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YAHORLYK WORKSHOP, CORE-FORMED VESSELS, AND THE "NATRON GLASS REVOLUTION" IN THE NORTH PONTIC REGION

ABSTRACT The archaic Greek settlement of Yahorlyk, in southern Ukraine, has yielded abundant evidence for glass-working. This paper reports the results of *de novo* chemical analyses of glass beads from the site excavated in the 1980s in the context of state-of-art concepts of Early Iron Age glass production in Europe. Yahorlyk craftsmen employed two main types of glass: natron-based glass for biconical beads, plant-ash glass and glass with low magnesium and high potassium content for eye-beads. In some cases the component parts of a single bead were made from glass of different chemical types. Yahorlyk beads were widespread in ancient Greek and barbarian contexts. By comparing this distribution pattern with that for clearly imported products (core-formed vessels), the author concludes that originality of Yahorlyk glass-working may result from its orientation towards two markets: those of Archaic Greece and Early Scythia.

Keywords: beads, natron glass, social organization of production, Archaic Greeks in the northern Pontic area

ABSTRAKT W trakcie badań archeologicznych na terenie greckiej osady z okresu archaicznego w miejscowości Jahorłyk, południowa Ukraina, natrafiono na bogate materiały świadczące o lokalnej produkcji szkła. W artykule zaprezentowano wyniki analiz chemicznych szklanych paciorków tamże znalezionych. Analizy wykonano w latach 1980-tych. Stwierdzono, że rzemieślnicy działający w osadzie wykorzystywali dwa rodzaje szkła – szkło sodowe oraz szkło z niewielką ilością magnezu i dużą zawartością potasu. Jedynie pojedyncze okazy wykonano z innego szkła. Zważywszy kierunki dystrybucji szklanych paciorków, które powstały w osadzie, zaproponowano, aby wskazaną dwoistość rodzaju szkła, z którego wykonano paciorki, tłumaczyć potrzebami odbiorców – Greków i Scytów.

Słowa kluczowe: paciorki, szkło sodowe, organizacja produkcji Grecy nad Morzem Czarnym, okres archaiczny

Introduction

Within the larger Mediterranean world, a characteristic of the Early Iron Age is the rapid spread of technological innovations up to cultural and natural thresholds. In the Near East the development of natron-glass technology is generally placed within the framework of cultural interactions and technological achievements of the Late Bronze Age and Early Iron Age. Its spread affected the various regions of Early Iron Age Europe and the raw material necessary for its production played an important role in the glass industry of Europe and Near East from the 8th century BC down until the 8th century AD[1].

The earliest objects produced from natron glasses are attested in Jordan, in burial 89 from Pella. The latter is dated to the mid-9th to the 10th centuries BC (1050-850 BC)[2]. They have also been found in the burial of Nesikhon in Egypt, dated to 974 BC[3]. The bead from Nesikhon's tomb is coloured by cobalt. Natron-based cobalt glass objects dating to the 9/8th centuries BC have also been discovered at Nimrud [4]. Equally early natron-based beads have been recovered from many sites in France dating to the 11-9th centuries BC[5]. Very early natron-based beads are known from Greece, from Elateia, Alatanti-Spartia, Livanates-Kokinonyzes, dating to the periods LHIIIA-LHIIIC (ca. 1425/1390-1000/950 BC)[6]. In Italy they have been revealed in Sarno, Cumae, Capua in the contexts dating to the 9th and 8th centuries BC[7].

1 Gratuze, Janssens 2004: 677.
2 Read et al. 2009.
3 Schlick-Nolte, Werthmann 2003.
4 Read et al. 2005.
5 Gratuze 2009.
6 Kalliopi, Nightingale, Chenery 2017: 518.
7 Conte et al. 2016.

