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Results of petrographic research of new finds from the archaeological monument Tokivske-1

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Abstract. The purpose of the work was to determine the provenance of the raw materials of ancient stone products, found during the excavations of the Bronze-Early Iron Age monument Tokivske-1, with the aim to establish connections of the ancient population of the area with residents of other regions. The archaeological monument Tokivske-1, located in the northern outskirts of the village Tokivske, Apostolove Raion, Dnipropetrovsk Oblast, has been explored by the expedition of Dnipropetrovsk National Historical Museum named after D.I. Yavornytskyi since 2012. The authors of this article already carried out petrographic study of stone artefacts from this monument, which had been found during the first five years of excavations. However, over the past two years, a number of stone and other items were found that could expand our knowledge of the links of Tokivske-1 with ancient industrial centers of other regions. To carry out the petrographic analysis, six artefacts were taken, mainly those made from macroscopically different rocks. Most of them can be related to metalworking. The analyzed samples are represented by an amphibolite hammer for forging jewels or peening sheet copper, a dolerite anvil-prop for a specified hammer, a fragment of an abrasive stone made of ferruginous quartzite, a quartz tile, which is a fragment of an altar, and fragments of an anvil and a scepter-pestle made of sandstone. Petrographic analysis of artefacts allowed determining the probable provenance of their raw materials. Amphibolites are quite common in the territory of the Middle Dnipro area, but by the color of the hornblende, the predominance of epidotization processes over sericitization and macrostructural features, the studied rock is more similar to the amphibolites from the middle stream of the Bazavluk River. Dolerites, similar to the raw material of the anvil-prop, are also common in the area of excavations, and by the presence of the micropegmatite in its composition, its origin can be localized in the middle stream of the river Bazavluk or in the valley of the river Mokra Sura. Magnetite quartzite – the raw material of the abrasive stone – most likely comes from the territory of the city of Kryvyi Rih. Quartz tile – a fragment of an altar – is a quartz vein, similar to those that intersect granites of the Tokivskyi massif directly near the village Tokivske. Sandstones, from which the anvil and the scepter-pestle were produced, appeared to be very similar in their petrographic features. They are represented by quartz sandstones with fragments of rocks and polymineral cement with the predominance of quartz regenerative and porous sericite cement. Also, the relic chalcedony and, more rarely, clay cement are present in the pores. In the territory of Ukraine, the most similar to them, according to petrographic characteristics, are the sandstones of the Carboniferous system, which crop out in the Donbas. Thus, the obtained data testifies to the connection of the Tokivske-1 archaeological complex with other parts of the Middle Dnipro area, such as the middle stream of the Bazavluk River and the Kryvyi Rih area, as well as with more distant regions such as the Donbas. It should be noted that scepter-pestles, similar to the one studied by us, are associated with metalworking, and the Donetsk basin, where the raw material of the indicated tool originates from, was the copper production center of the Late Bronze Age.

Keywords: petroarchaeology, stone tools, Bronze Age, Tokivske-1

Результати петрографічного дослідження нових знахідок з археологічної пам'ятки Токівське-1

