https://doi.org/10.33271/nvngu/2024-6/005

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# THE MATERIAL PROVENANCE OF STONE ARTEFACTS FROM THE NOVOOLEKSANDRIVKA KURGAN

**Purpose.** To establish the origin of the rocks used to produce ancient stone tools and goods found as a result of Novooleksandrivka Kurgan "Sura-Oba" excavations (Dnipropetrovsk Region, Ukraine).

**Methodology.** The research was carried out using the method of petrographic analysis of the materials of stone artefacts in thin sections. The chemical composition of the studied rocks was determined using X-ray fluorescence analysis. The obtained data was compared to the features of similar rocks from different occurrences, using thin sections of rocks from natural outcrops and previously studied stone artefacts, as well as the data of geological reports and appropriate literature.

**Findings.** Thirteen stone artefacts, represented by an altar stone, hammerstones, whetstones, a hammer-axe and different polyfunctional tools found in the burials of the Novooleksandrivka Kurgan "Sura-Oba" dated back to the Chalcolithic, Bronze Age and Early Iron Age were analyzed. As a result of the conducted research, it was ascertained that sandstones, granite, amphibolite, quartz rock, dolerite-basalt, actinolitite, and epidosite represent their materials. Most of the studied collection samples have similar analogues among the rocks found in the Middle Dnipro Area and may be of local provenance. The specimen of dolerite-basalt microporphyry may originate from the East Azov Sea Area, and the oligomictic sandstone, most likely, was delivered from the occurrences of the Donets Coal Basin Carboniferous system.

**Originality.** For the first time, stone tools and goods discovered during the excavations of the "Sura-Oba" mound in the village of Novooleksandrivka were studied using petrographic analysis; the probable places of their origin were established.

**Practical value.** The results obtained can be used in conducting research on history and archaeology, as well as in popular science works and excursion activities.

**Keywords:** *stone tools, petrography, Eneolithic, Bronze Age, Sarmatians, Novooleksandrivka Kurgan, Ukraine*

**Introduction.** Petrographic studies of the raw materials of stone artefacts are essential for understanding the manufacturing and exchange in prehistoric times. One of the most significant monuments of the Middle Dnipro Area, recently excavated, is the cromlech-crepidoma in the village of Novooleksandrivka to the south of the city of Dnipro, discovered as a result of the kurgan 6048-1 "Sura Oba" exploration. The cromlech, covered with the initial mound, is connected to the central entombment of the Eneolithic Age. The mound was re-completed 11 times and contained several peripheral burials dated back from the Eneolithic to the Early Iron Age. During the excavations, we studied the building stones of the cromlech, which allowed us to find the source of their delivery [1]. The petrographic studies of stone tools that come directly from the entombments and belong to the accompanying inventory are no less important. Their research will make it possible to determine which stone raw materials were used by the mound builders and if the products made from non-local raw materials are to be detected to discover the presence of inter-regional connections.

This article is devoted to the petrographic study of stone artefacts discovered during the excavation of the kurgan in the village of Novooleksandrivka and determining their provenance. The studied stone artefacts belong to the Eneolithic Age (finds from the primary mound of the kurgan), the time of the Yamna (a fragment of an axe-hammer from burial No. 17) (Fig. 1) and Catacomb (tools and artefacts from burials Nos. 6 and 8) cultures of the Bronze Age, as well as the Early Iron Age (fragment of a grinding stone from Sarmatian burial No. 25). It should be noted that Catacomb culture burial No. 6 was two-story. The earlier burial, the lower one, contained two tools. The rest of the stone tools from this grave are associated with the later monocultural burial of the child.

**Literature review.** Petrographic methods in the study of stone tools are widely used in archaeology worldwide. Among the recent publications on this topic, we should mention the work by Argentinian researchers M. Barros, A. Blasi, and G. Politis [2], devoted to the study of stone products found during the excavation of the site Arroyo Seco 2 (Province of Buenos Aires, Argentina). The performed studies indicated that the rocks analyzed originate from different outcrops of the Pampa Húmeda subregion. These sources are both primary and secondary. They are located in different sectors of the Ventana and Tandilia mountain ranges, in the Claromecó basin and the Atlantic coast. In the article by Portuguese researchers P. Jordão and N. Patrícia, the stone tools found during the excavations of the Eneolithic settlement Zambujal (Estremadura, Portugal) were studied. The study made it possible to identify local and regional ranges of provenance of stone materials and compare their petrographic characteristics [3]. Czech researchers P. Burget and A. Přichystal analyzed the use of marble for the production of bracelets in Neolithic Cen-


*Fig. 1. Hammer-axe fragment or a preform for an axe 21*

tral and Western Europe using petrographic and geochemical research methods [4]. The number of petrographic studies performed in some regions allows for the creation of databases and distribution maps of artefacts and various types of raw stone materials. Thus, a group of researchers led by K. Biró carried out work on creating a database for the analytical study of polished artefacts to reconstruct prehistoric transregional trade routes of the Carpathian Basin and its outskirts [5]. New archaeological excavations continue to provide new materials for petroarchaeological studies, which even now allows us to reveal the facts of the ancient use of some types of raw stones for the first time. So, a group of Polish researchers established the beginning of using quartz-sericite schists from Silesia to manufacture grinding stones by representatives of the La Tène culture of the Early Iron Age [6].