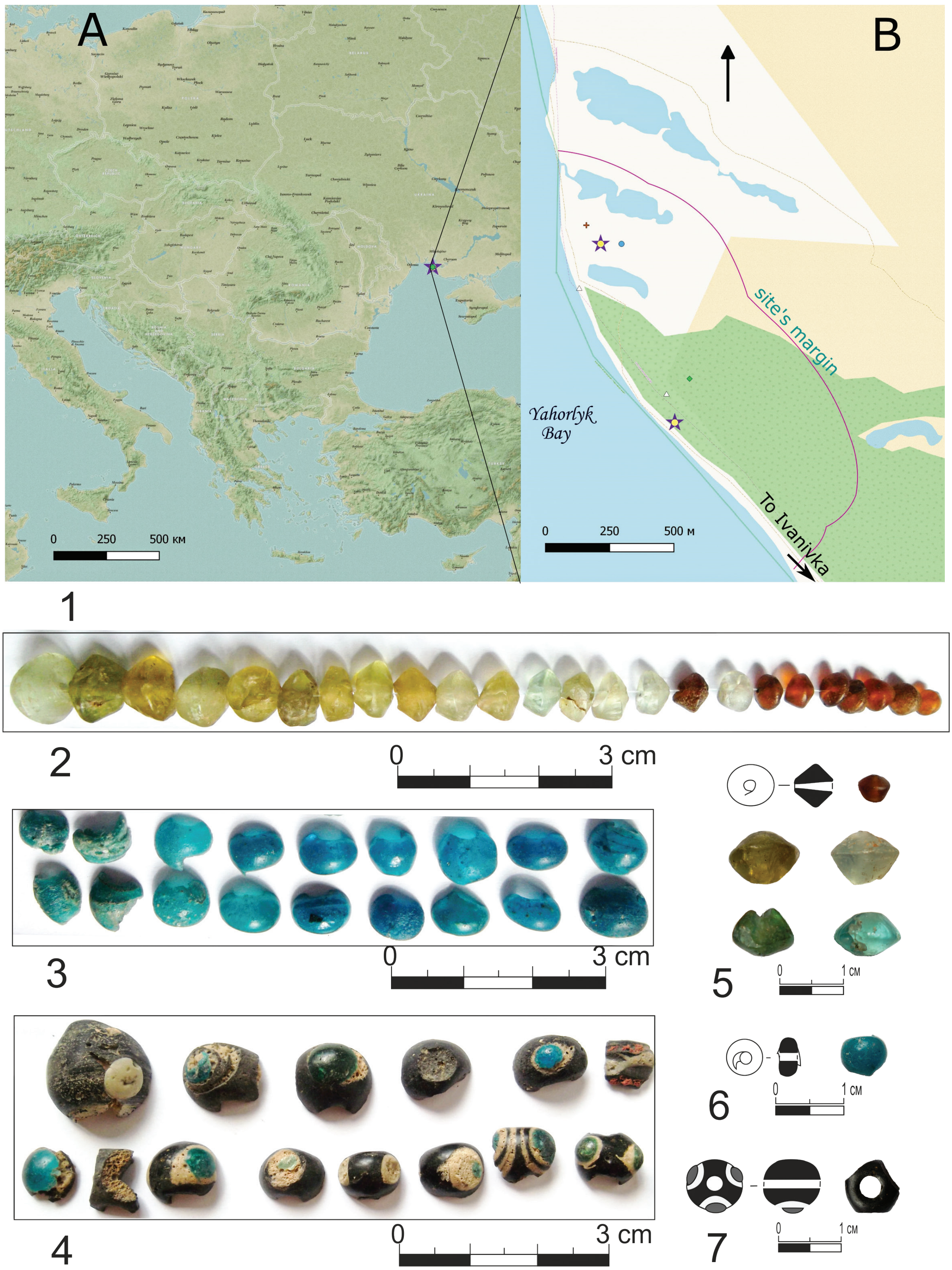

Fig.1. Yahorlyk site and its production. 1 – Location of the Yahorlyk site (A); the Yahorlyk sites's plan (B):
stars – concentrations of raw glass finds, broken and semi-finished beads, crucibles,
stones and potsherds with glassy cover, solid line – area of finds on surface;
2-7 – Yahorlyk beads typology: 2, 5 – biconical beads, 3, 6 – globular beads, 4, 7 – eye-beads

The archaeometry of early natron glass is, unfortunately, mostly based on beads coming from non-production contexts (burials or the domestic quarters of settlements). The range of dates ascribed to beads is often very wide, sometimes too wide, to the exasperation of researchers. Furthermore in the search for *l'idole des origins*[8] archaeologists and chemists have concentrated their attention on the earliest specimens of natron-based glass, whilst the social and technological processes underlying the surprising but overwhelming domination of natron-based glass in the Archaic and Classical Greek world remain poorly understood. In order to advance progress in this direction our attention should be rather turned to later glass objects coming from the 8th to the 6th centuries BC, the period which can be labelled 'the second stage of the natron-glass revolution' which is still insufficiently studied. In 2012 A. Oikonomou and other scholars studied the problem of the reception of natron-based glass in the Greek world. Finds from Rhodes indicate that this transition was prolonged and took place over several centuries. As late as 640-600 BC Rhodian glass was dominated by beads made of plant-ash glass, with only a small group of items being produced from the innovative raw material[9].

Thus, the mere discovery of natron-based glass is an insufficient explanation for its wide diffusion. It is clear that the prevalence of glass of this type has become established by the 5th century BC[10]. However the duration of the transitional period (along with the social and technological processes enabling this shift!) are still hypothetical. Is there continuity between early natron-glass beads production and the later industry of core-formed vessels which was also based completely on the use of the mineral natron as a flux?

It is probable that new light can be shed on these issues by a detailed study of the Archaic Greek bead-producing workshop of Yahorlyk, when compared with finds of beads and core-formed vessels found at other sites lying near-by in the Northern Pontic region.

Yahorlyk is famous for being an iron-producing, bronze-melting and glass-working centre. Here glass-working was concentrated on bead-production[11]. While numerous collections of beads have been studied from several sites all over Europe, combined research on finished products and technological waste is rarely possible for the 6th century BC. At Yahorlyk such a possibility exists. Moreover, beads produced in Yahorlyk enjoyed a wide distribution throughout ancient Greek and barbarian sites. Confronting this pattern with the distribution of clearly imported products (core-formed vessels) one can build a model for the social context(s) for glass-working and the circulation of glass items. The main objective of our research has been to present the massive of data on the Yahorlyk workshop accumulated mostly by the 'old' research conducted during the 1970s and to integrate this research into modern archaeological science.

The site

The site, in southern Ukraine, is located on the modern shore-line of the Black Sea, in the Kherson region (Fig. 1A). Nowadays, the site is situated on the sands surrounding the shallow and narrow Yahorlyk bay. The sands are covered with artificial coniferous forest. According to the best authorities the environment in antiquity was very different. At that time the sands of Yagorlyk bay were a part of a vast Dnieper delta, and the settlement itself stood on the southernmost channel through which the Dnieper flowed into the Black Sea. The original environment of the site should be envisioned as lowland, watered by fresh-water, well-forested, consisting of numerous islands and islets connected by channels and straights[12].

In 1963, the sands of Yahorlyk bay were deep-ploughed for the planting of a coniferous forest. Huge masses of archaeological material were disturbed and lay on the surface to be gathered by local collectors and tourists. The site was only surveyed by a professional archaeologist, Anatoly Ostroverkhov, in 1973[13]. He and his colleagues excavated small trenches on the site in 1976 and 77[14]. A. Ostroverkhov interpreted Yahorlyk as a craft centre specializing in metal- and glass-working and production[15]. Unfortunately, since then the site has not been excavated. It is continuously being destroyed by forest-planting, and abundant private collections have been assembled from materials from Yahorlyk, and consequently lost for scientific research.