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Анотація. За допомогою петрографічного аналізу визначається походження матеріалу кам'яних виробів епохи бронзи з матеріалів розкопок археологічної пам'ятки Токівське-1, розташованої на північній околиці с. Токівське Апостолівського району Дніпропетровської області. Досліджено шість виробів, знайдених під час останніх археологічних розкопок пам'ятки експедицією Дніпропетровського національного історичного музею ім. Д.І. Яворницького у 2017 – 2018 рр. Більшість із них за функціональним призначенням можуть бути пов'язані з металообробкою. Досліджувана колекція представлена молоточком для кування ювелірних виробів або проковування листової міді, підставкою-ковадлом для зазначеного молоточка, фрагментом абразивного каменя, плиткою – фрагментом жертовника, фрагментом ковадла та фрагментом товкача-скіпетра. Найбільш цікавим з досліджених знарядь був пісковиковий товкач-скіпетр, подібні якому, на думку більшості дослідників, належали майстрам-металургам. Для проведення дослідження були обрані зразки, виготовлені з макроскопічно відмінних порід, які могли мати різне походження. Визначення походження виробів є важливим для встановлення зв'язків археологічної пам'ятки з іншими регіонами, зокрема виявлення торговельних зв'язків з центрами металовиробництва. В результаті виконаного петрографічного дослідження визначено, що матеріал артефактів представлений амфіболітом, долеритом, залізистим кварцитом, жильним кварцом і пісковиком. За допомогою порівняння петрографічних особливостей досліджуваних зразків та зразків, відібраних з природних відслонень, а також за опублікованими і звітними даними, було визначено імовірне походження сировини виробів. Всі досліджувані зразки, окрім пісковиків, мають аналоги серед гірських порід Середнього Придніпров'я, при цьому амфіболіт та долерит, найімовірніше, походять з середньої течії р. Базавлук, а залізистий кварцит – з території Криворіжжя. Можливо, племінне об'єднання доби бронзи, якому належала пам'ятка Токівське-1, займало територію між річками Базавлук та Інгулець. Зразки пісковиків, найімовірніше, походять з території Донецького кряжу, що може свідчити на користь зв'язків Токівського-1 з Донецьким гірничо-металургійним центром доби бронзи.

Ключові слова: археологічна петрографія, кам'яні вироби, епоха бронзи, Токівське-1

Introduction. Petrographic analysis is widely used in modern archeology. It is applied to determine the provenance of the artefacts' raw materials that cannot be done using conventional archaeological methods. Determining the raw materials of stone products can detect the connections between remote areas, establish the facts of the exchange trade between regions, and may help in finding places of ancient mining of stone raw materials.

Most often, petrographic methods are used in the research of polished stone tools, which were widely used from the Neolithic to the Bronze Age. Recently, the materials of research of many such stone artefacts were published in the world literature, particularly stone axes and other tools of the archeological monument Wroclaw-Vidava-17 in Poland (Borowski, 2014), collections of Neolithic polished axes found in the southern Italy near Paestum (Aurino, 2017), basalt artefacts of the Bronze Age from Israel (Gluhak, 2018). One of the most comprehensive studies was the petrographic research of more than 400 polished stone tools and weapons dated to the Middle Bronze Age from central Hungary (Farkas-Pető, 2014). The subject of petrographic research were the altar stones of megalithic monuments as well, in particular, an additional study was recently conducted on the composition and provenance of the altar stone material of the world's most known Stonehenge complex in the United Kingdom (Ixter, 2019).

This article is devoted to the research of new finds of polished tools and constructional elements from the Tokivske-1 archaeological monument. It is located at a distance of 0.23 km from the northern outskirts of the village Tokivske, Apostolove Raion, Dnipropetrovsk Oblast, on the right bank of the river Kamianka, which is the right tributary of the Bazavluk River. Archaeological explorations and excavations on this site have been carried out by the expedition of the Dnipropetrovsk National Historical Museum named after D.I. Yavornytskyi since 2012. Studies in the territory of the monument showed three main cultural horizons. The lower one dates back to the transition period from the Middle to the Late Bronze Age (the cultural circle Babine), with which the creation of the monument is associated. The next layer is the Late Bronze Age (Sabatynivska culture). The upper horizon dates back to the Early Iron Age (Scythian culture) (Starik, 2017).

The authors already carried out a petrographic study of stone artefacts from Tokivske-1, found during the first five years of excavation (Nikitenko, 2018). However, new discoveries in the territory of the complex led to the need in revising the role of the studied monument, particularly as a metal processing center of the Bronze Age. Thus, in 2017, six stone and clay casting molds and their fragments with negatives for casting bronze pins with ball-shaped heads, sickles, needles, chisels, daggers, and socketed axe-celts were found. In 2018, two stone double-sided molds for casting of daggers, a mold with a lid for casting round-shaped ingots and a unique four-sided casting mold were also found. Thus, the issues of finding the other evidences of metalworking in the territory of the monument and the establishment of the raw materials sources of supply appeared.