In Ukraine, the studies of ancient stone tools in recent years have been performed by O. V. Mytrokhyn and M. N. Daragan, who studied the collection of 80 spheroidal stones from the Scythian burial in the village of Chervonyi Podil in Kherson Region and ascertained that the raw materials for their production were the actinolitites, which, more likely, originate from the territory of the Middle Dnipro Area [7]. V. I. Korinnyi, V. S. Rud and V. A. Kosakivskyi performed petrographic determinations of the Eneolithic tools from the Trypillia culture settlements in the interfluve of Buh and Dniester Rivers. It was ascertained that feldspar-quartz and quartz sandstones, granites, aplitoid granites, gneisses, crystalline schists, dolomite calciphyre, tectonic breccia, quartz, and wollastonite skarn were used for the manufacture of tools by Trypilians [8]. Also, petroarchaeological studies of ancient tools and products were conducted by one of the authors of this article. Among the recent works, we can note a study devoted to the search for the place of extraction of meta-ultrabasites for the manufacture of stone casting moulds, which were found during the excavations of the archaeological site Tokivske-1 in Dnipropetrovsk Region [9].

Thus, a comprehensive study of ancient stone artefacts using petrographic methods is necessary to understand the peculiarities of using raw stone materials on the territory of Ukraine in ancient times in the world context.

**Topicality.** The petrographic study and determination of the provenance of the raw material of stone artefacts discovered during the excavations of such an important monument as the Novooleksandrivka Kurgan, in the context of their archeology, will allow clarifying the peculiarities of the production, distribution, and use of various categories of stone inventory, which is of great importance for the study of the ancient history of the use of the mineral raw material base of Ukraine, as well as for further developments in the field of social and spiritual culture of ancient societies.

**Purpose.** To establish the origin of the rocks used to produce ancient stone tools and goods found as a result of Novooleksandrivka Kurgan “Sura-Oba” excavations.

**Methodology.** For the petrographic study, 13 samples were selected, the condition of which, particularly the presence of damages, allowed sampling for the production of transparent thin sections. One of the main tasks during sampling was to cause as minor damage as possible to the studied artefacts. The size of the selected samples was minimally sufficient to produce transparent petrographic sections. The research was performed using a POLAM R-312 polarizing microscope. Materials from geological reports, literary sources, thin sections of a collection of rocks from natural outcrops, and pre-examined stone artefacts from various regions were used to determine the provenance of the samples. X-ray fluorescence analysis (XRF) was used, if necessary, to determine the composition of rocks and establish their origin more accurately. The chemical composition was determined in powder on the ElvaX Plus device (analyst – A. S. Koveria) in the Analytical Research Laboratory of Dnipro University of Technology.

**Findings.** As a result of the petrographic research of the specimens of the collection in thin sections, it was ascertained that they are represented by sandstones *6, 7, 8, 11, 12, 17, 25*, granite *4*, amphibolite *9*, quartz rock *10*, dolerite-basalt *21*, actinolitite *33* and epidosite *34* (here and after the numbers of specimens are indicated according to the number in the catalogue). In Table 1, the list of studied artefacts is represented.

***Sandstones.*** The biggest group in the studied collection consists of sandstone products. Among the seven sandstone items, *samples 6, 7 and 11* are represented by almost identical quartz sandstones (quartz arenites) with siliceous cement (Fig. 2). Quartz makes up more than 99 % of the detrital material, single grains of potassium feldspar and chert are also present. The clastic material is represented by grains 0.1–0.2 mm in size. The shape of the grains is most often concave-convex due to compression; there are rounded and sub-rounded grains. The cement of the rock, according to its mineral composition, is chalcedonic, and according to the type of cementation, it is syntaxial rim (crust), sometimes pore-filling. Quartz syntaxial rim cement is also present in some areas, or the grains are compressed without cement. Sample *11* differs from the rest in the larger size of clastic grains. Most quartz grains have a size of 0.2–0.4 mm. More prominent in size, compared to most clasts, rounded quartz grains with the measurements of 0.7–1.8 mm are present.

*Sample 8* was determined as a sandstone with the syntaxial rim quartz cement (quartz arenite). The detrital material of the rock consists almost entirely of quartz, and a single grain of amphibole has been identified. The quartz is represented by the grains of rounded, lesser grains – sub-rounded shape, with the size of 0.1–0.6 mm. Most of the grains are 0.2–0.3 mm in size. Amphibole (anthophyllite) is represented by an elongated rounded grain that pleochroizes from light yellow to pale

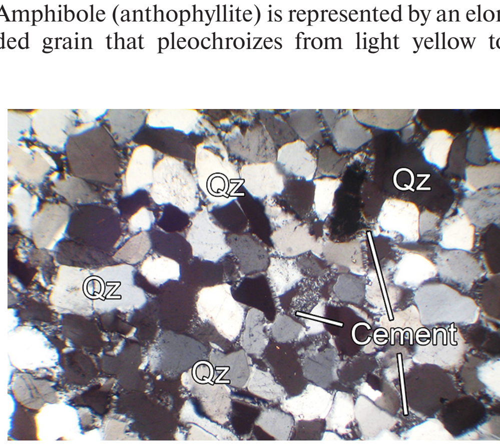


*Fig. 2. Quartz sandstone with siliceous cement (6):*
*Qz – quartz, Cement – siliceous cement.*
*Transmitted light, nicols* (+), *zoom* $47^x$