8 Bloch 1949.
9 Oikonomou et al. 2012; Beltsios et al.2012
10 Shortland et al. 2006: 522.
11 Безбородов, Островерхов 1978: 32-33.
12 Шилик 1975: 84-85; Агбунов 1985: 120-121; Ивлеев 2014: 68-70, рис. 19.
13 Островерхов 1974:323.
14 Загний, Островерхов, Черняков 1977: 294; Буйских, Островерхов 1978.
15 Островерхов 1978, 1978, 1981, 1975.

The work of 1970s produced the following picture of the structure of the site (Fig. 1: B). There was a metal-working centre in the central part of the site, and two glass-working facilities (the stars on the Fig. 1: B) the first being close to the metal-working furnaces, and the second in the northern part of the site. Recently the author has surveyed the site with GPS and mapped the finds. The general picture is confirmed, and it seems there was a previously unknown centre of craft activity by the mouth of lake Vysokhle, in between the two glass-production centres observed in the 1970s.

The Yahorlyk settlement was one of the Greek settlements in the region. The earlier settlement on Berezan island was founded at some time after the mid-7th century BC[16] and the main regional centre Olbia by the late 7th century BC[17]. Yahorlyk was among the earliest of the sites to be founded around these large centres. Greek colonization was observed by another group of new-comers, early Scythian nomads. Greek commodities have been attested at many Scythian sites of this age in Central Ukraine[18]. Almost dozen of their burials are known in the Lower Dnieper quite near to Yahorlyk[19]. The frontier character of the Yahorlyk site is reflected in its pottery[20]. Archaic Greek pottery dominates the collection, both amphorae and painted ware[21].

Different researchers have suggested somewhat different chronologies for the site based on the pottery finds. A. Ostroverkhov and N. Gavriliuk placed the existence of the settlement as running from the late 7th to the early 5th centuries BC[22]. Ostroverkhov was inclined to date the beginning of the site to the early 6th century BC[23]. The earliest foundation date, around the year 630 BC, has been proposed by V.V. Ruban[24]. The latest date, at the beginning of the first quarter of the 6th century BC, by S. and A. Bujskikh[25]. The date and the reasons for the site's abandonment are also unknown. Some authors believe that the Yahorlyk was deserted by its settlers around the mid-6th century BC[26]. The chronology of the site is open to dispute, but we can be sure that Yahorlyk is an Archaic Greek site of the first half of the 6th century BC.

The glass workshop products

The presence of glass workshop(s) at Yahorlyk is evidenced by the following archaeological finds: crucibles covered with melted glass, semi-worked beads, and beads broken in the course of production[27], potsherds with glassy walls, slag, and pebbles with glassy spots.

The following types of beads were probably produced on-site[28].

1. Biconical beads, types 90, 91, 94, 96. They were transparent light blue, green, amber, brown and colourless (Fig. 1: 2, 5).
2. Globular beads, type 12. They were transparent light blue or turquoise (Fig. 1: 3, 6).
3. Eye-beads (types 25 в, ж) with three eyes. They have a black or deep purple core, and three translucent light blue or green eyes on a white or grey opaque shield (Fig. 1: 4, 7).

More than 800 beads have been found at Yaholyk. The Yahorlyk assemblage is dominated by biconical beads (over 650 examples), with globular beads (around 100 examples) being in second place, followed by eye-beads (appr. 70) holding third place.

Methods

In the 1980s 65 samples from Yahorlyk were analyzed by V.A. Galibin in the Laboratory of the Institute of Material Culture in Saint-Petersburg. A.S. Ostroverkhov has published the results and extensively interpreted them[29]. The samples included beads, frits, slags and the glassy cover of crucibles. The technology applied was quantitative optical emission analysis. This paper is based on the quantitative and typological interpretation of the data on the chemical composition of the Yahorlyk beads mostly accumulated in the 1980s. This approach could be hampered by several obstacles.

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16 Виноградов 1989:35; Буйских 2013:23.

17 Буйских 2013: 223.

18 Онайко 1966; Болтрик 2000: 123-124; Задников 2017.

19 Мурзин 1984: рис. 1; Гребенников 2008; Оленковський 2010: 51.

20 Гаврилюк, Островерхов 1978: 63-64; Островерхов 1978: 74; Гаврилюк 2014: 32-33, рис. 5:5-11.

21 Рубан 1983: 287-289.

22 Гаврилюк, Островерхов 1978: 63.

23 Островерхов 1978: 112.

24 Рубан 1980: 112; Рубан 1983: 289.

25 Буйских С., Буйских А. 2010: 26; Bujskich S, Bujskich A. 2013: 27.

26 Рубан 1980: 112; Рубан 1983: 289; Буйских С., Буйских А. 2010: 26.

27 Островерхов 1981: 214.

28 Beads typology corresponds to the system developed by E.M. Alexeeva (Алексеева 1975: 59; Алексеева 1978: 64, 69, 149).

29 Островерхов 1993: табл. 2: ном. 1-39; табл. 3.