Petrographic study of a number of artefacts, which may indicate the existence of interregional relations, was necessary for solving the formulated problems. To

carry out the research, the artefacts, which origin was of the highest interest for archaeological study, were selected (Tab. 1). Most of them could be related to metal processing. Of special interest was the provenance of the raw material of the stone scepter-pestle (Fig. 1), since such instruments are quite rare and are related to the centers of metal processing in Eastern Europe and Central Asia. According to Boroffka and Sava it belongs to the type Ia, widespread from the Volga to the Danube River, mainly in the territory of Ukraine and Moldova (Boroffka, 1998).

Table 1. The list of studied stone artefacts

No.	Name	Inventory number	Measurements, cm	Material
1.	Working tool (hammer for forging jewels or peening sheet copper)	86	7 x 5.5 x 5	Amphibolite
2.	Anvil-prop for forging jewels or peening sheet copper	305	11.5 x 7 x 6.5	Dolerite
3.	Abrasive stone (fragment)	none	4 x 4 x 4.5	Ferruginous quartzite
4.	Tile (fragment of an altar)	none	6 x 12 x 8	Vein quartz
5.	Anvil (fragment)	none	7 x 6.5 x 6	Sandstone
6.	Scepter-pestle (fragment)	152	7.2 x 5 x 7.5	Sandstone

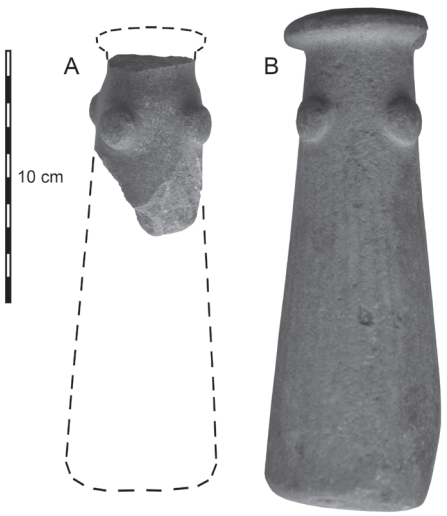

Fig. 1. Scepter-pestles of the Bronze Age.
A – studied fragment of the pestle from Tokivske-1 (sample 6); B – intact sample from the museum collection.

The purpose of the work is to determine the provenance of the materials of the Bronze Age stone artefacts that were found during the excavations of Tokivske-1 in order to establish connections between the monument and other regions.

Materials and methods. Microscopic research of thin sections was carried out using polarizing microscope LOMO POLAM R-312. The origin of raw materials of the artefacts was determined by comparative petrographic analysis with samples of similar rocks from the Middle Dnipro area and other regions. Similarly, the comparison was performed with the thin sections produced from the materials of other archaeological artefacts, which origin was established during previous studies. In addition, the data from the reports of primary geological survey and literary works of the mid-twentieth century were used, which provided a detailed petrographic description of rocks from natural exposures, since ancient miners could only use rocks that occur close to the day surface.

Results and their analysis. As a result of mineralogical and petrographic analysis of six artefacts it was established that they were made from amphibolite, dolerite, magnetite quartzite, vein quartz and sandstone (Tab. 1).