*Table 1*

The studied artefacts

| No. | Name and description of the find (the number in the catalogue corresponding to the number of the thin section) | The place of discovery | Archaeological culture or a period | Material |
|---|---|---|---|---|
| 1 | **4.** "Altar" in the form of a truncated cone with rounded walls, partially damaged.<br>Dimensions: diameter of the upper part – 9.8 cm; diameter of the lower part – 14.4 cm; height – 8 cm | Burial No. 6 | Catacomb culture | Quartzized trondhjemite |
| 2 | **6.** Polyfunctional stone tool (hammerstone?) of an irregular oval shape, semispherical in cross-section.<br>Dimensions: 7.8 × 5.2 × 2.7 cm | Burial No. 6 | Catacomb culture | Sandstone (quartz arenite), fine-grained with siliceous cement |
| 3 | **7.** Stone tool fragment (hammerstone?) of an asymmetric shape, semispherical in cross-section.<br>Dimensions: 8.1 × 6.0 × 3.3 cm | Burial No. 6 | Catacomb culture | Sandstone (quartz arenite), fine-grained with siliceous cement |
| 4 | **8.** Stone tool fragment of a sub-square shape, sub-triangular in cross-section.<br>Dimensions: 6.4 × 6.3 × 2.7 cm | Burial No. 6 | Catacomb culture | Sandstone (quartz arenite) with quartz cement |
| 5 | **9.** Stone tool of a rectangular shape, rectangular in cross-section.<br>Dimensions: 8.5 × 6.9 × 3.6 cm | Burial No. 6 | Catacomb culture | Amphibolite, altered |
| 6 | **10.** Stone tool (hammerstone?) of an asymmetric shape.<br>Dimensions: 6.5 × 5.3 × 4.2 cm | Burial No. 6 | Catacomb culture | Quartz rock |
| 7 | **11.** Stone tool fragment (hammerstone?) of an asymmetric shape, asymmetric in cross-section.<br>Dimensions: 8.8 × 8.3 × 5.6 cm | Burial No. 6 | Catacomb culture | Sandstone (quartz arenite) with siliceous cement |
| 8 | **12.** Stone grinding plate fragment of a trapezoidal shape, rectangular in cross-section.<br>Dimensions: 9.2 × 6.6 × 2.3 cm | Burial No. 6 | Catacomb culture | Sandstone (quartz arenite) with siliceous cement |
| 9 | **17.** Polyfunctional stone tool (whetstone?) of an asymmetric shape, asymmetric in cross-section. With a groove, perhaps for straightening arrow shafts.<br>Dimensions: 12.3 × 8.5 × 5.5 cm | Burial No. 8 | Catacomb culture | Silty sandstone (quartz aleuro-psammite) |
| 10 | **21.** Hammer-axe fragment or a preform for an axe with traces of repeated use as a multi-functional tool (pounder-grinder, hammerstone?). A trapezoidal tool, rectangular in cross-section with the remains of an axe eye.<br>Dimensions: 12 × 6 × 3.6 cm | Burial No. 17 | Yamna culture | Dolerite-basalt, microporphyric |
| 11 | **25.** Whetstone fragment, oval in cross-section.<br>Dimensions: 8.0 × 3.5 × 2.2 cm | Burial No. 25 | Sarmatian culture | Oligomictic sandstone (sublithic arenite) with polymineral cement |
| 12 | **33.** Stone tool (hammerstone?) from a river pebble of a sub-rectangular shape, elongated-oval shape in cross-section.<br>Dimensions: 14.5 × 8.9 × 4.9 cm | Mound, South–East sector | Eneolithic Period | Actinolitite |
| 13 | **34.** Stone tool (hammerstone?) from a river pebble debris, asymmetric in cross-section.<br>Dimensions: 10.4 × 7.7 × 7.5 cm | Mound, South–East sector | Eneolithic Period | Epidosite |

green. It has a slightly visible cleavage and parallel extinction under crossed nicols. Quartz cement contains an admixture of iron hydroxides and aggregates of carbonaceous substance.

*Sample 12* was identified as a sandstone with siliceous cement (quartz arenite). 99 % of the clastic material is composed of quartz grains; less than 1 % of polycrystalline quartz grains and a single zircon grain were detected in the thin section. The clastic material is poorly sorted and has different roundness – from rounded to angular grains, regardless of size. The measurements of the clasts are 0.1–1.5 mm, and the bulk of grains have a size of 0.3–0.6 mm. Quartz has an undulatory extinction; some quartz grains are polycrystalline and probably are represented by quartzite or vein quartz debris. The cement is mainly composed of microflakes of chalcedony, which do not have a specific orientation, and amorphous opal, highly coloured by other impurities (most likely, carbonaceous substance). In some areas, an admixture of dispersed goethite can be identified by colour. The cement also contains larger individuals of chalcedony, which turns into quartz. Some minor quartz grains in cement have an angular shape and probably represent a clastic admixture of aleurite size (matrix).

The clastic material of the quartz silty sandstone (*sample 17*) has the following composition (%): quartz – 99, chert – 1, muscovite – < 1, opaque aggregates (ore mineral) – < 1. Single grains of glauconite, microcline, plagioclase and zircon are also present in the rock. The size of clastic grains is 0.05–0.3 mm. Quartz grains have different degrees of rounding, from rounded to angular. Often, at contact with other quartz grains, the shape of the fragments is concave-convex. Chert is represented by grains with a scaly and radially fibrous internal structure. The cement of the rock is quartz, pore-filling, and syntaxial rim; also, the connection of grains without cement is observed. The texture of the rock is aleuropsammitic.