There was no verification with international samples with known composition (for example with Corning glass). Older analyses are evidently less precise. They result in larger confidence intervals. The minimum and maximum values of the percentages of certain oxides are always dispersed wider than is the case with modern chemical techniques. The techniques of analysis employed by V.A. Galibin were destructive and cannot be reproduced on the same samples nowadays. In the course of optical emission larger samples were burnt. This led to the 'levelling' up of the chemical composition of different part of a single bead. Sometimes the result cited by the laboratory concerns other portions of a bead, and not exactly that part we were interested in. And last but not the least, the Saint Petersburg laboratory had a detectability level of 2% for potassium[30]. Lower percentages were not recorded as they were below the level of detection. Potassium content is essential for the very definition of the chemical type of glass. For facilitating the graphical representation of the chemical composition we will assign a conventional value of 1% as being 'below the limit of detection' for the samples of V.A. Galibin. It should be kept in mind however, that in fact the real content can vary from 0 to 2%.

However, after this long list of 'minuses' there is also a list of some 'pluses'. At least we know something about ancient glass from the southern Ukraine. The results of the Saint-Petersburg lab are in weighted oxides, and as such they are expressed in a similar way to modern data. Some case-studies showed a good correspondence between the results of the Saint-Petersburg lab, and some labs in Great Britain and the USA; however, it must be said they mainly concern the metal artefacts[31]. The validity of the Saint-Petersburg analyses of the glass samples can be confirmed by their reasonably good correspondence to LA-ICP-MS analyses on typological identical glass beads from Modlnica[32].

In my opinion direct numerical comparison of the Saint-Petersburg laboratory results and the results of modern chemical composition analyses is impossible. The only way to proceed is to detect rough patterns in the 'old' data, and compare them with patterns based on the 'modern' chemistry. In the following discussion we compare broad patterns rather than exact numbers, mostly by interpretation of bi-plot for pairs of weighted oxides.

[30] Галибин 2001: 48

[31] Егорьков 2006: 159.

[32] Purowski 2015.

Another methodological approach applied in this text is the systematic comparison of chemical varieties and archaeological morphological classification of the analysed items. Usually archaeometric specialists paid little attention to traditional archaeological tools like old-fashioned typology. However, at least in the case of the sample under study, the bead typology appeared to correlate with the chemical composition of such beads.

The chemical composition

The chemical composition of the Yahorlyk beads indicate that two main types of raw material were used: HMG (high magnesia glass) and LMG (low magnesia glass), alongside with some other glasses that were different from both the above mentioned varieties (Fig. 2).

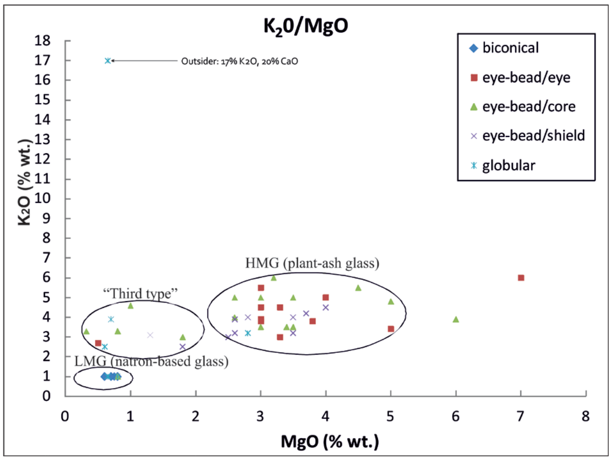

Fig. 2. K2O vs. MgO. The types of glass characteristic for the beads of Yahorlyk in dotted ovals

HMG (plant-ash glass). The vast majority of the eye-beads analyzed were made of glass of this type. Its composition is characterized by relatively high levels of potassium (K_2O 3-6%, av. 4.2%) and magnesium (MgO 2.5-7%, av. 3.6%) (Fig. 2). Other important constituents are CaO (5-13%, av. 8.85%) (Fig. 3), Fe_2O_3 (0.8-5%, av. 2.7%), NaO (6.5-22%, av. 14.7%). The levels of iron oxide are variable. It is present in low percentages in two turquoise beads coloured by the addition of some substance rich in copper (CuO – 3.5-4%). Plant-ash glass typically had quite high content of alumina (Al_2O_3 – 1.9-10%, av. 4.4%). This fact makes it clearly different from the LMG found in the Yahorlyk beads. Taking into account that alumina mostly entered ancient glass composition as impurities in the sand used in the glass-making process,[33] it is reasonable to assume that the LMG and HMG of Yahorlyk were made from different raw materials, and thus probably in diverse centres of production.

LMG (natron-based glass). Every analyzed biconical bead was made of glass of this type as was the case with some of the globular beads. It is characterized by a content of potassium lower than 2%, and so invisible for the equipment utilized by V.A. Galibin. Its actual levels could be as low as 0.5% as evidenced by 'wet' chemical analysis conducted by S. Dzhalalova on a single bead from the Yahorlyk site[34]. The single bead of this type and colour as studied by T. Purowski and the co-authors of the Hallstatt site of Modlnica had a potassium oxide percentage of 0.13%[35]. The magnesium is equally low: 0.6 up to 0.8%, av. 0.7% (Fig. 2). LMG from Yahorlyk is relatively poor in aluminium: 0.45 – 0.9%, av. 0.6% (Fig. 4), the only exception is a trapezoid bead (3%), a clear outlier also from typological point of view, and iron oxide (0.4-0.9%), so a very pure source of silica was used for its production. In a single case a black opaque eye bead was made from natron-based glass probably coloured by iron (7% of iron oxide content). LMG contains also NaO: 8-22%, av. 16.9%, CaO: 9-15%, av. 12% (Fig.3). The colourants are represented by copper oxide (2.8% in the single globular bead of turquoise colour).