Amphibolite (sample 1) is represented by a fine-grained rock, in which the femic mineral – hornblende

– contrastingly stands out against the background of a lighter salic mineral – plagioclase. Mineral composition of amphibolite (vol. %): hornblende – 50 – 55; plagioclase – 45 – 50; quartz, epidote, opaque mineral, sphene – less than one percent. Hornblende forms tabular crystals of light green color with rhombic amphibole cleavage. It demonstrates pleochroism from green-yellow to turquoise-green with brown-green spots. The size of crystals is 0.5 – 2.0 mm, mainly 1.0 – 1.5 mm (Fig. 2). Plagioclase is represented by crystals of a tabular and irregular shape (conformal boundaries) with polysynthetic twins. The size of the plagioclase crystals is from 0.5 to 1.5 mm, the mineral is weakly sericitized. Quartz forms crystals of isometric shape up to 0.2 mm in size. In contrast to plagioclase, it is transparent and has no impurities of secondary minerals. The epidote is contained in the form of crystals of irregular and tabular form in the size up to 0.2 mm with anomalous interference colors. Usually, the crystals of epidote form aggregates. The mineral replaces the hornblende, less – plagioclase. The opaque mineral is represented by angular crystals. Several grains on the edges are translucent in red, which makes it possible to relate the opaque mineral to hematite. Sphene in the studied amphibolite forms isometric crystals that differ in the thin section with a high refractive index and interference color. Sphene is surrounded by aureoles of secondary alteration products with lower refractive index (epidote?). The main minerals of the amphibolite are gathered into aggregates, therefore its texture can be defined as glomerogranoblastic.

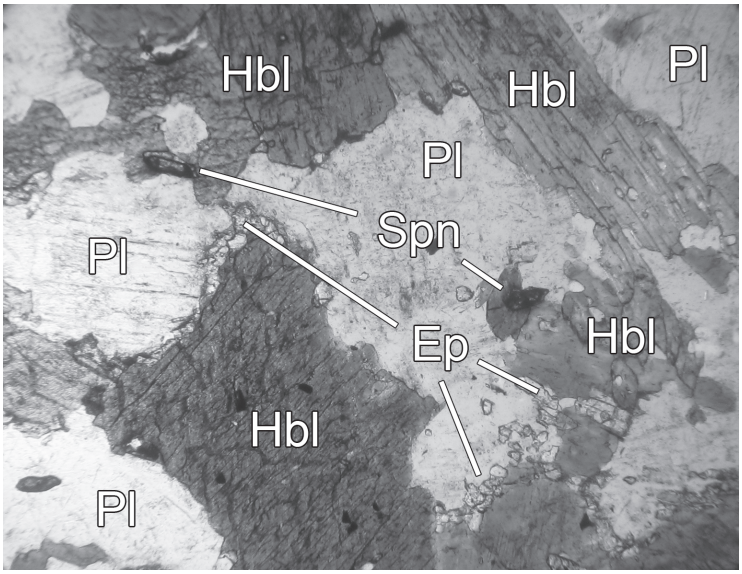

Fig. 2. Amphibolite (sample 1).
Hbl – hornblende; Pl – plagioclase; Ep – epidote; Spn – sphene. *Transmitted light, nicols (–), x 47*

Provenance. Amphibolites are common rocks in the Middle Dnipro area; also, they are exposed in the North Azov Sea area, the Bug River area, in the Inhulno-Inhuletskyi and Rosynsko-Tikytskyi areas of the Ukrainian Shield (Yesypchuk, 2004). The biggest outcrops of amphibolites are located in the Kryvyi Rih area and in the right-bank part of the Middle Dnipro area in the valleys of the rivers Bazavluk, Mokra Sura, Chortomlyk and their tributaries. The analyzed sample differs from the Kryvyi Rih amphibolites, exposed in the valleys of Saksahan and Inhulets rivers, by the shape of hornblende crystals and lack of biotite; from Saksahan amphibolites it also differs by the presence of twins in plagioclase. According to Usenko, amphibolites of the right-bank part of the Middle Dnipro area, which form natural outcrops, are divided into two groups: amphibolites of the middle stream of the river Bazavluk and the group of amphibolites of the lower stream of the Bazavluk River (Sholokhove village), Chortomlyk River and the river of Mokra Sura (Usenko, 1953). At all of these occurrences the varieties of amphibolites, which have common features with the analyzed sample, crop out. But, taking into account the predominance of epidotization (as opposed to the sericitization that is typical for Sholokhove amphibolites), lighter, spotty color of hornblende, high content of plagioclase, macrostructural features (dark crystals of hornblende stand out against a background of light-gray plagioclase), the studied sample is more similar to the amphibolites of the middle stream of the river Bazavluk. The comparative petrographic analysis of amphibolites from this

area and the raw material of the analyzed tool showed the greatest similarity to the sample we picked up at the rocky outcrop in the village Udachne in the middle stream of the river Bazavluk.