*Sample 25* was identified as an oligomictic sandstone with polymineral cement (sublithic arenite) (Fig. 3). Composition of detrital material by rock volume (%): quartz – 80, chert – 6, plagioclase – 3, micaceous quartzite – < 1, muscovite – < 1, goethite (secondary aggregates-pseudomorphoses) – 1, sider-

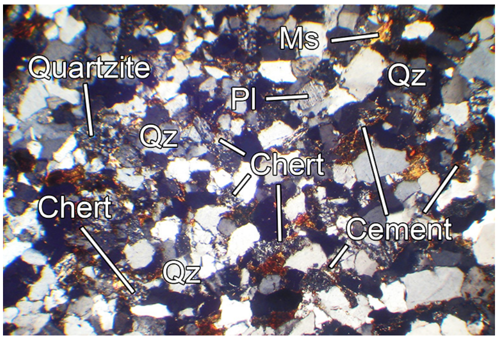


*Fig. 3. Oligomictic sandstone (25):*

*Qz – quartz, Pl – plagioclase, Ms – muscovite, Chert – debris of silicious rocks, Cement – polymineral cement. Transmitted light, nicols (+), zoom 47*

ite (aggregates) – <1. Single fragments of argillite, potassium feldspar, volcanic rock, and zircon grains are also present. The size of the detrital grains is 0.05–0.3, mostly 0.1–0.2 mm. Quartz grains have concave-convex boundaries in places of compression with other grains, sometimes they are rounded. Plagioclase is represented by crystals with polysynthetic twinning or grains without twins, the shape of fragments is conformal or tabular, idiomorphic. Plagioclase is weakly altered by sericite. Quartz grains are mostly combined without cement. Pore-filling cement makes up about 10 % of the rock volume. According to its mineral composition, it is divided into argillaceous-ferruginous and argillaceous-siliceous (illite-chalcedony). The texture of the rock is aleuropsammitic.

***Granite.*** In the investigated collection, the material of the conical "altar"of light grey-yellow colour (*sample 4*) is represented by granite (Fig. 4). The rock was identified as quartzized trondhjemite (plagioclase granite). Mineral composition of the rock (%): plagioclase – 45–50, quartz – 35–45, microcline (including antiperthite) – 5–10, epidote – 1, muscovite – <1. Sericite is moderately altering plagioclase; an ore mineral is present as a single angular grain. Plagioclase is represented by tabular crystals with often manifested polysynthetic twins. The crystals are up to 3.5 mm, and the main bulk is about 1.5 mm. Plagioclase is moderately sericitized, to a lesser extent it is replaced by epidote at the edges. Quartz forms aggregates of grains of irregular shape with weak undulatory extinction. Part of the crystals is cracked (cataclased). The grain size is up to 1.7 mm, and the main bulk is 0.5–1.0 mm. Quartz is granulated, and a quartz vein that penetrates the rock is present. The microcline forms tabular crystals with indistinct crosshatched twinning. It has a lower degree of secondary changes than plagioclase; the mineral is mainly replaced by epidote, and it is less often slightly altered by sericite (single flakes). The size of microcline crystals is up to 2 mm. Part of them is represented by antiperthites in plagioclase. Epidote crystals are distinguished by higher interference colours, mostly anomalous – violet and dirty blue – characteristic of the epidote-clinozoisite isomorphic series. Muscovite is represented by single scales with high interference colours, perfect cleavage and parallel extinction. The texture of granite is hypidiomorphic-granular (Fig. 5).


*Fig. 4. "Altar" in the form of a truncated cone (4)*

***Amphibolite.*** An altered amphibolite represents the studied *sample 9.* Mineral composition of the rock (%): hornblende – 80, plagioclase (together with alteration products) – 20, quartz – <1, ore mineral – <1 (oxidized); secondary minerals: apatite, sericite, chlorite and epidote. Hornblende forms prismatic crystals oriented in one direction. Cross sections show amphibole cleavage. The hornblende pleochroism is from light green to bluish green colour, and it is weakly replaced by epidote.

Plagioclase is represented by relict crystals, most of which are intensively altered by secondary minerals. The bulk of plagioclase crystals is entirely replaced by sericite and by aggregates of epidote grains and chlorite flakes, which form pseudomorphs, altering some of the primary crystals. Quartz creates single aggregates of irregularly shaped grains with undulatory extinctions. The texture of the rock is glomerolepidogranoblastic, and the structure is linear-parallel. With the help of X-ray fluorescence analysis (XRF) of the sample in powder, data on the chemical composition of the amphibolite were obtained (Table 2).

***Quartz rock.*** *Sample 10* consists of quartz crystals of irregular shape, which mainly have jagged edges. The extinction of quartz crystals is undulatory. Small, elongated aggregates of micro-flaky sericite are present. The size of quartz individuals is 3–8 mm. The rock texture is granoblastic.

***Dolerite-basalt.*** *Sample 21* was identified as a microporphyric dolerite-basalt because the rock has tiny porphyric inclusions, and the crystals that form its matrix are small, corresponding to basalt. However, at the same time, its texture is fully crystalline and does not contain glass or the products of its alteration (Fig. 6).