Outliers. Returning to the bi-plot of Potassium versus Magnesium (Fig. 2, '*the third type*'), one can see that there is a third scatter of points with a low-magnesium and an elevated percentage of potassium. This scatter holds an intermediate position between plant-ash glass and natron-based glass. It is quite a heterogeneous entity. The opaque blue globular bead contains an extremely high concentration of potassium (17%) and equally high content of calcium (20%). In combination with low magnesium it makes the chemical composition of this bead really unusual. Some samples had intermediate values of potassium (2.5 %) and magnesia (1.8%) when compared to LMG and HMG scatters. They can result from the joint melting of plant-ash glass and natron-based glass, maybe in the course of recycling of broken beads made from both types of glass, or it can represent a chemically distinct type of glass similar to the LMMK glass of Purowski et al. (2012). Some other beads (conventionally called '*the third type*' in the following discussion) had low content of alumina: 0.4-1.3%, and magnesium: 0.32-1% (Fig. 4), typical for LMG, and potassium oxide percentages of circa 3-4.6%, and calcium oxide: 3.5-13%, av. 8% (Fig. 3). Their interpretation is disputable. Ian Freestone and his co-authors demonstrated that the recycling of natron glass can result in saturation of the raw material by potassium from the ashes of the materials used for heating the glassy mix[36].

Additional information on the issue comes from chemical composition of raw glass chunks, frits and slags found on-site[37]. They correspond to the observed three types. The third type with high potassium and low magnesium is quite common.

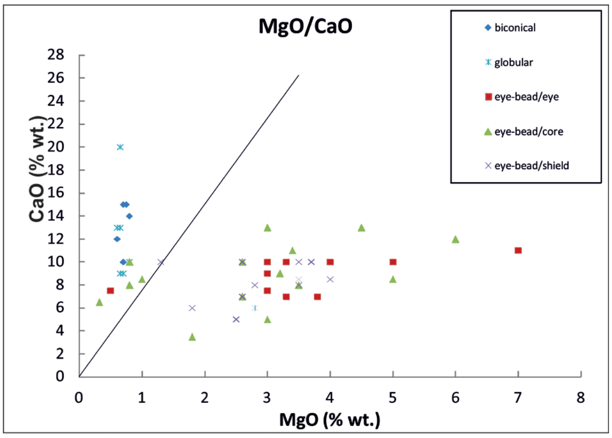

Fig. 3. MgO vs. CaO. Yahorlyk beads. Solid line – CaO%=7,5xMgO%. The natron-glass samples are situated to the left of the solid line

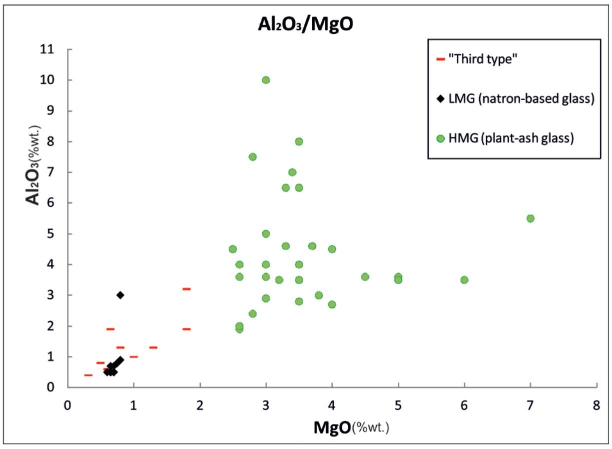

Fig. 4. Al2O3 vs. MgO. Yahorlyk beads

33 Галибин 2001: 48; Jackson et al. 2003.

34 Островерхов 1993: 53.

35 Purowski et al. 2015: Tab.2.

36 Freestone 2015: 38; Davis, Freestone 2018: 116-117.

37 Островерхов 1993: Табл. 3.

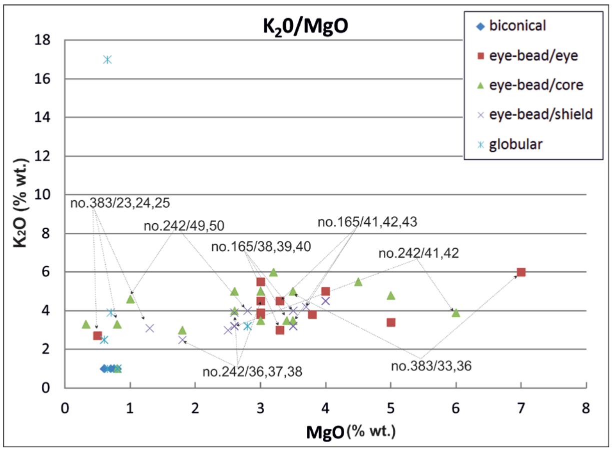

Fig. 5. K2O vs. MgO. Yahorlyk beads.
Parts of a single bead are joined by a bundle of arrows.
Numbers of beads taken from Ostroverkhov 1993

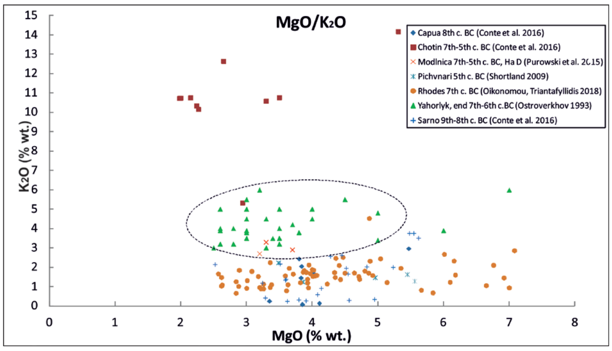

Fig. 6. K2O vs. MgO. Yahorlyk plant-ash glass beads and HMHK glass beads from Early Iron Age Europe