Dolerite *Provenance.* Dolerites (diabases) are quite common in the territory of the Middle Dnipro Megablock of the Ukrainian Shield. Fresh olivineless species form natural outcrops along the river Bazavluk, in the middle stream of the river Bazavluchok, as well as in the southern part of the Mokra Sura River and the river Dnipro. We investigated a similar rock in the valley of the river Mokra Sura. The peculiarity of the raw material of the artefact is the presence of micropegmatite, which is the intergrowth of feldspar and quartz. Similar inclusions were noted by Usenko in pyroxene diabases, which are exposed on the river Mokra Sura and between the tributaries of the river Bazavluk – the gullies Krynychevata and Bakulin Brid (Usenko, 1952).

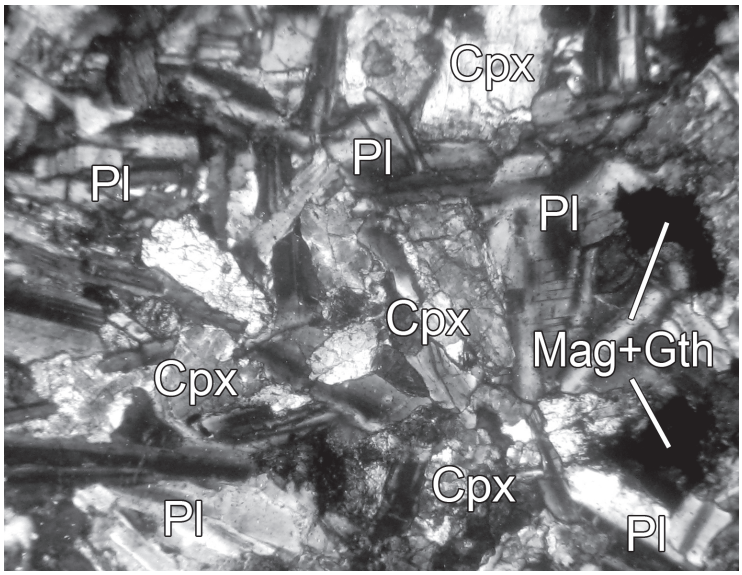

Fig. 3. Dolerite (sample 2).
Cpx – clinopyroxene; Pl – plagioclase; Mag+Gth – magnetite and goethite. *Transmitted light, nicols (+), x 90*

Ferruginous quartzite (sample 3) is represented by a dark grey, fine-grained rock. The examined sample is magnetic, the ore layers have a black streak. The rock consists of parallel substantially ferruginous and substantially quartz layers up to 1 cm thick. A study of the rock under a microscope showed that the ferruginous layers contain less than half the volume of quartz, and the quartz layers contain up to 10% of linearly located grains of an ore mineral. The size of quartz and ore mineral crystals is 0.05 – 0.3 mm. Between crystals of quartz there are aggregates of flakes of a transparent mineral of the group of sheet silicates with straight extinction and higher than quartz interference colors, probably, talc, which could replace a mineral of the cummingtonite-grunerite series (Fig. 4). Goethite is represented by single large grains, as well as a disperse admixture that tinctures the sericite flakes and fills the gaps between quartz grains. As a result of the polished section analysis, it was determined that the ore mineral crystals are represented by one mineral species with the same reflectance, which is shown by all aggregates. Considering the results of macroscopic and microscopic study, the rock can be defined as a magnetite quartzite.