Mineral composition of the rock is as follows (%): plagioclase – 63, clinopyroxene – 24, orthopyroxene – 3, olivine – 3, ore mineral (magnetite) – 4, biotite – 1, talc – <1, bowlingite – <1, chlorite – <1. Plagioclase, which makes up the groundmass of the rock, is represented by prismatic crystals 0.1–0.4 mm in size. Most pyroxene crystals have a size close to

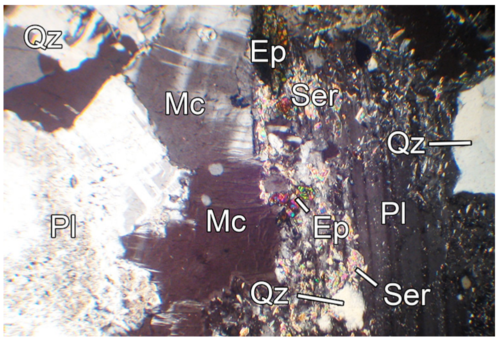


*Fig. 5. Trondhjemite (4):*

*Qz – quartz, Pl – plagioclase, Mc – microcline, Ser – sericite, Ep – epidote. Transmitted light, nicols (+), zoom 47ˣ*

*Table 2*

Results of XRF analysis of the amphibolite sample *9*

| Element | Intensity | Concentration, % |
|---|---|---|
| $SiO_2$ | 289,341 | 47.955 ± 0.205 |
| $Fe_2O_3$ | 1,880,959 | 15.594 ± 0.056 |
| $Al_2O_3$ | 34,320 | 12.602 ± 0.159 |
| CaO | 96,226 | 12.113 ± 0.079 |
| MgO | 6,852 | 9.610 ± 0.340 |
| $K_2O$ | 3,708 | 0.833 ± 0.055 |
| $TiO_2$ | 12,861 | 0.601 ± 0.019 |
| MnO | 17,783 | 0.197 ± 0.004 |
| $Sc_2O_3$ | 1,910 | 0.165 ± 0.044 |
| $TeO_2$ | 346 | 0.053 ± 0.189 |
| PdO | 17,537 | 0.047 ± 0.003 |
| $V_2O_5$ | 1,189 | 0.041 ± 0.010 |
| $Cr_2O_3$ | 2,134 | 0.041 ± 0.005 |
| Rh | 24,297 | 0.041 ± 0.002 |
| NiO | 4,417 | 0.025 ± 0.002 |
| SrO | 26,313 | 0.023 ± 0.001 |
| $P_2O_5$ | 400 | 0.019 ± 0.018 |
| ZnO | 5,132 | 0.014 ± 0.001 |
| S | 1,028 | 0.008 ± 0.002 |
| $ZrO_2$ | 7,864 | 0.008 ± 0.001 |
| $Y_2O_3$ | 3,291 | 0.003 ± 0.001 |
| CuO | 736 | 0.003 ± 0.001 |
| $Ga_2O_3$ | 682 | 0.002 ± 0.000 |
| $RuO_2$ | 1,214 | 0.001 ± 0.001 |

plagioclase. Clinopyroxene, orthopyroxene and olivine form microporphyric inclusions. Porphyric olivine crystals have a rounded shape and a size of up to 1.5 mm. Porphyric inclusions of pyroxenes have an angular shape and often manifest twinning. The size of individual crystals is up to 0.8 mm. Pyroxenes often form aggregates up to 1.5 mm in size. Olivine is intensively replaced by an ore mineral (magnetite), bowlingite, chlorite, and talc, sometimes to the point of complete replacement. Biotite slightly alters pyroxene. The texture of the rock is microporphyric and glomeroporphyric.

***Actinolitite.*** The material of *sample 33*, represented by a tool, probably a hammerstone made from a sub-rectangular river pebble fragment, elongated-oval in cross-section, was

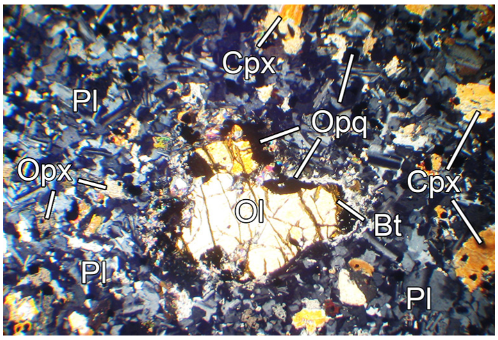


*Fig. 6. Dolerite-basalt (21):*

*Pl – plagioclase, Ol – olivine, Cpx – clinopyroxene, Opx – orthopyroxene, Bt – biotite, Opq – ore mineral.*
*Transmitted light, nicols (+), zoom 47x*

identified as actinolitite. In the excavation materials, the rock is identified as granite. The studied sample consists of actinolite and plagioclase and contains a small amount of quartz grains. Among the accessory minerals is sphene, which developed due to replacing titanomagnetite (titanomorphite). Actinolite makes up about 70 % of the volume of the rock and is represented by prismatic and long-prismatic crystals, pleochroizing from light green to yellow. Plagioclase is granular and forms aggregates between amphibole crystals. Some plagioclase crystals exhibit polysynthetic twins. The texture of the rock is glomeroheteronematogranoblastic (Fig. 7).