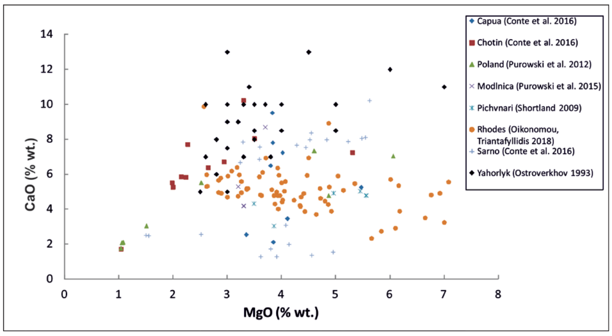

Fig. 7. CaO vs. MgO. Yahorlyk plant-ash glass beads and HMG beads from Early Iron Age Europe

Discussion

The Yahorlyk site yielded glass-working products (beads) of a certain typological variety made of (at least) three chemical types of glass. The plant-ash glass of Yahorlyk holds a distinctive place on the scatter plot K/Mg, when compared to other plant-ash glasses of Early Iron Age Europe (Fig. 6). It is characterized by an approximately equal content of potassium and magnesium and, thus, scatters around the bisector of the angle between the axes. The high percentages of the elements under discussion relate the Yahorlyk high magnesium glass to a group of Mesopotamian glasses of the Late Bronze Age known from several sites in Europe[38] as well as to Early Iron Age glasses from Pella in Jordan[39]. However, in the case of Yahorlyk, it is the potassium which outnumbers its counterpart, not the magnesium like in the Rhodian, Italian and Mesopotamian samples. The plant-ash glass of Yahorlyk is rich in alumina and iron oxide. Sometimes their quantities are high enough to suggest an additional admixture of the substances containing alumina or iron or both. Usually it is exactly the black translucent glass of the cores of the eye-beads which had so much iron inside. The chemical composition of the Yahorlyk plant-ash glass is quite original. So the issue of the technological and / or cultural reasons for its peculiarity arises.

A. Ostroverkhov suggested that the local North Pontic technique of Early Bronze Age plant-ash glass was revived by some local craftsmen in the Greek *milieu* of the Yahorlyk settlers. However, it was exactly A. Ostroverkhov who has shown that there was a pronounced break in the production of plant-ash glass in the region. The autochthonous inhabitants of the Northern Pontic coast in the Final Bronze Age, representatives of the Belozerka culture, used and probably made glass of mixed alkali receipt[40]. However, finds have been made of glass beads in the burials in the tradition of the Thracian Hallstatt. Their chemical composition is still poorly known. Taking into account the visible presence of Thracians among the inhabitants of the earliest Greek sites in the Northern Pontus, they are the most likely candidate for introducing plant-ash as a flux for glass at the Yahorlyk site.

Alongside with the cultural model of explanation outlined above, we suppose that the ancient craftsmen also employed plant-ash glass due to technological reasons, for example due to the limited importation of natron-based raw glass. A. Oikonomou et al. (2012, 2018) had demonstrated that plant-ash glass was worked on Rhodes for much longer period than was previously thought: up to the late 7th century BC. Thus, glass production using plant-ash glass was included in the

38 Varberg et al. 2016: 5, fig. 8.
39 Reade et al. 2009: 48, fig.1.
40 Островерхов 2003: 418-419.

technological repertoire available to the glass-makers of the Archaic period. Maybe, in the conditions of limited (or insufficient) supply, and growing demand experienced on the edge of Greek *oikumene*, the Yahorlyk craftsmen remembered and revived the techniques used in their recently abandoned homeland. A Rhodian wave of immigrants who arrived in the North Pontic region in the late 7th century BC has been hypothetically reconstructed by S. Kaposhina in 1956[41]. Modern researchers prefer rather to speak about Ionian influences in general (D. Chistov, pers. comm. with thanks). However, it is beyond doubt that the Yahorlyk craftsmen employed mostly, if not exclusively, archaic Greek techniques not only in glass-working but also in iron- and bronze-production[42]. Their cultural identity was predominantly Greek, as has been evidenced by the complete spectrum of material culture which has been revealed at the site of Yahorlyk. So, the model applied to explain the set of technological techniques should rather refer to the contemporary situation in the Aegean basin, rather than to distant local (and highly hypothetical) forebearers.

At this point we should note that the chemical composition of Yahorlyk plant-ash glass is different from the glass of this type found on Rhodes. Thus, maybe it is possible to speak about the transmission of the plant-ash glass recipe to a new set of raw materials (the local sands of the Dnieper delta). The direct import of plant-ash glass from Rhodes or some other Ionian centre seems less likely at the moment. In this context, we can also resurrect an old hypothesis of A. Ostroverkhov (1978) about local plant-ash glass-making at Yahorlyk. The new evidence in favour of this hypothesis is indirect. However the very logic of historical connections seems to support his view. Forthcoming trace elements analysis[43] will probably shed new light on this issue, and will supply a crucial argument in explaining the puzzle of the origin of Yahorlyk plant-ash glass.

The natron-based glass of Yahorlyk shows a pattern which is distinctively different from the plant-ash glass, when it is compared with other earlier or contemporary samples from all over Europe (Fig. 8). It does not form a separate cluster; rather it is similar in some way to most of the known groups of early natron-based glass. Some samples from south-west Poland, southern Italy, Rhodes and Methoni recall the natron-based glass of Yahorlyk. Maybe, this unclear pattern is due to the general large variability of early natron-based glass, noted by various authors on several occasions[44].