Provenance. Ferruginous quartzites are widespread in the territory of the Ukrainian Shield inside numerous iron-siliceous formations, most of which are covered with sedimentary rocks. The outcrops, sufficient for surface development in ancient times, are located along the Inhulets and Saksahan rivers (modern Kryvyi Rih basin) and at the Korsak-Mohyla deposit in the North Azov Sea area (Usenko, 1975). Taking into consideration the proximity of the place of the sample finding to Kryvyi Rih, most likely, the raw material of the tool originates from there.

Vein quartz (sample 4) is represented by a tiled sample obtained as a result of a thin quartz vein separation from the adjoining granitic rock. The investigated sample is composed of coarse-crystalline quartz. Between quartz crystals, the crystals of feldspar (microcline and plagioclase) are located, which make up to 5 % of the volume of the rock. Plagioclase is replaced by secondary sericite. The size of quartz crystals – up to 10 mm, feldspar – up to 1 mm. The texture of the rock is heterogranoblastic.

Provenance. The veins of quartz intersect pink granites of the Tokivskyi massif in the area of the excavations. Similar mineral bodies were observed by the authors in rocky outcrops of granites in the valley of the river Kamianka.

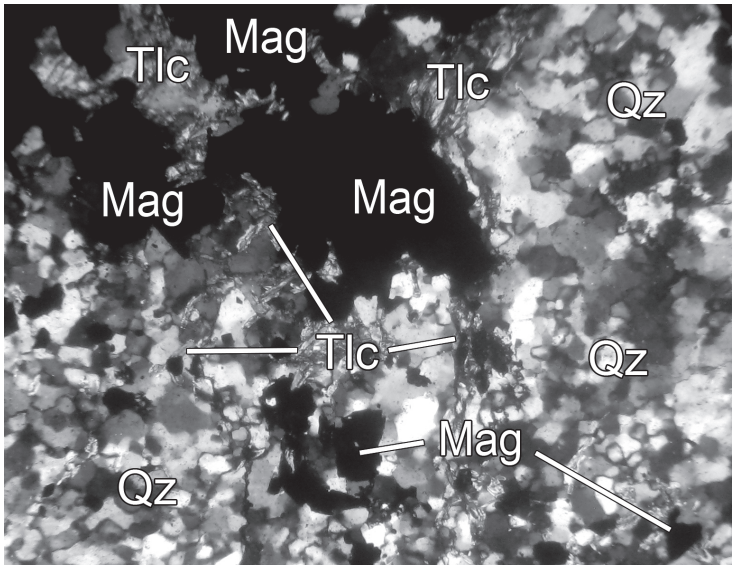

Fig. 4. Ferruginous quartzite (sample 3).
Qz – quartz; Mag – magnetite; Tlc – talc. *Transmitted light, nicols (+), x 90*

Sandstone in the collection is represented by two samples with similar mineral composition and lithological features (samples 5 and 6). Both rocks can be defined as quartz sandstones with polymineral cement.

The ratio of clastic material and cement in the sandstone is nearly 95 to 5. Composition of clastic grains (% of clastic material): quartz – 97; chert – up to 2; feldspars and microquartzite – less than a percent (Fig. 5). It should be noted that the sample 5 differs from the other by lower content of clastic grains of chert, as well as the presence of single flakes of muscovite in the thin section. Quartz is represented by grains with conformal boundaries formed as a result of dense compression. The size of the fragments is 0.2 – 1.4 mm, mostly 0.3 – 0.5 mm. The regenerative cement encircles many of quartz grains. Chert is mainly represented by semi-coarse isometric grains with the size of 0.2 – 0.4 mm, formed by a micro-flaky aggregate of chalcedony, and sometimes also contains admixture of hydromica flakes (siliceous slate). Crystals of feldspar are close in size to quartz grains and differ from the latter by intensive alteration with sericite. Possibly, some individual aggregates of sericite were