Using XRD analysis of the specimen in powder the data on the chemical composition of actinolitite were obtained (Table 3).

***Epidosite.*** *Sample 34* was identified as an epidosite. 95 % of the rock consists of minerals of the epidote-clinozoisite isomorphic series, 5 % of the volume is quartz. The bulk mass of tabular crystals of clinozoisite and epidote has a size of less

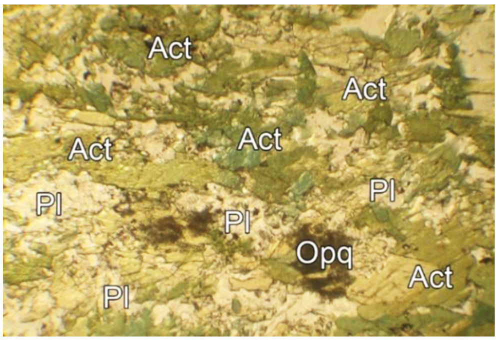


*Fig. 7. Actinolitite (33):*

*Pl – plagioclase, Act – actinolite; Opq – altered ore mineral.*
*Transmitted light, nicols (+), zoom 47x*

*Table 3*

Results of XRF analysis of the actinolitite sample *33*

| Element | Intensity | Concentration, % |
|---|---|---|
| $SiO_2$ | 326,220 | 49.169 ± 0.203 |
| CaO | 100,762 | 13.207 ± 0.083 |
| $Al_2O_3$ | 39,694 | 13.136 ± 0.152 |
| $Fe_2O_3$ | 1,471,674 | 12.564 ± 0.046 |
| MgO | 8,392 | 10.456 ± 0.320 |
| $TiO_2$ | 7,832 | 0.390 ± 0.018 |
| $K_2O$ | 1,554 | 0.367 ± 0.053 |
| $Sc_2O_3$ | 2,144 | 0.197 ± 0.047 |
| MnO | 14,104 | 0.161 ± 0.004 |
| $Cr_2O_3$ | 6,524 | 0.134 ± 0.006 |
| PdO | 22,771 | 0.059 ± 0.003 |
| Rh | 32,383 | 0.052 ± 0.002 |
| $V_2O_5$ | 996 | 0.037 ± 0.009 |
| NiO | 5,890 | 0.032 ± 0.002 |
| SrO | 16,735 | 0.014 ± 0.001 |
| ZnO | 3,541 | 0.009 ± 0.001 |
| S | 888 | 0.007 ± 0.002 |
| $ZrO_2$ | 4,558 | 0.004 ± 0.001 |
| $Y_2O_3$ | 2,704 | 0.002 ± 0.001 |
| $Ga_2O_3$ | 700 | 0.002 ± 0.000 |
| $Nb_2O_5$ | 1,439 | 0.001 ± 0.001 |

than 0.1 mm. Crystals show anomalous blue interference colour, more rarely – purple. In the groundmass, there are inclusions of larger crystals of epidote and quartz. Quartz forms crystals of irregular shape, often containing inclusions of epidote-clinozoisite. Epidote has a visible cleavage, inclined extinction on all sections. The colour under parallel nicols is greenish-yellow. The texture of the rock is heterogranoloblastic, microgranular.

**Provenance of rocks and discussion.** Quartz sandstones similar to *samples 6, 7* and *11,* which have siliceous cement, are found on the left bank of Dnipropetrovsk Region and in other parts of the Middle Dnipro Area, in particular, we studied similar rocks from the area of Slovianka Village of Synelnykivskyi Raion. Also, rocks similar in composition are exposed in Novomoskovsk Raion of Dnipropetrovsk Region, differing in the presence of a larger volume of opal and impurities of opaque substances in the cement. These sandstones belong to the Neogene Poltava series. On the right bank of the Dnipro River, the nearest occurrence of ferruginous sandstones to the excavation site, similar to *sample 8*, was recorded in the gully of Hlyniana near the former village of Fedosiivka, Nikopol Raion. Most likely, the sandstone is of Sarmatian age. Similar sandstones are widely distributed in the Middle and Lower Dnipro Areas [10] (Vidergauz, L. M., 1964). The closest in petrographic features to *sample 12,* not well-sorted sandstones, in particular, composed of quartz fragments of various sizes, as well as those containing fine quartz fragments in siliceous cement, were found among the sandstone pebbles contained in the Mandrykivka Layers of the Paleogene age in the territory of the city of Dnipro. Quartz silty sandstones with quartz cement (*sample 17*) are widely distributed in the Middle and Lower Dnipro Areas. It is most probable that the specimen belongs to sandstones of the Poltavska series or the Sarmatian stage, which may have regenerated quartz cement and contain single fragments of chert and glauconite (Tkachuk, L. G., 1981). Most likely, the rock originates from the region of the find. Oligomictic sandstones with polymineral cement, similar to *sample 25*, are not typical for the Middle Dnipro Area. Similar sandstones are characteristic of the sediments of the Donets Coal Basin Carboniferous system and the Vendian system sedimentary cover of the Podilskyi ledge [11] (Tkachuk, L. G., 1981). The nearest outcrops of these rocks from the place of discovery are in the east, within Donetsk and Luhansk Regions and belong to the deposits of the Carboniferous system of Donbas. In particular, these rocks are characterized by a significant admixture of chert fragments, volcanic rocks, feldspars from granitoids and sedimentary rocks, as well as cement of a mixed composition (Tkachuk, L. G., 1981), in which, in particular, siderite is often present [12]. The oligomictic sandstones of the Yampilski strata of the Mohylivska suite of Podillia differ from the studied sample by the predominance of plagioclase over rock fragments and structural features (we are grateful to Ye. V. Kosarieva (Soldatenko) for the thin sections provided for the study) [13]. Regarding petrographic features, the studied sample most closely corresponds to the Carboniferous sandstones of the Donets Basin. We encountered similar sandstones while studying the collection of Polovtsian stone statues originating from the Donbas [14].