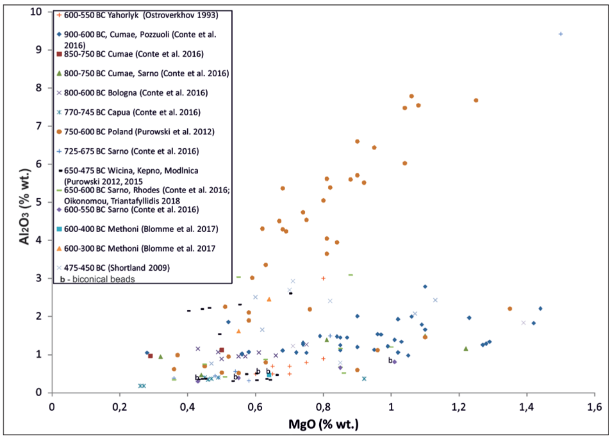

Fig. 8. Al2O3 vs. MgO. Yahorlyk biconical natron-based glass beads and LMLK glass beads from Early Iron Age Europe

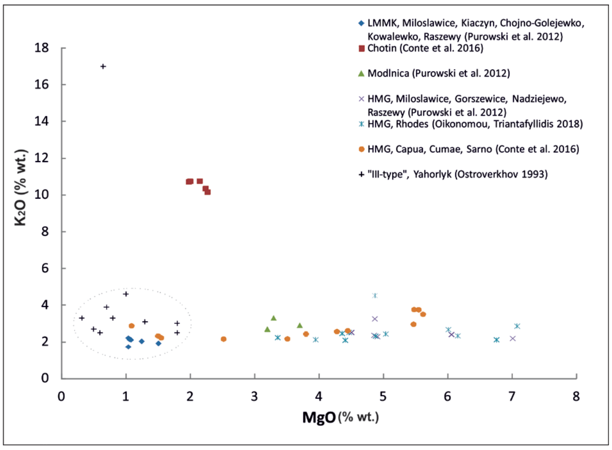

Fig. 9. K2O vs. MgO. Yahorlyk "IIIrd type" glass beads and "particular" types of glass from Early Iron Age Europe

The distinctive feature of Yahorlyk natron-based glass is the low content of alumina (Fig. 8), usually less than 1%. Such figures suggest the application of artificially purified sand or even pure quartz to produce the Yahorlyk glass[45]. A similar level of purity was reached by few contemporaneous or earlier samples. A low content of Al_2O_3 and of Fe_2O_3 was detected in plant-ash glasses of

[41] Капошина 1956: 233-234.

[42] Островерхов 1978: 31.

[43] O. Yatsuk will carry out such analysis in ARCHMAT, University of Evora.

[44] Gratuze 2009: 13.

[45] Freestone 2008: 89.

Nimrud, Rhodes and Lisht[46]. Natron-based glass entered the Northern Pontus region most probably as raw glass in the shape of broken objects and/or chunks. Its exact origin remains unknown but generally speaking it is not natron glass of an early type, it is the natron glass of already well-established production, a product with standardized characteristics of a developed industry.

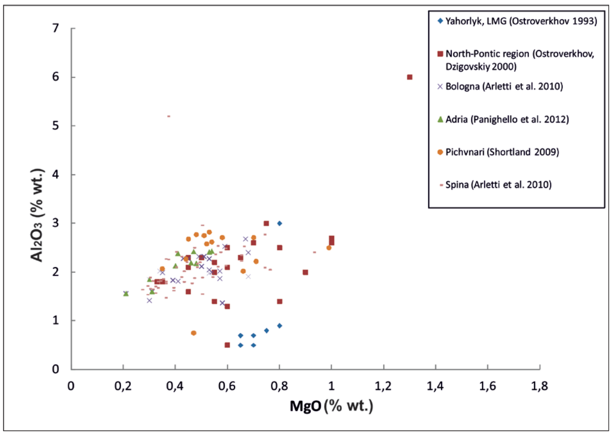

Fig. 10. Al2O3 vs. MgO. Yahorlyk biconical natron-based glass beads and LMG core-formed vessels.

Yahorlyk natron-based glass is also different from the natron-based glass found in the North Pontic region in the form of core-formed vessels (Fig. 10), which comes from well-dated contexts of the late 6th and early 5th centuries BC[47]. The glass of these vessels was made from dirtier sand and usually contains 1-2% of alumina. Some of them (including a specimen from Pichvnari) can be compared to Yahorlyk biconical beads in their alumina content, but in general *en masse* the glass of the core-formed vessels, and the glass of the Yahorlyk biconical beads have distinctive chemical compositions, despite belonging to the same chemical type of early glass. Probably, the raw glass for the core-formed vessels of the Ist Mediterranean group, and the glass for bead production in Yahorlyk were made in different glass-making centres. Production of Yahorlyk natron-based glass required certain procedures aimed at the purification of sand or other sources of silica.

The 'third type' of glass found on Yahorlyk is different from some other 'peculiar' varieties of glass discovered recently in Europe (Fig. 9). Technically speaking the third type of glass from Yahorlyk has a low magnesium and a high potassium content, but it is markedly different from the classical LMHK glasses of Late Bronze Age Europe[48]. It contains less potassium (usually below 6%) and too much calcium to be treated as the chemical relative of mixed-alkali glasses. It also differs from various particular types of glass for bead-making from roughly contemporaneous sites of Europe, mostly in the much higher content of potassium than that of magnesium. The most analogous composition is shown by LMMK glasses discovered by T. Purowski and his co-authors in south-west Poland[49]. However, Yahorlyk glasses have a larger content of potassium (over 2,5%) than the latter. The LMMK glass is treated as natron-based glass of a particular recipe [50]. The Yahorlyk glass of the third type can result from saturation of natron glass by potassium in the course of multiple recycling, a process well-described by I. Freestone for Roman Age Britain[51]. The low levels of alumina connect the Yahorlyk glass of the third type with natron-based glass, as opposed to alumina-rich plant-ash glass found on the site. This observation is an additional argument in favour of the recycling hypothesis.