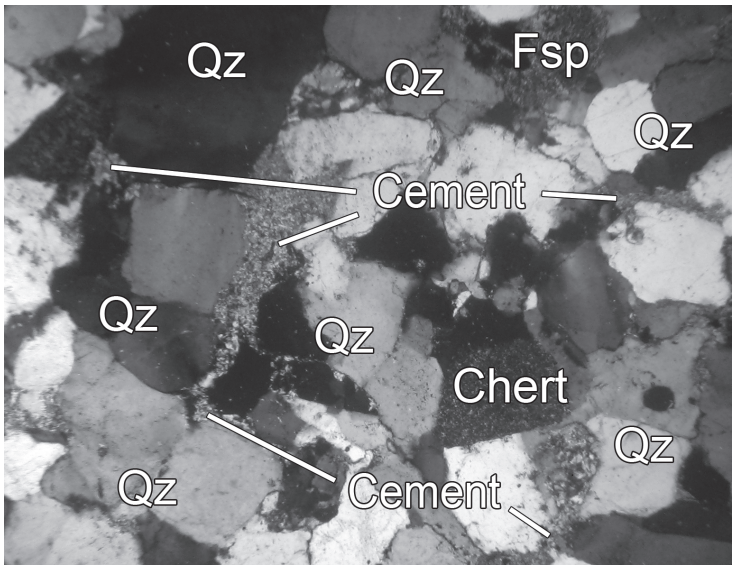

Fig. 5. Sandstone (sample 6).
Qz – quartz; Fsp – sericitized feldspar; Chert – fragment of chert; Cement – sericite and chalcedony cement.
Transmitted light, nicols (+), x 47

formed due to the replacement of feldspars.

Cement of the sandstones has a polymineral composition with a predominance of sericite and regenerative quartz cement. In general, the most of clastic grains are connected without cement (dense arrangement) or have thin rims of quartz regenerative cement around. Relic cement is contained mainly in pores, sometimes it forms thin interlayers between clastic grains. Porous cement is represented by the micaceous (sericite) and siliceous (chalcedony) types. Sericite cement fills pores as well as it is contained in small quantities between clastic grains. Chalcedony cement is represented by a micro-flaky aggregate that fills the pores (Fig. 6). In both samples, the two types of cement may coexist in one pore. In the sample 5, in some pores, the zones of kaolinite cement are also contained. Also, there are aggregates and disperse admixture of goethite in the cement. The texture of both samples of sandstone is psammitic.

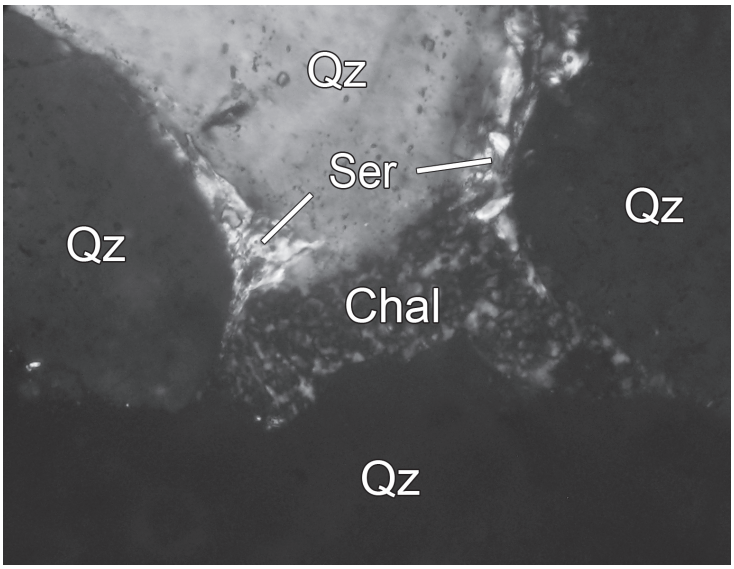

Fig. 6. Sandstone (sample 6).
Qz – quartz; Ser – sericite cement; Chal – chalcedony cement. *Transmitted light, nicols (+), x 400*