The granite *sample 4* differs from the most common trondhjemites of the Dnipropetrovsk and Surskyi complexes, distributed in the area where the artefact was found by the absence of biotite [15]. The rock can belong either to the vein aplite-pegmatitic microcline-albite plagioclase granites that intersect other granitoid rocks or to the leucocratic varieties of trondhjemites of the Dnipropetrovsk complex [16, 17]. Thus, the material of the specified product may come from the area of the Middle Dnipro megablock of the Ukrainian Shield.

Amphibolites (*sample 9*) are widely distributed in the Middle Dnipro Area. They make up Archean greenstone structures and also form xenoliths as part of migmatites [18]. According to petrographic features, the studied sample is more similar to metabasites of greenstone structures. It may belong to the amphibolites of the Surska suite of the Konkska series, the closest outcrops of which from the place where the artefact was found are upstream of the Mokra Sura River, within the Surska greenstone structure [19]. According to the features of the chemical composition, the amphibolite sample is close to similar rocks exposed in the basins of the Mokra Sura, Bazavluk and the former Chortomlyk rivers. All the mentioned rocks, in particular, have a ratio of FeO, MgO, and CaO close to 1 : 1 : 1, which differs them from the amphibolites of Kryvyi Rih Area and the Hirskyi Tikich and Hnylyi Tikych Rivers, in which the total iron content is equal to the sum of magnesium and calcium. This predominance is also characteristic of albitized amphibolites of the Mokra Sura River; however, in the valley of the Mokra Sura, non-albitized amphibolites have a chemical composition close to the studied sample, which can also have a melanocratic composition (up to 80 % hornblende) (Usenko, I. S., 1953).

Quartz rocks *(sample 10)*, mainly represented by hydrothermal formations, are widespread in the zone of the Ukrainian Shield. Quartz veins intersect the granitoids in the area where the artefact was found.

In the Middle Dnipro Area, as well as in most parts of the Ukrainian Shield, where crystalline basement rocks are exposed, a rock similar to the dolerite-basalt of *sample 21* could have originated from the marginal part of the olivine dolerite dyke. Within the limits of the Middle Dnipro megablock, olivine dolerites are found along the Bazavluk River and in Kryvyi Rih Area. However, the provenance of this sample from the distribution zone of flow basalts is more likely. On the territory of Ukraine, basalts are most common in Transcarpathia, in Volyn, and the southwestern part of Donbas (Usenko, I. S., 1975). Among the basalts of Transcarpathia, in contrast to the studied sample, secondary carbonates are highly developed, olivine in a significant volume is present in the groundmass of the rocks, and there is also a significant admixture of glass. However, microporphyric inclusions, similar to those in the studied sample, are quite common. In Volyn, the two main types of basalts are aphanitic and amygdaloidal basalt. The sample under study is not amygdaloidal. The aphanite species of this region contain a large volume of volcanic glass, and the microporphyric texture is also not characteristic of them.

It should be noted that we studied basalts of the Rafalivske deposit, which do not belong to the two mentioned groups but, in terms of structural features, are closer to phaneritic dolerites. However, the studied rock differs from them both in terms of texture and mineral composition. Basalts exposed along the Mokra Volnovakha River, which form natural outcrops along the Anton-Tamara, Vasyl-Tamara, Kamyshevakha, and Tsyhanka gullies, are the closest in petrographic features to the studied sample. The rocks have a microporphyric texture with a microdolerite or intersertal texture of the groundmass. The rocks contain plagioclase, pyroxene, magnetite, biotite and secondary chlorite. The glass and calcite content are optional. The phenocrysts are mainly represented by pyroxene, occasionally by olivine and plagioclase (Usenko, I. S., 1975). Thus, according to many features, the studied sample is the closest in composition and textural peculiarities to the basalts of the East Azov Sea Area.

Actinolitites (*sample 33*) in the Middle Dnipro Area are common among the Konkska series of Archaean rocks that form greenstone structures [19, 20]. The tool was found near the area where the rocks of the Surska greenstone structure are distributed. Similar rocks are also found in the form of vein bodies; in particular, outcrops of meta-ultrabasite are mentioned in the materials of geological reports of the middle of the last century in gullies flowing into the Mokra Sura River downstream of the excavation site. Significant outcrops of actinolitites were noted by I. S. Usenko along the Chortomlyk River, which have not survived to this day. In particular, Chortomlyk actinolitites have a very close chemical composition to the raw material of the studied artefact (Usenko, I. S., 1953). Thus, the rock may originate from the Middle Dnipro Area.

Epidosites *(sample 34)* are widespread among the rocks of the Dnipropetrovsk complex in the area where the product was found. Epidotization processes are ubiquitous downstream of the Mokra Sura River from the village of Novooleksandrivka, reflected in the materials of the geological survey by A. A. Zaitsev and confirmed as a result of field surveys of preserved natural outcrops by one of the authors of this research.