Following the strict typological approach developed by E. Alexeeva[52], the author plotted the results for beads of different typologies separately. Every analyzed biconical bead was made of natron-based glass. Globular beads are omnipresent, two of them were made of natron-based glass, one from plant-ash glass, two fell into the third intermediate scatter and a single specimen is an outsider with extremely high potassium.

Eye-beads are the most interesting group (Fig. 5). The author plotted the results for eyes, cores and eye-shields separately. Eye-beads were made mostly of plant ash glass and from glass of the intermediate type. Some eye-beads were completely made of a single type of glass. For example the beads N165/38-40, 165/41-43, 242/41-42 and 383/33, 36 are made up completely of plant-ash glass. Bead N383/23-25 is made completely of intermediate type of glass. Some beads have cores made of glass of intermediate type and eyes made of plant-ash glass – N242/49, 50 and 242/36-38.

Thus, biconical beads were produced from natron-based glass. Eye-beads were made on a rod

[46] Brill 1999; Oikonomou, Triantafyllidis 2018: 4.

[47] Дзиговский, Островерхов 2000: 94-103; Shortland, Schroeder 2009.

[48] Towle et. al. 2001.

[49] Purowski et al. 2012: 160-161.

[50] Conte et al. 2016: 426.

[51] Freestone 2015.

[52] Алексеева 1975, 1978.

from different types of glass. Different types of glass were worked in the course of a single technological process – the production of one eye bead. So, probably, different types of glass were worked by a single group of craftsmen.

The Yahorlyk workshop is a bright manifestation of ancient glass-working of the first millennium BC. It indicates that the shift from the plant-ash recipe of glass, to using mineral natron as a flux took longer than has previously been thought, and that a group of craftsmen from the Archaic Greek settlement of Yahorlyk employed plant-ash glass for the systematic production of eye-beads as late as the first half of the 6th century BC. They produced biconical beads from imported natron-based glass, and sometimes applied both types of glass in order to make different parts of a single bead. Thus, it seems unlikely that the natron glass revolution was ruled by the technological features of natron as a flux. Plant-ash glass was not losing ground due to the better qualities of its natron-based competitor. Plant-ash was used in various parts of Europe for centuries after the first introduction of natron-based glass, and even by people who, like the Yahorlyk craftsmen, were well acquainted with the natron recipe and the technology of natron glass-working. The prevalence of natron glass for over millennium, then, should be explained in terms of the social importance of glass-making, the trade in raw glass and glass finished products, and the organization of glass-making and glass-working.

The natron glass revolution was made possible by the access to mineral natron as a flux, and *per se* was based on the developed trade connections inside the large Mediterranean world[53]. Any decline in trade connections would also mean a decline in natron glass production. In a certain way, the ready availability of mineral natron is a by-product of exchange in other more commonly traded items of Near Eastern origin. And in conditions of limited supply, as for example at the edge of Scythia, it is quite probable that shortages in the imported raw glass were compensated for by recourse to the ancient technique of plant-ash glass making.

An interesting social perspective on the importance of the products of ancient glass-working is provided by a comparison of the distribution pattern of biconical beads, with that of core-formed vessels in the North Pontic region during the 6th to 5th centuries BC. Core-formed vessels are clearly an imported product. Their finds are concentrated at Greek centres, sometimes there are up to several hundred of them found (in Olbia Pontica and Panticapeum for example[54]). They are quite rare in barbarian contexts[55]. It seems that rich Scythian nobles prefered to decorate their graves with gold artefacts and jewellery of Greek production, but not by core-formed glass vessels, together with the perfumes they probably contained. Some other, more luxurious glass bowls have been found in Scythian graves, almost in the same quantity as core-formed vessels[56]. Probably, the Greek practice of the use of aromatic oils for hygienic purposes was little appreciated by the Scythian nomads, for whom adhering to the traditions of their ancestors in the nomadic elite was crucial exactly in this aspect.

On the contrary, biconical beads are quite common in both Archaic Greek and Early Scythian contexts. Their geographical distribution is very broad; from south-western Poland[57] (a biconical bead of almost identical morphology and chemical composition to those of Yahorlyk was found in Modlnica, south Poland[58]) up to the Caucasus mountains[59]. Were they all made at Yahorlyk? At least, partially yes, but nobody can exclude the possibility of production of similar beads from identical raw material in some other unknown workshops in Olbia or in the Olbian *chora*.

So, the Yahorlyk workshop was aimed at local Greek customers, as well as at the Barbarian market with its fairly infinite capacity. Scythian hand-made ceramic has been excavated on the Yahorlyk site, making it a place of vivid cultural interaction. In this sense, it recalls a later case of the glass-workshop of Komarov, which was situated on the very margin between the Roman Empire and the Chernyakhiv culture, and was oriented principally towards the needs of Barbarian society[60]. This orientation towards export adds some validity to the conclusions arrived at above on the originality of glass-working at Yahorlyk. It is quite probable that some beads were produced intentionally for intercultural exchange, and were designed according to tastes and preferences of Barbarian customers. Yahorlyk craftsmen sought technological decisions in order to satisfy this somewhat peculiar demand, and found a resolution of them in the unusual duality of application of two chemical types of glass in a single technological process.

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53 Conte et al. 2016.

54 Кунина 1997; Кунина 2008; Колесниченко 2017.

55 Дзиговский, Островерхов 2000: 81-84.

56 Дзиговский, Островерхов 2000: 56-57, 81-84.

57 Purowski 2015:223-226.

58 Purowski et al. 2015.

59 Островерхов 1981: 216.

60 Rumyantseva, Belikov 2017.

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