Provenance. Similar varieties of sandstones are not typical for the Middle Dnipro area. (Tkachuk, 1981; Vidergauz, 1964). Sandstones of the late stage of catagenesis are characteristic for geosynclinal structures. In the territory of Ukraine the nearest occurrences of the rocks that are similar in petrographic features are located in the Central Donbas, where Carboniferous quartz sandstones, which contain debris of rocks (mainly chert), muscovite, have regenerative quartz, sericite-siliceous and kaolinite cement, crop out (Tkachuk, 1981). Similar rocks are also common in Podilia as a part of the Yampil layers of the upper Vend, but these sandstones are more catagenetically altered, they contain significantly less debris of sedimentary rocks and practically do not have relic cement, which is composed of sedimentary minerals. Based on this, we are inclined to regard the raw materials of the investigated tools as a Donbas Carboniferous sandstone.

Thus, based on the petrographic study, it was established that the most of analyzed artefacts were made from the rocks that are common in the Middle Dnipro area – the region of excavations. The amphibolite of sample 1 has close analogues among the rocks, which are exposed in the middle stream of the river Bazavluk. From there the dolerite of the sample 2 may also originate. Ferruginous quartzites, similar to the sample 3, are most common in the Kryvyi Rih area, where they crop out in the valleys of the rivers Inhulets and Saksahan. The quartz of the sample 4 is found in the form of veins that intersect the granites of the Tokivskyi massif in the village Tokivske. Only the sandstones of specimens 5 and 6 have no analogues among the rocks of the Middle Dnipro area, and the most similar rocks to them are the Carboniferous sandstones of the Donets Basin.

Based on the obtained data, we can make assumptions about a certain ethnic homogeneity and close trade and cultural connections of the population of the Bronze Age, which lived in the territory of the Bazavluk and Inhulets rivers' basins in the Middle Dnipro area, who created and used the archaeological monument Tokivske-1. Probably, there lived a tribal union in these territories, and the Tokivske-1 belonged to one of its centers. The production of the scepter-pestle from the sandstone, which most likely originates from the territory of the Donets Ridge, may

indicate the connection of the monument with the Donets Mining and Metallurgical Center of the Late Bronze Age, where the development of copper ores was carried out within the Bakhmut Basin (Brovender, 2007). It is also necessary to take into account the assumption that similar scepter-pestles belonged to masters-metallurgists who enjoyed a high status in the contemporary society. In the petrographic study of stone tools of ancient miners and metallurgists, found during excavations at the Kartamysh deposit (Luhansk Oblast), one of the authors established the origin of a considerable number of them from the Middle Dnipro area, in particular casting molds (Nikitenko, 2010). Thus, the obtained data once again testifies in favor of the existence of an ancient trade route, which connected both regions.

Conclusions. As a result of the study, the list of rocks that were used as raw materials for the production of tools and for the construction of cult objects in the territory of the archaeological monument Tokivske-1 was expanded. In particular, taking into account the data of previous studies, in the Bronze Age, such rocks as granite, amphibolite, dolerite, metadolerite, quartzite, quartz-zoisite-actinolite schist, pyroxene quartzite, magnetite quartzite, vein quartz and sandstone were used. Most types of stone raw materials have analogues among the rocks that exposure directly in the village Tokivske or, most often, near the neighboring village Sholokhove. Among the investigated artefacts, not of local origin are the samples made of amphibolite and dolerite similar to those, which crop out in the middle stream of the Bazavluk River, as well as those made from magnetite and pyroxene quartzites, which most likely originate from the Kryvyi Rih area. Two artefacts made of sandstone, which is not typical for the Middle Dnipro area, are most likely to come from the territory of the Donets Ridge. This fact indicates the possible trade relations of Tokivske-1 with that region.

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