata of the rocks that crop out (Vidergauz et al., 1964), in addition, Upper Sarmatian sediments do not go beyond the distribution of the Middle Sarmatian rocks (Didkovskiy et al., 1975).

Conclusions.

As a result of the study, it was found that the stone of the Eneolithic burials of the kurgan No 29 near the Shakhtar village was most likely taken from the nearest granitoid outcrops located in the valley of the Solona River. Carbonate rocks represented by oncoids could originate either from the Dnipro valley in the area of the former Dnipro Reeds (Kakhovskie Reservoir), or from the occurrences of Sarmatian limestones on the Solona, Chortomlyk, and other rivers, if they existed at the time of the cromlech construction. The fact of the use of oncoids in mound construction that has been established as a result of this study is currently unique. It should be noted that the choice of the nearest outcrops was a common practice during the Eneolithic. Nevertheless, the results of the study prove that the extraction of stone blocks, which was actively carried out in the Nikopol Dnipro Area in connection with the construction of mounds, including the Middle Ages, began in this area in the Eneolithic. The extraction of stone blocks required the use of certain mining techniques, which testifies in favor of stone mining in the Eneolithic Age in the area.

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