Thus, the raw materials of most of the studied stone artefacts most likely originate from the territory of the Middle Dnipro Area. Artefacts dating to the Yamna culture (dolerite-basalt of the Azov Sea Area) and the Sarmatian culture (sandstone of the Donets Basin) are indirect evidence of connections with distant territories. The material of the Eneolithic products was local and came from the area of excavation. The studied artefacts of the Catacomb culture were made from raw materials common in the Middle Dnipro Area. However, the nearest sources of some rocks could be a hundred or more kilometers away, including the Left Bank of the river Dnipro.

This picture is fully correlated with the results of other petroarchaeological studies. We know that during the Eneolithic Period, the local population actively used local rocks. Among the Yamna culture artefacts found in the Middle Dnipro Area, products brought from the east were recorded, but the use of imported dolerite-basalts in this region in ancient times is not mentioned in the literature. Traditionally, hammer-axes are considered a prestigious category of burial equipment. Therefore, they, or their preforms, were most likely a subject of exchange and, even after damages, continued to be used for another purpose. Representatives of the Catacomb culture had numerous workshops for stone processing, located in the Dnipro valley not far from the site of excavations, the most famous of which is the one discovered on the island Strilcha Skelia. To date, the number of investigated stone artefacts of the Sarmatian culture remains very small, and the results of the study of the raw material of the whetstone (*sample 25)* speak of interregional connections or the mobility of the population of the Sarmatian period. An additional argument in favour of the latter is the discovery of a vessel originating from the Kuban River Area (thanks to Prof. O. V. Symonenko for the consultation) from the same burial. Before that, in the territory of the Middle Dnipro Area, Sarmatian sandstone whetstones were discovered by I. F. Kovaliova on the Left Bank of the river Dnipro, but they were made from local stone raw materials.

**Conclusions.** Most of the samples of the studied collection have similar analogues among the rocks found in the Middle Dnipro Area and may be of local origin (leucocratic trondhjemite *4*, quartz sandstones *6, 7, 8, 11, 12, 17*, quartz rock *10*; actinolitite *33*, epidosite *34*), although similar rocks are also common in neighbouring regions. Oligomictic sandstone *25* is more likely to be of non-local provenance, which is more typical of the Open Donbas. The *sample 21* – microporphyric dolerite-basalt – is also of distant origin. The most likely provenance of this sample is from the zone of spread of basalt flows in the East Azov Sea Area, in the transitional zone of the Ukrainian Shield and the Donets folded structure. As a result of the research, the active use of rocks of the Middle Dnipro Area in ancient times, from the Eneolithic to the Early Iron Age, was once again confirmed. For the first time, evidence of the supply of basalt products from the East Azov Sea Area during the Bronze Age, as well as sandstone products from the territory of the Donets Basin by Sarmatians to the Middle Dnipro Area was obtained.

**Acknowledgements.** *The authors are grateful to Ye. V. Kosarieva, A. S. Koveria, O. V. Symonenko, I. V. Yakimova for consultations and help in research.*

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## Походження матеріалу кам'яних артефактів з Новоолександрівського кургану

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**Мета.** Визначити походження гірських порід, що були використані для виробництва стародавніх кам'яних знарядь та виробів, знайдених при розкопках Новоолександрівського кургану «Сура-Оба».

**Методика.** Дослідження проводилося із застосуванням методу петрографічного аналізу матеріалу кам'яних артефактів у прозорих шліфах. Хімічний склад досліджуваних порід визначався методом рентгенофлуоресцентного аналізу. Отримані дані порівнювалися з особливостями подібних порід із різних проявів, використовуючи шліфи гірських порід із природних відслонень і раніше вивчених кам'яних артефактів, а також дані геологічних звітів і відповідної літератури.

**Результати.** Було досліджено 13 кам'яних артефактів епохи енеоліту, доби бронзи й раннього залізного віку, представлених вівтарним каменем, відбійниками, точильними каменями, сокирою-молотом і різноманітними поліфункціональними знаряддями з поховань Новоолександрівського кургану «Сура-Оба». У результаті проведених досліджень встановлено, що їх матеріал представлений пісковиками, гранітом, амфіболітом, кварцовою породою, долерито-базальтом, актинолітитом та епідозитом. Більшість зразків досліджуваної колекції мають подібні аналоги серед порід Середнього Придніпров'я та можуть бути місцевого походження. З території Східного Приазов'я може походити зразок мікропорфірового долерито-базальту, а олігоміктовий пісковик, найбільш вірогідно, походить із проявів кам'яновугільної системи Донецького басейну.

**Наукова новизна.** Уперше кам'яні знаряддя й вироби, знайдені під час археологічних розкопок кургану «Сура-Оба» у с. Новоолександрівка, були досліджені за допомогою петрографічного аналізу, а також встановлені вірогідні місця їх походження.

**Практична значимість.** Отримані результати можуть бути використані при проведенні наукових досліджень з історії та археології, а також у науково-популярних працях та екскурсійній діяльності.

**Ключові слова:** *кам'яні знаряддя, петрографія, енеоліт, доба бронзи, сармати, Новоолександрівський курган, Україна*

*The manuscript was submitted 06.06.24.*